

# **Age Differences in Verbal Short-Term Memory and the Process of Redintegration**

Submitted by

Amanda Christine Scicluna

B. Soc Sci, B Psyc Sci (Hons)

A thesis submitted in total (partial) fulfilment of the requirements of the degree of  
Master of Psychology (Education and Developmental) / PhD

School of Psychology

Faculty of Health Sciences

October 5<sup>th</sup>, 2015

## Table of Contents

<b>Table of Contents</b> .....	ii
List of Tables.....	viii
List of Figures.....	x
Abstract.....	xi
Acknowledgments .....	xiv
Dedication.....	xvi
Statement of Sources .....	xvii
Overview of PhD .....	xviii
Chapter one: A brief introduction into memory .....	19
Dual model of memory.....	20
Baddeley and Hitch's (1974) working memory model. ....	21
Central executive. ....	22
Visuo-spatial sketchpad.....	23
Phonological loop. ....	23
Episodic buffer. ....	24
Variations of the working memory model.....	24
Decay and short-term forgetting.....	26
Unitary model of memory .....	28
Interference and short-term forgetting.....	31
Proactive interference. ....	31
Retroactive interference.....	33
Conclusion.....	35
Chapter two: Redintegration and verbal short-term memory .....	37
Schweickert's (1993) Multinomial Processing Tree Model of Redintegration.....	38
Redintegration and immediate serial recall tasks .....	40
The lexicality effect. ....	43
The word frequency effect.....	49
The semantic similarity effect. ....	54
The concreteness effect. ....	57
Conclusion.....	60
Chapter three: Neale and Tehan study.....	62
Experiment one.....	62
Experiment two .....	69
Discussion.....	70
Conclusion.....	71
Chapter four: Task difficulty and redintegration.....	73
Recall interval (immediate, two-second filled retention interval).....	74
Study condition (silent, irrelevant speech) .....	77

Presentation rate (one second, two seconds) .....	81
A new measure of task difficulty.....	84
Conclusion .....	85
Chapter five: Age differences in verbal STM .....	87
Theoretical accounts of age differences in verbal STM .....	87
General cognitive slowing. ....	88
Declines in processing resources. ....	90
Reduced inhibition.....	93
Contextual/environmental support. ....	96
Empirical findings .....	99
Conclusion .....	104
Chapter six: First empirical study-Word length and redintegration .....	106
Current explanations for the word length effect .....	107
Phonological complexity. ....	108
Feature model of memory.....	111
Item-order framework.....	113
Age differences and the word length effect.....	117
Aims .....	119
Hypotheses .....	120
Method.....	122
Participants .....	122
Design .....	124
Materials .....	125
Background measures.....	125
Word stimuli.....	126
Word trials. ....	127
Procedure .....	130
Scoring.....	131
Results .....	132
Data screening .....	132
Data analysis.....	133
Correct-in-position recall.....	135
Descriptive statistics. ....	135
Inferential statistics.....	137
Item recall .....	138
Descriptive statistics. ....	138
Inferential statistics.....	140
Order accuracy.....	140
Descriptive statistics. ....	140
Inferential statistics.....	142
Transposition errors.....	143
Descriptive statistics. ....	143
Inferential statistics.....	145

Omission errors .....	146
Descriptive statistics.....	146
Inferential statistics.....	148
Task Difficulty and redintegration .....	148
Task difficulty. ....	148
Redintegration. ....	151
Discussion.....	156
Study overview .....	156
The word length effect and redintegration .....	157
Age differences, the word length effect, and redintegration .....	161
Recall errors and redintegration in verbal STM .....	163
Transposition and omission errors in redintegration. ....	164
Conclusion.....	166
Chapter seven: Second empirical study-Associate word pairs and redintegration.....	169
Semantic factors facilitating verbal STM performance.....	170
Semantic relatedness.....	170
Inter-item associative strength.....	174
Age differences in associate memory tasks.....	179
Aims .....	185
Hypotheses .....	186
Method.....	188
Participants .....	188
Design .....	189
Materials .....	190
Background measures.....	190
Word stimuli.....	190
Word trials.....	191
Procedure .....	193
Scoring.....	193
Results .....	193
Data screening .....	193
Data analysis.....	193
Correct-in-position recall.....	194
Descriptive statistics.....	194
Inferential statistics.....	196
Item recall .....	197
Descriptive statistics.....	197
Order accuracy.....	200
Descriptive statistics.....	200
Transposition errors.....	203
Descriptive statistics.....	203
Omission errors .....	206
Descriptive statistics.....	206

Task difficulty and Redintegration .....	208
Task difficulty. ....	208
Redintegration. ....	209
Discussion.....	214
Study overview .....	214
Associate word pairs and redintegration .....	215
Age differences, associate word pairs, and redintegration .....	219
Recall errors and redintegrative processing.....	222
Transposition and omission errors in redintegration. ....	222
Extra-list intrusions and redintegration. ....	225
Conclusion.....	227
Chapter eight: Third empirical study-False memory and redintegration .....	229
The false memory effect and verbal short-term memory .....	229
Ageing and the false memory effect in verbal verbal short-term memory.....	236
Attentional control.....	237
Source monitoring. ....	240
Aims .....	245
Hypotheses .....	246
Method.....	248
Participants .....	248
Design.....	250
Materials .....	251
Background measures.....	251
Word stimuli.....	251
Word trials.....	252
Procedure .....	254
Scoring.....	254
Results .....	254
Data screening .....	254
Data analysis.....	254
Correct-in-position recall.....	255
Descriptive statistics.....	255
Inferential statistics.....	257
Item recall .....	258
Descriptive statistics.....	258
Inferential statistics.....	260
Order accuracy.....	260
Descriptive statistics.....	260
Inferential statistics.....	262
Transposition errors.....	262
Descriptive statistics.....	262
Inferential statistics.....	264
Critical non-presented lures.....	265

Descriptive statistics.....	265
Inferential statistics.....	266
Omission errors .....	267
Descriptive statistics.....	267
Inferential statistics.....	269
Task difficulty and redintegration .....	269
Task difficulty. ....	269
Redintegration. ....	270
Discussion.....	275
Study overview .....	275
False memory and redintegration .....	276
Age differences, false memory, and redintegration.....	282
Recall errors and redintegration .....	286
Conclusion.....	288
Chapter nine: General discussion .....	290
Research overview.....	290
Redintegration .....	293
Task difficulty .....	298
Ageing .....	301
Limitations, conclusions, future directions, and practical implications .....	305
Limitations.....	305
Conclusions. ....	307
Future directions.....	308
Practical implications. ....	309
References .....	311
Appendices .....	320
Appendix A: Information Letters, Consent Forms, and Human Research Ethics Committee Approval .....	320
Appendix A – 1: Information letter for young adults.....	320
Appendix A – 2: Consent form for young adults .....	322
Appendix A – 3: Information letter for older adults.....	324
Appendix A – 4: Consent form for older adults .....	326
Appendix A – 5: Human Research Ethics Committee Approval Form (V2009 31).....	328
Appendix B: Materials .....	329
Appendix B – 1: Poster for young adult participant recruitment .....	329
Appendix B – 2: Poster for older adult participant recruitment .....	330
Appendix B – 3: Biographical questionnaire .....	331
Appendix B – 4: Mill Hill Vocabulary Scale (Raven, 1989) .....	332
Appendix B – 5: Experimental stimuli for chapter six (Word length) .....	333
Appendix B – 6: Example word trial from chapter six (Word length).....	334
Appendix B – 7: Experimental stimuli for chapter seven (Word pairs).....	336
Appendix B – 8: Example word trial from chapter seven (Word pairs).....	337
Appendix B – 9: Experimental stimuli for chapter eight (False memory) .....	339
Appendix B – 10: Example word trial from chapter eight (False memory).....	341

Appendix C: Results .....	343
Appendix C – 1: Scoring guide .....	343
Appendix C – 2: Additional analyses for chapter six (Word length) .....	344
Appendix C – 3: Additional analyses for chapter seven (Word pairs) .....	401
Appendix C – 4: Additional analyses for chapter eight (False memory) .....	446

## List of Tables

Table 6.1 <i>Demographic Characteristics across Age</i> .....	124
Table 6.2 <i>Means With Confidence Intervals (CIs) and Standard Deviations for Proportions of Correct-in-Position Recall across Task Difficulty, Word Length, and Age</i> .....	136
Table 6.3 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Item Recall across Task Difficulty, Word Length, and Age</i> .....	139
Table 6.4 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Order Accuracy across Task Difficulty, Word Length, and Age</i> .....	141
Table 6.5 <i>Means with Confidence Intervals (CIs) and Standard Deviations for Proportions of Transposition Errors across Task Difficulty, Word Length, and Age</i> .....	144
Table 6.6 <i>Means With Confidence Intervals (CIs) and Standard Deviations for Proportion of Omission Errors across Task Difficulty, Word Length, and Age</i> .....	147
Table 6.7 <i>Spearman's Rank Order Correlations for Task Difficulty as Function of Word Length and Age</i> .....	150
Table 7.1 <i>Demographic Characteristics across Age</i> .....	189
Table 7.2 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Correct-in-Position Recall across Task Difficulty, Word Pair, and Age</i> .....	195
Table 7.3 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Item Recall across Task Difficulty, Word Pair, and Age</i> .....	198
Table 7.4 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Order Accuracy across Task Difficulty, Word Pair, and Age</i> .....	201
Table 7.5 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Transposition Errors across Task Difficulty, Word Pair, and Age</i> .....	204
Table 7.6 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Omission Errors across Task Difficulty, Word Pair, and Age</i> .....	207
Table 7.7 <i>Spearman's Rank Order Correlations for Task Difficulty as a Function of Word Pair and Age</i> .....	209
Table 8.1 <i>Demographic Characteristics across Age</i> .....	250
Table 8.2 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Correct-in-Position Recall across Task Difficulty, Word Relatedness, and Age</i> .....	256
Table 8.3 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Item Recall across Task Difficulty, Word Relatedness, and Age</i> .....	259
Table 8.4 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Order Accuracy across Task Difficulty, Word Relatedness, and Age</i> .....	261
Table 8.5 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Transposition Errors across Task Difficulty, Word Relatedness, and Age</i> .....	263



Table 8.6 <i>Means with Confidence Intervals (CIs) and Standard Deviations for the Proportions of Critical Non-presented Lures for Related Trials across Task Difficulty and Age</i> .....	265
Table 8.7 <i>Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Omission Errors across Task Difficulty, Word Relatedness, and Age</i> .....	268
Table 8.8 <i>Spearman's Rank Order Correlations for Task Difficulty as a Function of Word Relatedness and Age</i> .....	270

## List of Figures

<i>Figure 1.</i> Diagram outlining thesis sections and progression of chapters.....	xviii
<i>Figure 1.1.</i> Components of the Baddeley and Hitch (1974) Working Memory Model with the inclusion of the Episodic Buffer (Baddeley, 2000a). .....	22
<i>Figure 2.1.</i> Schweickert's (1993) Multinomial Processing Tree Model of Redintegration. $I$ = the probability of retrieving the TBR item intact and that TBR item can be recalled directly and correctly from verbal STM. $R$ = the probability that the TBR item can be reconstructed through redintegration. ....	39
<i>Figure 6.1.</i> Composition of the task difficulty conditions using recall interval, study condition, and presentation rate across word length.....	129
<i>Figure 6.2.</i> Word length advantage as a function of task difficulty for correct-in-position recall for young adults (diamonds) and older adults (triangles).....	153
<i>Figure 6.3.</i> Word length advantage as a function of task difficulty for item recall for young adults (diamonds) and older adults (triangles) .....	154
<i>Figure 6.4.</i> Word length advantage as a function of task difficulty for order accuracy for young adults (diamonds) and older adults (triangles) .....	155
<i>Figure 7.1.</i> Composition of the task difficulty conditions using recall interval, study condition, and presentation rate across word pair. ....	192
<i>Figure 7.2.</i> Associate advantage as a function of task difficulty for correct-in-position recall for young adults (diamonds) and older adults (triangles).....	211
<i>Figure 7.3.</i> Associate advantage as a function of task difficulty for item recall for young adults (diamonds) and older adults (triangles) .....	212
<i>Figure 7.4.</i> Associate advantage as a function of task difficulty for order accuracy for young adults (diamonds) and older adults (triangles) .....	213
<i>Figure 8.1.</i> Composition of the word trials using recall interval, study condition, and presentation rate across word relatedness.....	253
<i>Figure 8.2.</i> Relatedness advantage as a function of task difficulty for correct-in-position recall across young adults (diamonds) and older adults (triangles) .....	272
<i>Figure 8.3.</i> Relatedness advantage as a function of task difficulty for item recall across young adults (diamonds) and older adults (triangles) .....	273
<i>Figure 8.4.</i> Relatedness advantage as a function of task difficulty for order accuracy for young adults (diamonds) and older adults (triangles) .....	274

## **Abstract**

There are long-standing but ongoing debates in the literature about the composition of memory and the causes of short-term forgetting. Some researchers believe human memory is a dual system that comprises separate stores for verbal short-term memory (STM) and long-term memory (LTM), best exemplified by Baddeley and Hitch's (1974) Working Memory Model. Dual memory researchers also believe that information stored in verbal STM decays over time if it is not refreshed through engaging in some form of covert rehearsal. However, other researchers believe verbal STM and LTM are intrinsically related, with short-term forgetting resulting from some level of interference that disrupts encoding the newly acquired information into verbal STM. The literature has indicated that the Working Memory Model could explain some but not all of the effects in verbal STM. In addition, while information degrades from verbal STM, it is not entirely lost and individuals use their LTM to assist with short-term recall. Moreover, researchers have found that decay does not explain all short-term forgetting and that interference does cause short-term forgetting. This thesis examined the unitary view of human memory by investigating the redintegration explanation for short-term recall, whereby individuals access long-term knowledge to aid in the reconstruction of degraded phonological memory traces for later recall. Redintegration emphasises that verbal

STM and LTM work in unison to help individuals retrieve information for later recall. The three studies comprising this thesis examined the predictions of redintegration in relation to short-term recall and age differences by varying the difficulty level of the memory task. All studies operationalised task difficulty by manipulating the combination of recall intervals (immediate vs. delayed), study conditions (silence vs. irrelevant speech), and presentation rates (one second vs. two seconds). Twenty young and 20 older adults were instructed to remember short lists of words across eight different memory conditions. In Study one, redintegration was measured using the word length effect (Baddeley, Thompson, & Buchanan, 1975) and findings showed that as task difficulty increased, recall was higher for short words because they had fewer segments to reassemble from LTM compared with long words. In Study two, redintegration was measured using associate word pairs and findings showed that as task difficulty increased, recall was higher for words in the associate pairs because participants used the semantic relationships in LTM as additional retrieval cues to reconstruct the short-term phonological traces that rapidly dissipated during encoding. In Study three, redintegration was measured using the false memory effect (Roediger III & McDermott, 1995) and findings showed that as task difficulty increased, recall was higher for words related to a non-presented critical lure words because participants used the relatedness among the words along with the critical lure as additional retrieval cues to search LTM and reconstruct the degraded short-term phonological traces. For all studies, there were no significant age differences in redintegration, suggesting that young and older adults engage in the same process by using long-term information to rebuild the rapidly dissipating phonological memory traces for short-term recall and use additional retrieval cues to enhance the redintegration process. Collectively, these findings provide support for the redintegration process that emphasises the intrinsic relationship between verbal STM and LTM. When short-

term recall became difficult, young and older adults effectively cued the search for long-term information to facilitate the redintegration process and aid short-term recall. This thesis also substantiated the interference view on short-term forgetting, where increasing task difficulty increased the reliance on redintegration to improve verbal STM performance.

## Acknowledgments

Completing my PhD over the past six years is on the same level as winning an Academy award without the glitz and glamour. I have achieved one of my greatest life accomplishments and this would not have happened without the following people:

Thank you to my principal supervisor Associate Professor Anne Tolan for her patience and commitment throughout the PhD journey. Despite being on opposite sides of the country, it was an absolute pleasure working with you and I am proud of all the work we have achieved, including my first ever trip overseas.

Thank you to Professor Gerry Tehan for his generosity and wealth of knowledge in helping me develop my PhD. You are a true character and memory research would not be the same without your incredible insight. Your matching t-shirt and sneaker combinations will always remain with me.

Thank you to Dr Rachel Grieve and Dr Kate Witteveen for coming on board at various stages in my PhD as my co-supervisors. You brought a fresh perspective on my PhD and helped me refine my research skills. A second and third set of eyes made my PhD stronger and for that, I am very grateful.

I would not have completed my PhD without the love and support of my friends, especially Kim, Dave, Susan, Angeline, Caroline, Alyssa, and Albert. Your collective positive energy and belief in me motivated me to finish, even in the face of despair, tears, and sadness. There are not enough words to express my gratitude to you all.

Thank you to my family for their support and continual food supply. Although tumultuous at times, your love has helped me through the last six years of my PhD journey. It is all over now and the family home can return to normal.

Last and certainly not least, my final thank you is to my boyfriend Glen Michael Smart. Your unrelenting support, strength, continual optimism, belief, and smile never wavered and you helped me realise that my PhD was worthwhile. I would not have submitted my PhD without you.

## **Dedication**

I dedicate this thesis to the late Professor Barry Fallon of the Melbourne Campus at Australian Catholic University for his mentorship throughout my PhD journey and as a psychology student. Thank you for helping me to remember to enjoy the work that I do as a psychologist and to believe in my research abilities.



### Statement of Sources

This thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degree or diploma.

No parts of this thesis have been submitted towards the award of any degree or diploma in any other tertiary institution.

No other person's work has been used without due acknowledgement in the main text of the thesis.

All research procedures reported in this thesis received the approval of the relevant Ethics/Safety Committees (where required).

Signed .....

Date ..... 05 / 10 / 2015 .....

## Overview of PhD

### Chapter one: A brief introduction into memory

- Introduces two ongoing debates in the memory literature:
- Is memory a dual or unitary system?
- Does short-term forgetting result from decay or interference?

### Chapter two: Redintegration and immediate serial recall

- Defines redintegration.
- Describes Schweickert's (1993) Multinomial Processing Tree Model Tree of Redintegration and various definitions of redintegration.

### Chapter three: Neale and Tehan study

- Reviews the Neale and Tehan (2007) study.

### Chapter four: Task difficulty and redintegration

- Describes task difficulty and the variables comprising the task difficulty measure.

### Chapter five: Age differences and verbal short-term memory

- Describes age differences in verbal short-term memory tasks.

### Chapter six: Word length and redintegration

- First empirical study:
- Defines redintegration using the Word Length Effect (Baddeley, Thompson & Buchanan, 1975).

### Chapter seven: Associate word pairs and redintegration

- Second empirical study:
- Defines redintegration using associate word pairs.

### Chapter eight: False memory and redintegration

- Third empirical study:
- Defines redintegration using the False Memory Effect (Roediger and McDermott, 1995).

### Chapter nine: General discussion

- Summarises the main research findings across the three empirical studies.
- Discusses the major outcomes of the thesis, limitations, conclusions, practical implications, and directions for future research.

*Figure 1.* Diagram outlining thesis sections and progression of chapters.

## **Chapter one: A brief introduction into memory**

There has been continued disagreement amongst memory researchers who have attempted to explain the mechanisms underpinning memory, the composition of memory, and its various structures. Explanations of how information is stored in memory, why individuals forget their newly acquired information, and how they subsequently retained and retrieved information to assist with later recall, vary considerably. What emerged was an ongoing debate about whether memory is a dual system or a unitary system. Researchers (e.g., Baddeley & Hitch, 1974) who advocated for memory as a dual system purported that verbal short-term memory (STM) and long-term memory (LTM) are two separate memory systems, where information is stored in verbal STM before the information is then transferred to LTM. Dual memory system theorists explained short-term forgetting in terms of decay when rehearsal is prevented and, subsequently, information is lost over time (Baddeley & Hitch, 1974). On the other hand, researchers (e.g., Melton, 1963; Nairne, 1990, 2002; Schweickert, 1993) who advocated for memory as a unitary system abandoned the notion of verbal STM and LTM as two separate systems. They purported that verbal STM and LTM are intrinsically related and there is a constant interplay between them. According to the unitary theory of memory, information is stored in verbal STM, but rather than transferring information to LTM, individuals use their long-term knowledge as a cue to assist with short-term recall (Nairne, 2002). Furthermore, unitary memory theorists explained short-term forgetting from an interference perspective, whereby the information is not entirely lost. Rather, over a short period, interference impairs the individual's capacity to encode and retain this information in verbal STM for later output (Nairne, 2002).

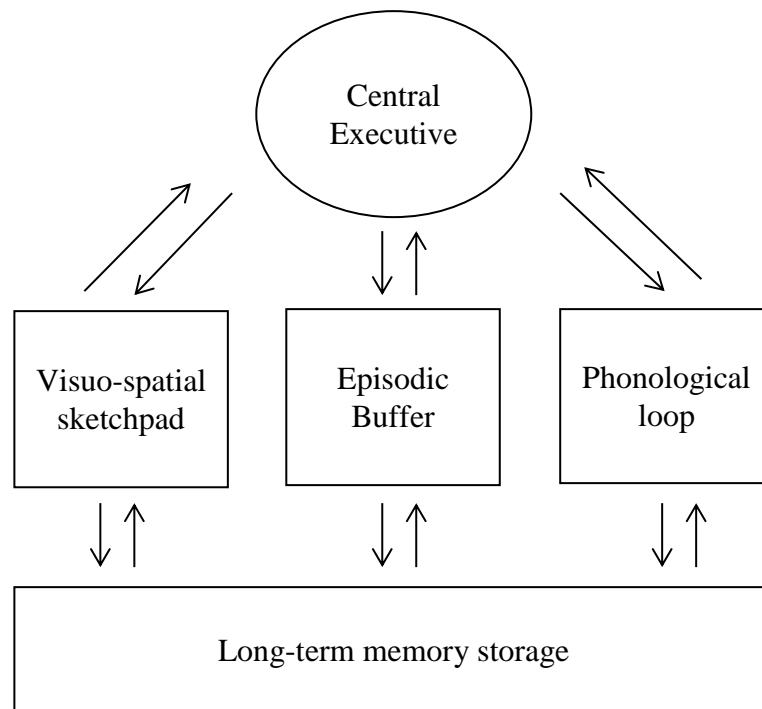
Given the importance of this debate in memory research, Chapter one examines the propositions of the dual memory theorists, including their position on short-term forgetting through time-based decay of the short-term phonological memory traces for the to-be-remembered (TBR) items. The discussion will then outline the position of the unitary memory theorists in terms of the acquisition of knowledge and the subsequent forgetting of this information through interference.

### **Dual model of memory**

Traditionally, memory is thought to be comprised of a verbal STM, described as a mental workspace where individuals can cognitively manipulate and store information (Nairne, 2002), and a LTM, described as a permanent store for learned information (Nairne, 2002). Dual memory system theorists (e.g., Baddeley & Hitch, 1974) attempt to explain this dichotomous relationship and the many models that advocate for this relationship have been grouped under what Nairne (2002) defined as the “standard model”. Underlying the “standard model” are three key assumptions that conceptualise the processing of incoming information for later short-term recall. The first assumption, activation, refers to keeping information in an active form that is readily accessible for later retrieval. The second assumption, decay, refers to when information that is not kept active in verbal STM rapidly dissipates. Decay is understood to have an adaptive function, where memories are continually updated by removing the unnecessary activated information. The third assumption, rehearsal, counters the effects of decay by maintaining the information in its active state in verbal STM. The single most influential model that has dominated discussions of memory and encapsulates the assumptions of the “standard model” is Baddeley and Hitch’s (1974) Working Memory Model.

**Baddeley and Hitch's (1974) working memory model.** Baddeley and Hitch's (1974)

Working Memory Model (WMM) primarily focused on the different components that comprise an individual's memory and how these components work in parallel to encode, store, and retrieve information for later short-term recall. This model also described the active integration of both conscious and unconscious processes that inform how information is encoded, stored, and retrieved. Baddeley and Hitch asserted that initially, information from the environment enters sensory memory, a very brief storage unit that is based on the sensory systems, where the newly acquired information is processed and converted into a useable form. This newly acquired information is then transferred to the verbal STM store for additional encoding and storage. However, rather than conceptualising verbal STM as the sole store for retaining information before transferring this information to LTM, Baddeley and Hitch suggested that verbal STM comprises several subsystems, each having their own specialised function. They referred to verbal STM as 'working memory' to emphasise the functional importance of the multiple subsystems 'working' simultaneously to retain information that would be transferred to LTM. Figure 1.1 presents a diagram of the components of the WMM and the communication that occurs between the various components.



*Figure 1.1.* Components of the Baddeley and Hitch (1974) Working Memory Model with the inclusion of the Episodic Buffer (Baddeley, 2000a).

Baddeley and Hitch (1974) proposed there are three core components that are essential to their WMM. Each component is relatively independent of one another, has its respective capabilities, and is limited in its capacity.

**Central executive.** The central executive processes new information and has several responsibilities. It coordinates the actions of the phonological loop and the visuo-spatial sketchpad, integrates all of the incoming information into memory, and controls the allocation of resources within the working memory system by focusing, dividing, and switching the individual's attention as necessary (Baddeley, 1992, 2000b, 2004; Baddeley, Chincotta, Stafford, & Turk, 2002; Gathercole, 1999). The central executive can also be conceptualised as having a supervisory role in memory, particularly when switching attention while simultaneously completing two tasks. For example, individuals may attempt to repeat a series

of numbers while rehearsing the TBR items for later output and the central executive plays a role in switching the individual's attention between the two tasks. Baddeley and Hitch (1974) purposely placed the central executive between the visuo-spatial sketchpad and the phonological loop because it also functions as a storage system that integrates visual and verbal codes for later use in short-term recall.

**Visuo-spatial sketchpad.** The visuo-spatial sketchpad is domain specific and is primarily responsible for temporarily storing and manipulating the visual or spatial information in memory for short periods of time (Baddeley, 1992, 2000b, 2004; Baddeley & Hitch, 1974). Information in this store rapidly decays unless it is refreshed through rehearsal (Henry, 2012). Such information includes one's memory for shapes, colours, the location of objects, and the speed of objects in the environment. The visuo-spatial sketchpad also helps with coordinating spatial movements (Baddeley & Hitch, 1974; Henry, 2012).

**Phonological loop.** The phonological loop, the component specifically relevant to this thesis, comprises two separate mechanisms. The phonological store is responsible for processing and retaining newly acquired acoustic (or speech-based) information in memory for approximately two seconds before it rapidly dissipates through decay, if not refreshed via rehearsal (Baddeley, 1992, 2000b, 2004; Baddeley et al., 1975; Nairne, 2002; Neath & Suprenant, 2003). The articulatory control processes are primarily responsible for translating the visual information into a speech-based code that is deposited into the phonological store (Neath & Suprenant, 2003) and are also responsible for refreshing the short-term phonological memory traces in the phonological store through sub vocal rehearsal processes that serves to offset decay (Neath & Suprenant, 2003). Baddeley (1986) argued that the phonological loop can account for four of the major verbal STM effects reported in the memory literature: (1) the

phonological similarity effect (Baddeley, 1966; Conrad, 1964); (2) the articulatory suppression effect (Henry, 2012; Nairne, 2002; Neath & Suprenant, 2003); (3) the irrelevant speech effect (Colle & Welsh, 1976; Jones & Morris, 1992; Salame & Baddeley, 1990); and (4) the word length effect (WLE) (Baddeley et al., 1975).

**Episodic buffer.** The episodic buffer is responsible for binding together information from different external sources and integrating previously stored information from LTM with newly acquired information in verbal STM to create a clear and coherent memory episode (Baddeley, 2000a; Henry, 2012; Neath & Suprenant, 2003). Baddeley (2000a) included the episodic buffer to acknowledge the growing importance of long-term knowledge aiding verbal STM performance. Specifically, it acts as a link between the central executive and LTM so individuals can access and utilise their previously stored knowledge during ongoing cognitive tasks and activities (Baddeley, 2000a; Henry, 2012; Neath & Suprenant, 2003). Baddeley's acknowledgement of the long-term contributions to the WMM (Baddeley & Hitch, 1974) is important in the context of this thesis, as there is growing recognition in the memory literature that long-term knowledge is essential in facilitating verbal STM performance. Such acknowledgement is observed in the redintegration process, which is the basis of this thesis and will be examined in Chapter Two.

**Variations of the working memory model.** Since the inception of Baddeley and Hitch's (1974) WMM, researchers have also developed other models that incorporate the core assumptions of the "standard model" (Nairne, 2002). Such models include the Start End Model (Henson, 1998), that focused on an order-based approach to memory, where each item has a particular level of activation that corresponds to its position in a sequence stored in memory. Cowan et al.'s (1998) Focus of Attention Model assumed that working memory is



organised at two levels. Firstly, the representations held in working memory activate the representations in LTM and this level of activation is unlimited. Secondly, the representations that are activated are maintained in a limited capacity focus of attention, which can hold up to four items. Cowan et al. asserted that retaining these items is related to the item's level of activation and, if not kept active by sitting in the focus of attention, the item is lost over time through decay. Burgess and Hitch (1999) also developed their phonological loop model from Baddeley and Hitch's phonological loop component of the WMM (Baddeley & Hitch, 1974), where information is represented by lexical items and phonemes that are characterised by nodes which have different levels of activation. Individuals achieved learning by rehearsal through strengthening the associations between nodes at the different layers. However, if this learning is not achieved over time, the connections decay, resulting in short-term forgetting. Together, these models shared the assumptions of the "standard model", predominantly explaining the retention of information by keeping it active in verbal STM through rehearsal and the loss of information through decay (Nairne, 2002).

In conclusion, Baddeley and Hitch's WMM (1974) has been prominent in memory research. Components of the model, especially the phonological loop, have accounted for an array of verbal STM phenomena such as the phonological similarity effect (Baddeley, 1966; Conrad, 1964; Peterson & Johnson, 1971), the articulatory suppression effect (Nairne, 2002; Neath & Suprenant, 2003), the irrelevant speech effect (Colle & Welsh, 1976; Jones, Madden, & Miles, 1992; Jones & Morris, 1992; Salame & Baddeley, 1990), and the WLE (Baddeley et al., 1975). While explaining the processes involved in encoding information that is temporarily stored in verbal STM, Baddeley and Hitch also explained short-term forgetting through the WMM. Specifically, if the newly acquired information is not rehearsed in time,

the short-term phonological memory traces for the TBR items decay over time from verbal STM.

### **Decay and short-term forgetting**

Researchers have widely accepted that short-term forgetting results from the spontaneous information loss of short-term phonological memory traces of the TBR items that occurs as a function of time (Nairne, 2002; Neath & Suprenant, 2003). As described in the WMM (Baddeley & Hitch, 1974), when individuals acquire new information from their environment, they create a new short-term phonological memory trace. Over time, the short-term phonological memory trace is susceptible to damage and can rapidly dissipate. To retain the information for short-term recall, individuals engage in some form of covert sub vocal rehearsal using the articulatory control processes in the phonological loop to keep the short-term phonological memory trace active and counter the effects of decay. If they do not engage in a form of sub vocal rehearsal, the short-term phonological memory trace will decay beyond the point of retrieval, resulting in short-term forgetting (Brown, 1958).

Decay theorists (e.g., Brown, 1958; Peterson & Peterson, 1959) posited that if forgetting results from decay, then the amount of information individuals recall depends on the length of the retention interval (i.e., the length of time between encoding the last TBR item and short-term recall). Moreover, longer retention intervals allow individuals more time to rehearse the TBR items and keep the items active in verbal STM before output. Peterson and Peterson (1959) completed one of the seminal studies that demonstrated this relationship. The rapid forgetting by participants in their study implied that rehearsal was crucial to maintaining the availability of short-term verbal information for later recall. To demonstrate this observation, Peterson and Peterson examined the impact of increasing retention intervals on short-term

recall performance by preventing participants from rehearsing the TBR items. They required participants to remember three-consonant trigrams (e.g., *HLN*) over short retention intervals. To prevent them from rehearsing the letters while viewing the three-consonant trigram, participants were required to count backwards by three, (e.g., *503, 500, 497*) and continue counting until they saw a light that signalled for them to recall the three-consonant trigram.

Peterson and Peterson (1959) found that as the duration of the retention interval increased, the probability of participants correctly recalling the three-consonant trigram rapidly declined. After three seconds, participants recalled 80% of the three-consonant trigrams. However, after 18 seconds, participants recalled less than 10% of the three-consonant trigrams. Peterson and Peterson suggested individuals engaged in some form of sub vocal rehearsal to keep the information active in verbal STM so it was readily available for later output. The loss of short-term information resulted from decaying short-term phonological memory traces for the three-consonant trigrams not refreshed through rehearsal as the length of the retention interval increased. They attributed this conclusion to increases in the number of TBR items in the list, the size of the retention interval, and preventing individuals from rehearsing the TBR items.

To conclude, the dual memory model theorists have offered a widely accepted view on the structures underlying memory and the composition of memory. The “standard model”, underlined by the main assumptions of activation, rehearsal, and decay, have provided an account of the short-term retention of newly acquired information (Nairne, 2002). The decay perspective on short-term forgetting has also explained the dissipation of short-term information if not offset by engaging in some form of covert sub vocal rehearsal (Brown, 1958; Peterson & Peterson, 1959). However, there are some researchers (e.g., Brown, Preece,

& Hulme, 2000; Melton, 1963; Neath & Nairne, 1995) who have disputed the propositions of dual memory models, specifically the WMM (Baddeley & Hitch, 1974) and the decay perspective on short-term forgetting (Brown, 1958; Peterson & Peterson, 1959) and as such, the simple distinction between verbal STM and LTM stores is often challenged. These researchers have abandoned the notion of separate stores for verbal STM and LTM and instead favour an intrinsic and reciprocal relationship between short-term recall and long-term knowledge.

### **Unitary model of memory**

Researchers (e.g., Melton, 1963; Nairne, 2002; Schweickert, 1993) advocating for unitary memory models proposed that there is an intrinsic relationship between verbal STM and LTM, a view held in opposition to the dual memory theorists who posit a dichotomy between the two systems. Unitary models do not share the same assumptions of the “standard model” (Nairne, 2002) and assume that the processes for short-term recall are similar across verbal STM and LTM. These theorists proposed that individuals encode newly acquired information from the environment and the phonological features of the short-term phonological memory trace rapidly dissipate over short retention intervals. To recall the TBR item, individuals used the degraded short-term phonological memory trace to locate potential recall candidates in LTM for later recall. For example, using the remaining phonological features of the short-term phonological memory trace *e\_eph\_nt*, individuals could use this available information as a cue to delimit the number of potential recall candidates in LTM by searching for *animals* beginning with the letter *e* and contain all the remaining letters.

Melton (1963) was one of the earliest researchers who supported a unitary view of memory, asserting that memory exists on a continuum where long-term knowledge can be

used in a short-term recall task. He adapted Peterson and Peterson's (1959) experiment by incorporating a level of repetition during the task to demonstrate the use of long-term learning in a short-term recall task. Melton hypothesised that when an object is presented a number of times, given that rehearsal is possible, the probability of retaining the repeated object in verbal STM increases. Melton presented participants with 80 trials of a specific nine-digit number. After they viewed the nine-digit number, participants were given four seconds to write down the number. However, during presentation, participants also viewed a new sequence of nine-digit numbers that aimed to interfere with repeating the original nine-digit number. The new sequences of nine-digit numbers contained two, three, five, or eight different nine-digit numbers. Melton found that as repetition of the original nine-digit number increased, the average number of digits participants recalled also increased. Melton believed this finding was evidence of long-term learning, where repeating the original nine-digit number created a form of long-term knowledge that individuals used to aid short-term recall and combat against the intervening sequence of numbers presented during the experimental task. However, when the number of new nine-digit numbers that intervened between repeating the original nine-digit number increased, recall of the original nine-digit number decreased. Melton interpreted this finding as being a form of retroactive interference that emerged during the experimental task, where the increased number of new nine-digit numbers interfered with repetition of the original nine-digit number. Melton solidified his unitary view on memory by arguing that the repeated presentation of the nine-digit number coupled with the retroactive interference produced from the intervening sequences during the experimental task was evidence to suggest that individuals used their long-term knowledge of the original nine-digit sequence to assist with short-term recall.

Unitary memory model theorists differ from the dual memory theorists in their conceptualisation of memory in a couple of ways (Nairne, 2002). First, successful recall of information held in verbal STM is not reliant on the individual keeping the newly acquired information active once it enters verbal STM, although this information is assumed to rapidly dissipate. Secondly, rehearsal is not required to keep the newly acquired information active in verbal STM. For example, when rehearsal was eliminated by rapidly presenting the TBR stimuli (e.g., 100 milliseconds per item), verbal STM effects such as the WLE remained (Neath & Nairne, 1995). Examples of models that have illustrated the assumptions of the unitary perspective of memory are Neath and Nairne's (1995) Feature Model of Immediate Memory. In their model, remembering is cue driven, where the activated information that sits in verbal STM is a constellation of cues that individuals use to search for long-term information that would aid memory performance (Neath & Nairne, 1995; Nairne, 2002). The OSCillator-Based Associative Recall Model (OSCAR) (Brown et al., 2000) is another model which asserts that memories are represented as context vectors that are presented as sets of oscillators that systematically change over time. If a memory is not being used in verbal STM, the context vector oscillates further away from its starting position and is forgotten. Both models demonstrate the unitary view of memory through the symbiotic relationship between information held in verbal STM that cues the retrieval of information from a subsection of LTM to assist with later memory performance.

In summary, unitary memory theorists (Brown et al., 2000; Melton, 1963; Nairne, 2002; Neath & Nairne, 1995) ascribe to the view that memory exists on a continuum where individuals utilise their long-term knowledge as a cue to help facilitate short-term recall. More importantly, these models did not advocate that short-term forgetting results from decaying

short-term phonological memory traces. Rather, deficits in short-term recall result from some level of interference produced during the memory task that increases the reliance on long-term knowledge to support verbal STM performance.

### **Interference and short-term forgetting**

Unitary memory theorists (e.g., Brown et al., 2000; Melton, 1963; Nairne, 2002; Neath & Nairne, 1995) posit that short-term forgetting is interference based, where some form of information or activity interferes with encoding the newly acquired information into verbal STM (Melton, 1963). Support for the interference-based perspective largely stemmed from challenges made to the conclusions Peterson and Peterson (1959) reached in their study about short-term forgetting, where the increased length of the retention interval meant the short-term phonological memory traces for the TBR items began to decay as they could not be refreshed using rehearsal. Methodological manipulations of Peterson and Peterson's experimental task have found that the activity of counting backwards in threes did not prevent rehearsal of the three-consonant trigrams. Rather, counting backwards in threes created new memories that interfered with recalling the three-consonant trigrams (Keppel & Underwood, 1962; Waugh & Norman, 1965; Wickens, Born, & Allen, 1963). Researchers have explained this form of interference produced from the intervening activity through proactive and retroactive interference.

**Proactive interference.** Proactive interference occurs when previously learned information interferes with newly learnt information (Neath & Suprenant, 2003; Suprenant & Neath, 2009). Researchers have established that proactive interference could account for the forgetting observed in Peterson and Peterson's (1959) study because of the similarity of the three-consonant trigrams across all of the study trials (Keppel & Underwood, 1962; Neath &

Suprenant, 2003). A study by Keppel and Underwood (1962) closely examined Peterson and Peterson's finding, arguing that proactive interference was not observed initially because recall performance was averaged across the 12 trials in block one of their experimental task. Keppel and Underwood replicated Peterson and Peterson's study by keeping the retention interval between the last presented item and recall at 12 seconds, and examined memory performance for the first four trials. Their analyses revealed support for proactive interference occurring in Peterson and Peterson's study: in the first trial, irrespective of whether they imposed a three-second delay or an 18-second delay prior to recall, there was no forgetting as participants correctly recalled all of the three-consonant trigrams after each time delay. However, short-term recall for the three-consonant trigrams decreased for the subsequent trials, especially after the third trial. Keppel and Underwood argued that this finding was inconsistent with the decay-based perspective on short-term forgetting because recall performance for every trial should differ after a three-second time delay and after an 18-second time delay, with poorer performance after the 18-second delay (Neath & Suprenant, 2003). Rather, they suggested that participants relied on the concept of unlearning, where they attempt to eliminate previously learned information that was no longer needed by forming new associations with newly learnt information. This process weakened, particularly during longer retention intervals and, as a result, proactive interference became worse because it allowed more time for the spontaneous recovery of lists from the previous trials to interfere with memory performance.

Wickens, Born, and Allen (1963) also explained the patterns of forgetting observed in the Peterson and Peterson (1959) study through proactive interference, purporting there was a build-up of proactive interference because of multiple retrieval attempts to recall lists of TBR



items that were highly similar (Neath & Suprenant, 2003; Wickens et al., 1963). In the Peterson and Peterson study, recall performance suggested that participants found it increasingly difficult to distinguish between consonants presented on the current trial and consonants presented on earlier trials. To combat this, Wickens et al. argued that when there is a change in the category of the TBR items, irrespective of the change in direction of the TBR items (i.e., letters to numbers or numbers to letters), there would be a release of proactive interference. Wickens et al. therefore examined this proposition by manipulating the TBR items where the first three trials of the experiment contained consonants and, after each trial, participants completed a distractor activity. However, on the fourth trial, half of the participants viewed numbers instead of letters to determine whether the switch in the TBR materials would influence short-term recall performance and reduce proactive interference during the experimental task. Wickens et al. found a significant difference in memory performance, where short-term recall was higher for participants who had a switch in the TBR stimuli (i.e., numbers to letters or letters to numbers) compared with participants who viewed the same type of TBR stimuli (i.e., all numbers or all letters). The TBR stimuli in the first three trials were perceptually different from the TBR stimuli in the fourth trial. Even though rehearsal was prevented via the distractor activity, performance was near perfect when the TBR stimuli changed, supporting their initial propositions. Therefore, given the decay-based perspective on short-term forgetting could not account for this finding, the empirical research (Keppel & Underwood, 1962; Wickens et al., 1963) provides continued support for the interference-based account on short-term forgetting.

**Retroactive interference.** Further empirical support for the interference-based account of short-term forgetting came from the Waugh and Norman (1965) study that also challenged

the Peterson and Peterson (1959) finding from the view of retroactive interference, where newly learnt information interferes with previously learned information (Waugh & Norman, 1965). Waugh and Norman posited that the task of counting backwards in threes retroactively interfered with short-term recall. They presented participants with a list of 16 digits. The last digit in the sequence was the probe item and it always appeared exactly once in the sequence. For example, in the sequence 5 1 9 6 3 5 **4** 1 2 8 6 2 7 3 9 4, **4** was the probe digit. Participants were required to recall the number that immediately followed the probe item (i.e., the number 4). In this example, the correct response would have been 1. Waugh and Norman also manipulated the number of interfering items and the location of the probe item in the sequence. In this example, six digits preceded the probe digit and they assumed that six was the number of interfering items in the experimental task. They hypothesised that if the interference theory was correct, then the number of digits preceding the test item would dictate recall performance because increases in the number of interfering items would decrease the probability of correctly recalling the test item.

Waugh and Norman (1965) found the number of interfering items that preceded the test item affected short-term retention. They argued the number of interfering items acted as a form of retroactive interference because those items interfered with the participant's capacity to locate and subsequently retain the test item in verbal STM. They concluded that retroactive interference accounted for Peterson and Peterson's (1959) finding along with short-term forgetting observed in their study.

To conclude, researchers such as Keppell and Underwood (1962), Wickens et al. (1963), along with Waugh and Norman (1965) have convincingly challenged the decay perspective by demonstrating that short-term forgetting results from some level of interference when creating

the short-term phonological memory traces for the TBR items. Interference in short-term recall can either be proactive (Keppel & Underwood, 1962; Wickens et al., 1963) or retroactive (Melton, 1963; Waugh & Norman, 1965), substantiating the notion that interference increased the reliance on long-term knowledge to assist with short-term recall.

## **Conclusion**

In conclusion, memory researchers have sought to explain whether memory is a dual system or a unitary system. The dominant view that is held by dual memory theorists asserts there is a dichotomous relationship between verbal STM and LTM and this relationship is best conceptualised by Baddeley and Hitch's (1974) WMM, along with a number of derivatives of this model that are collectively referred to as the "standard model" (Nairne, 2002).

Furthermore, dual memory theorists asserted that short-term phonological memory traces decay over time if they are not refreshed using covert sub vocal rehearsal (Baddeley & Hitch, 1974; Brown, 1958; Peterson & Peterson, 1959). However, unitary memory theorists have asserted that there is an intrinsic relationship between verbal STM and LTM (Brown et al., 2000; Melton, 1963; Neath & Nairne, 1995). While information degrades from short-term phonological memory traces, it does not completely dissipate as phonological features remain which individuals use as cues to search for long-term information and aid short-term recall. Furthermore, unitary memory theorists posit that short-term forgetting occurs when there is some level of interference interrupting the short-term phonological memory traces of newly acquired information into verbal STM, rather than decay. This thesis aligned with the propositions of the unitary memory theorists because there is increased acknowledgment in the memory literature that LTM facilitates verbal STM performance. Specifically, there is one explanation, redintegration, which has received increasing support in the memory literature.

The redintegration literature has proposed that there is a secondary process, where the short-term phonological memory trace can be reconstructed with pre-existing phonemic and semantic knowledge. Such demonstrations include important effects in verbal STM that the WMM cannot explain: lexicality (Hulme, Maughan, & Brown, 1991; Hulme, Roodenrys, Brown, & Mercer, 1995), word frequency (Hulme et al., 1997), semantic similarity (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b), and concreteness (Millers & Roodenrys, 2009; Walker & Hulme, 1999). Given the viability of redintegration occurring in verbal STM, this thesis continued to examine the unitary view of memory by conducting a thorough review of redintegration and the research that supports this account of memory performance in Chapter two.

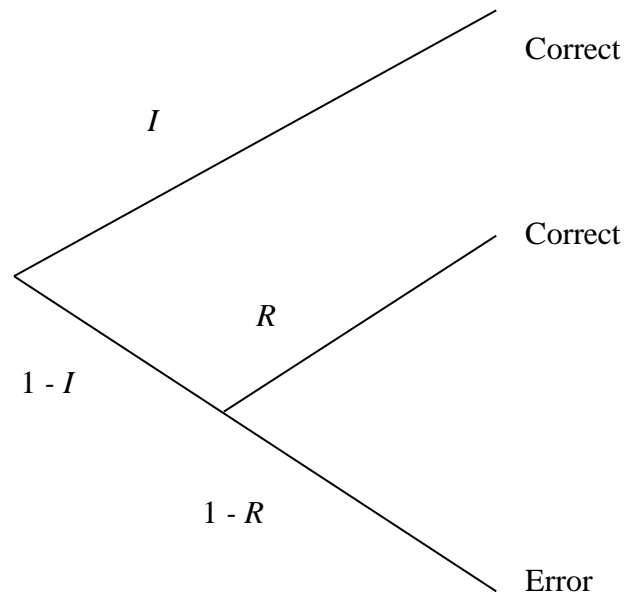
## Chapter two: Redintegration and verbal short-term memory

As verbal STM is transient in nature, the phonological (i.e., verbal) memory traces for the TBR items dissipate rapidly (Neale & Tehan, 2007; Schweickert, 1993; Thorn, Gathercole, & Frankish, 2004). Depending upon the remembering conditions, these short-term phonological memory traces can be either intact or degraded at the stage of recall. It is assumed that recall performance should not be problematic if the short-term phonological memory trace for the TBR item is intact. However, if the short-term phonological memory trace for the TBR item is degraded, access to long-term lexical and semantic memory is required in order to reconstruct the degraded short-term phonological memory traces for accurate retrieval. For example, knowledge of words and animals would allow individuals to generate the word *crocodile* from the word fragment *cr\_ \_ od\_le* that remains in the short-term phonological memory trace. This process of reconstructing a short-term phonological memory trace from long-term knowledge for short-term recall is known as redintegration (Schweickert, 1993).

The processes underlying redintegration have been formalised in other models such as the Brain-State-In-A-Box (Anderson, Silverstein, Jones, & Jones, 1977) and the Theory of Distributed Associate Memory (Lewandowsky & Murdock, 1989). However, this thesis used Schweickert's (1993) Multinomial Processing Tree Model of Redintegration because it was the most parsimonious approach in the context of how redintegration was measured using different variables and how task difficulty was manipulated in the experimental task. Chapter Two conducts a review of Schweickert's model and the various measurements of redintegration that have been established in the verbal STM literature to solidify the unitary view of human memory.

### **Schweickert's (1993) Multinomial Processing Tree Model of Redintegration.**

Schweickert's (1993) Multinomial Processing Tree Model of Redintegration proposed that at recall, the short-term phonological memory trace for a TBR item is either intact or degraded to the extent that it is vague and unclear in facilitating recall (Neale & Tehan, 2007; Thorn et al., 2004). Schweickert noted that there are three possible outcomes at recall, which were formalised in a model using a multinomial processing tree, as seen in Figure 2.1. It was not the intention of this thesis to evaluate or distinguish between the different models of redintegration. It is also important to note that this thesis was not a formal test of Schweickert's model. In this thesis, redintegration was examined at a general level whereas Schweickert's model is a very specific mathematical model of redintegration. Using Schweickert's model is one way of measuring redintegration. The methodology and procedures used to examine redintegration are in alignment with the Neale and Tehan (2007) study and this study is explored in Chapter three.



*Figure 2.1.* Schweickert's (1993) Multinomial Processing Tree Model of Redintegration.  $I$  = the probability of retrieving the TBR item intact and that TBR item can be recalled directly and correctly from verbal STM.  $R$  = the probability that the TBR item can be reconstructed through redintegration.

As Schweickert (1993) described, attempts to recall a TBR item are carried out through a sequence of cognitive processes, which are represented by branches on a path from the root of the tree to one of the terminal nodes at the end of the branch, and the outcome of the recall attempt depends on which terminal node individuals reach. Applying this to redintegration, first if at recall the short-term phonological memory trace is intact, the TBR item can be recalled directly from verbal STM, resulting in successful recall of that item. The certain probability of this outcome is denoted by  $I$  in Figure 2.1. If the short-term phonological memory trace for the TBR item has degraded to the extent where it can no longer support short-term recall, the process of redintegration begins and two further outcomes are possible. The first of these two possibilities occurs when some phonological characteristics of the short-term memory traces for the TBR items are still available and can aid in the search of long-term

characteristics. Successful redintegration results in individuals recalling the TBR item because the degraded short-term phonological memory trace was rebuilt from available long-term information and was not degraded to an extent that it was no longer useful, as denoted by  $R$  in Figure 2.1. The second of these two possibilities occurs when redintegration is unsuccessful and instead, individuals produce an error during recall. Essentially, if the short-term phonological memory trace has degraded to such an extent that no useable information remains, there is nothing on which to build a trace from LTM using the remaining short-term cues. Consequently, redintegration cannot take place and recall results in an error, as seen in Figure 2.1. Together, these assumptions led Schweickert to devise the equation that the probability of correctly recalling a TBR item is  $I + (1 - I)R$ . This is the sum of the probability of retrieving the TBR item intact ( $I$ ) plus the product of the probability of the item not being intact ( $1 - I$ ) with the probability that it can be reconstructed ( $R$ ).

### **Redintegration and immediate serial recall tasks**

Redintegration has been predominantly measured using immediate serial recall tasks, where the TBR items are presented visually using a computer program or verbally using an audiotape. Immediately after presenting the last item, individuals are required to recall, verbatim, the list of TBR items in their original serial order (Poirier & Saint-Aubin, 1996; Roodenrys & Quinlan, 2000; Saint-Aubin & Poirier, 1995, 1999a, 1999b). When recall commences, individuals rely on their long-term semantic and short-term phonological knowledge to rebuild the short-term phonological memory traces for the TBR items. The traces for those items presented earlier in the list are relatively intact as they can be retrieved directly from verbal STM (Hulme et al., 1997; Saint-Aubin & Poirier, 1995, 1999a, 1999b; Schweickert, Chen, & Poirier, 1999). Items presented in the middle or later in the list,



however, are more reliant on redintegration to assist with short-term recall because those items are subject to more degradation from other interfering factors during encoding (Hulme et al., 1997; Saint-Aubin & Poirier, 1995, 1999a, 1999b; Schweickert et al., 1999).

Immediate serial recall tasks also use a strict criterion when scoring the TBR items as correct or incorrect to account for the influence of long-term knowledge upon short-term recall (Saint-Aubin & Poirier, 2000). For item scoring, an item is scored as correct if it is one of the originally presented items, irrespective of the serial position in which the TBR item was produced at output. From the redintegration perspective, item recall is influenced by the effectiveness of the retrieval process. Factors that have been found to improve this retrieval process include the lexical properties of the word (Hulme et al., 1991; Hulme et al., 1995), word frequency (Hulme et al., 1997), semantic similarity (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b), and word concreteness (Millers & Roodenrys, 2009; Roche, Tolan, & Tehan, 2011; Walker & Hulme, 1999) because these factors increase access to the long-term representations to facilitate redintegration and later recall. Item recall can be hindered by factors such as articulatory suppression (Nairne, 2002; Neath & Suprenant, 2003) and irrelevant speech (Colle & Welsh, 1976; Jones & Morris, 1992) because they increase degradation of the short-term phonological memory traces that may assist in reconstructing the memory traces for those TBR items. In these instances, an omission error generally occurs because there is insufficient information to reconstruct a possible contender for short-term recall.

For order scoring, however, an item is scored as correct if it is one of the originally presented items recalled in its original serial position (Saint-Aubin & Poirier, 2000). As Saint-Aubin and Poirier (2000) outline, deficits in order recall are thought to occur because of errors

when interpreting the short-term phonological memory trace of the TBR item, particularly if there are factors that have interfered with encoding the TBR items into verbal STM; for example articulatory suppression (Nairne, 2002; Neath & Suprenant, 2003) and irrelevant speech (Colle & Welsh, 1976; Jones & Morris, 1992). One type of order error is a transposition, which occurs when two adjacent items switch serial position at output. This may result from individuals having difficulty interpreting the short-term phonological memory trace for a given TBR item as another item presented in the list because there was an absence of a distinctive feature to distinguish one TBR item from another TBR item in the list (Saint-Aubin & Poirier, 2000). For example, this list of TBR items shares the same phonological feature being a sound (e.g., *cat, bat, fat, hat, rat*). There is a higher probability of recalling these words in a different serial order to how they were originally presented because all of the words in the list sound similar. This is in comparison to another list of TBR items that do not share the same phonological feature, where each word has a different sound (e.g., *dog, bone, pig, hop, ant*). This discriminating feature of sound enhances the likelihood of recalling the items in their correct serial position because each item is quite distinct from each other.

Redintegration is best examined through immediate serial recall tasks because decomposing scoring in terms of item and order information helps to understand the factors that influence the degradation and subsequent redintegration of those degraded short-term phonological representations for later output (Schweickert et al., 1999). One such study by Schweickert, Chen, and Poirier (1999) identified factors such as word length and serial position that selectively influenced degradation and factors such as word frequency, lexicality, and phonological similarity that selectively influenced redintegration across a series of experiments. Using Schweickert's (1993) Processing Tree Model of Redintegration,

Schweickert et al. found that the more degraded a short-term phonological representation was for the TBR item, the greater the role of redintegration to facilitate short-term recall. One well-documented example of redintegration effects facilitating verbal STM performance is the lexicality effect (Hulme et al., 1991; Hulme et al., 1995).

**The lexicality effect.** The lexicality effect refers to the superior recall of lists of words (e.g., *apple, cat, star, house*) compared with lists of nonwords (e.g., *fonf, blig, crot, tenk*) (Hulme et al., 1991; Hulme et al., 1995). This effect can be explained from the redintegration perspective, which suggests that individuals call upon their long-term lexical/semantic knowledge to reconstruct the damaged short-term phonological memory trace of the TBR item for later output (Hulme et al., 1991; Hulme et al., 1995). For example, with the item *apple*, individuals would use their long-term semantic knowledge of *apple*, knowing it is a *fruit* and their phonological knowledge that *apple* contains two syllables to locate the correct information to rebuild the short-term phonological memory trace (Hulme et al., 1991; Hulme et al., 1995). However, using long-term knowledge to reconstruct nonwords such as *flinb* is of limited utility because there are no previously stored representations to use, should redintegration be required (Hulme et al., 1991; Hulme et al., 1995). Consequently, attempts at reconstructing the degraded short-term phonological memory traces becomes difficult, if at all possible (Hulme et al., 1991; Hulme et al., 1995). For example, using redintegration for the nonword *flinb*, individuals can only rely on the lexical and phonological properties of the TBR item that remain in verbal STM to support any reconstruction attempt (Hulme et al., 1991; Hulme et al., 1995). Although, redintegration is still possible for nonwords, despite not having a true lexical form, if the phonological characteristics resemble real words (Besner & Davelaar, 1982; Frisch, Large, & Pisoni, 2000; Gathercole, 1995). For example, the nonword

*foan* phonologically resembles the word *phone*. Redintegration attempts are possible for *foan* because a phonological code can be stored in LTM to use for later recall. Long-term knowledge of words and sound patterns can facilitate the match between the available information that remains in the degraded short-term phonological memory trace for *foan* and the long-term semantic representation for *phone*, leading to recalling the nonword *foan* (Besner & Davelaar, 1982; Frisch et al., 2000; Gathercole, 1995).

Research investigating the lexicality effect in verbal STM has emphasised it is the availability of long-term phonological representations that gives rise to the higher recall of words compared with nonwords, as initially demonstrated in memory span tasks (Hulme et al., 1991; Hulme et al., 1995). A study by Hulme, Maughan, and Brown (1991) demonstrated long-term knowledge contributions to memory span performance by investigating the memory span and speech rate for words and nonwords. Hulme et al. acknowledged that while Baddeley and Hitch's (1974) WMM has dominated explanations for the limits on memory span, research suggesting the role of long-term contributions in short-term recall motivated Hulme et al. to reconsider the trace-decay explanation of memory span. Hulme et al. conducted two experiments to clarify the nature of LTM contributions to memory span and separate it from the storage component in a short-term store that is subject to decay. Furthermore, because nonwords are unfamiliar and lack long-term representations, they believed this would provide a pure measure of the articulatory loop in the absence of LTM support. That is, the speech rate for nonwords may be lower compared with words because of a lack of long-term representations that influence their rehearsal when present in the articulatory loop.

For experiment one, Hulme et al. (1991) created three pools of eight words that varied in length: words with short spoken duration (i.e., one syllable), medium spoken duration (i.e.,

two syllables), and long spoken duration (i.e., three syllables). They also created three pools of eight nonwords with short, medium, and long spoken duration. To measure speech rate, they gave participants four pairs of words and four pairs of nonwords to repeat five times. To measure memory span (i.e., the capacity of verbal STM), participants were presented with lists of words and lists of nonwords beginning with two-word sequences. These sequences increased until the participant could no longer recall the lists. Examining the linear relationship between memory span and speech rate, Hulme et al. used the slopes of the linear relationship as the measure of the articulatory loop (i.e., their estimate of the capacity store) and the intercepts as a measure of LTM contributions (i.e., the number of items recalled). Based on the slopes, memory span for words and nonwords increased as item length decreased. Yet, based on the difference in the intercepts, memory span was consistently lower for nonwords compared with words. Hulme et al. made a tentative conclusion that items recalled in a memory span task are rehearsed through the articulatory loop but these items are more likely to be successfully recalled if long-term information is available.

In a second experiment, Hulme et al. (1991) gave participants Italian words that were initially unfamiliar to them, and were then taught their English translation. They believed that teaching participants the English translations would create a long-term representation of the Italian word that could be later retrieved to assist with short-term recall. Hulme et al. used a similar methodology to experiment one but also included a control group of English words, of which they gave participants the Italian translation. The findings revealed that before and after training (i.e., learning the English translation of the Italian words), memory span was higher for the English words than the Italian words. More importantly though, the memory span for Italian words increased substantially after learning the translations while there was no

comparable change in the memory span for English words whose Italian translations were learned. These findings led Hulme et al. to conclude that as the Italian words were initially new to the participant, there was no form of long-term representation that could be retrieved to assist short-term recall. However, learning the English translations of the Italian words provided participants with access to a long-term semantic representation for the Italian word, thus contributing to a substantial increase in their memory span. Furthermore, when participants retrieved the TBR items, they also utilised their knowledge about phonological structures of words to reconstruct the TBR item. As Hulme et al. provided participants with semantic information, semantic coding might have also taken place during retrieval. Thus, it appears that the availability of long-term phonological and semantic information increased the likelihood of retrieving the TBR information from verbal STM for later output.

Hulme, Roodenrys, Brown, and Mercer (1995) also substantiated the view that the availability of long-term representations contributed to improved short-term recall performance for words and nonwords. Over two testing sessions, participants completed a phonological training procedure, where they viewed the lists of words and nonwords, and were asked to repeat each list five times in a memory span task and a speech rate task. Session two occurred 24 hours later, where participants completed the same training procedure but completed the tasks in a counterbalanced order. Hulme et al. argued that if long-term phonological representations did contribute to memory span, then phonological training procedure should benefit memory span for nonwords, as this would increase familiarity with these nonwords. The phonological training would have little effect on memory span for words because participants already have previously stored phonological representations for these words. Participants were also required to complete a brief questionnaire and rate the

importance of sound, word association and semantic associations in completing the memory span task.

Hulme et al. (1995) observed the lexicality effect, where recall was significantly higher for words than nonwords. However, the difference in memory span between sessions one and two for nonwords was higher than the difference in memory span between sessions one and two for words. These differential improvements remained even after controlling for the effects of speech rate. Similarly, there were increases in the speech rate between session one and two, with the increase being larger for nonwords than for words, and the size of the differences in memory span outweighed the differences in speech rate. Hulme et al. attributed the improvements in performance for nonwords to the phonological training achieved through the familiarisation task that helped create new long-term representations, which permitted the reconstruction of the partially decayed short-term phonological memory traces for the TBR items. Further evidence for the benefits of the phonological training stemmed from the questionnaire results, where the familiarity with sounds of the test items, particularly the nonwords was critical in improving memory performance. This was in comparison to lexical factors such as associations between words and nonwords, and semantic factors such as semantic associations between nonwords and any meaning that may be attached to them. Therefore, irrespective of whether the long-term representations were phonological or semantic in nature, it appears that the availability of such long-term representations facilitated short-term recall performance.

The redintegration account of the lexicality effect can also be explained from the item-order perspective (Nairne, Riegler, & Serra, 1991), where short-term recall performance is examined by measuring factors in item and order information. As Saint-Aubin and Poirier

(2000) reported, higher item recall for words than nonwords occurred because words have long-term semantic representations that can be accessed to interpret the short-term phonological memory trace and subsequently recall the TBR item. Nonwords, however, do not have previously stored long-term phonological and semantic representations to facilitate a potential reconstruction attempt for later recall. On the contrary, for order recall, a reverse lexicality effect is often observed, where recall is higher for nonwords because they do not have long-term representations that, if degraded, have the possibility of potentially confusing the interpretation of this trace with a degraded short-term phonological memory trace for another item. In other words, each nonword is unique, which makes each short-term phonological representation distinguishable from another nonword. For words, however, there is a higher probability of confusion when interpreting the long-term semantic representations because if those traces lose some of their unique features, the long-term presentation of another list item that has common features can be selected erroneously as a recall candidate.

To test their suggestions, Saint-Aubin and Poirier (2000) used an immediate serial recall task and asked participants to view five lists containing 24 words and five lists containing 24 nonwords. Half of the word lists were presented in silence and for the remaining lists, participants engaged in an articulatory suppression task by repeating the word *mathématiques* while recalling the TBR items. Under quiet and articulatory suppression conditions, they replicated the lexicality effect, where recall was significantly higher for words compared with nonwords. Examination of the errors produced under articulatory suppression conditions revealed errors were most pronounced during order recall, where participants produced a higher number of errors for words compared with nonwords. Saint-Aubin and Poirier explained their findings through the redintegration account with lexicality benefiting item



recall but hindering order recall. Therefore, even from the item-order perspective, long-term phonological and semantic representations gave rise to the lexicality effect observed in short-term recall.

To conclude, the lexicality effect adequately demonstrates the symbiotic relationship between long-term lexical/phonological representations facilitating verbal STM performance. Recall is higher for words because attempts to reconstruct their degraded short-term phonological memory trace are possible as individuals can retrieve the semantic representations, which are readily available in LTM for recall compared with nonwords that lack previously stored long-term representations (Hulme et al., 1991; Hulme et al., 1995; Saint-Aubin & Poirier, 2000). Nonwords only benefit from long-term knowledge in reconstructing their short-term phonological memory trace if their phonological characteristics resemble a real word (Besner & Davelaar, 1982; Frisch et al., 2000; Gathercole, 1995). It is clear the availability of long-term phonological representations is essential in order to locate information from which to reconstruct a partially degraded short-term phonological memory trace for verbal STM performance (Hulme et al., 1991; Hulme et al., 1995; Saint-Aubin & Poirier, 2000). Researchers have also observed the benefits of long-term knowledge supporting verbal STM performance from the redintegration perspective through another well-documented finding, the word frequency effect (Hulme et al., 1997).

**The word frequency effect.** The word frequency effect refers to the well-established finding that short-term recall is greater for high frequency words compared with low frequency words, based on the frequency with which the word appears in the English lexicon (Hulme et al., 1997). The impetus for the word frequency effect centres on the accessibility of phonological and semantic representations to aid short-term recall (Hulme et al., 1997). The

long-term semantic representations for high frequency words are more accessible and more integrated in memory, and are thus more easily retrieved for later output (Hulme et al., 1997). For low frequency words, however, long-term semantic representations are available but they are less accessible because the phonological representations are less integrated in memory, making them difficult to access and subsequently retrieve from LTM. As such, attempts at reconstructing the degraded short-term phonological memory trace for those TBR items are considerably reduced (Hulme et al., 1997).

Similar to investigations examining the lexicality effect (Hulme et al., 1991; Hulme et al., 1995), there is empirical support for the contribution of long-term semantic and phonological knowledge to the word frequency effect. A study by Hulme et al. (1997) demonstrated this notion in a series of experiments, arguing that, much like examinations of the lexicality effect, the WMM (Baddeley & Hitch, 1974) does not adequately explain the word frequency effect and that redintegration was a better account because there was growing acknowledgement of long-term knowledge supporting verbal STM performance. In experiment one, Hulme et al. measured the memory span for high and low frequency words of different spoken lengths. Using monosyllabic high and low frequency words, they found the word frequency effect, where participants recalled a significantly higher proportion of high frequency words than low frequency words, and this difference was independent of articulation rate. Believing this recall difference reflected differences in accessing long-term phonological representations, Hulme et al. then used an immediate serial recall task, with a particular focus on serial position, to examine where the contributions of long-term knowledge was at its greatest. In other words, did participants recall the TBR items directly from LTM or did they retrieve information from LTM to assist with recall. Hulme et al. found that the word

frequency increased across serial positions, consistent with a retrieval-type process. However, when assessed backward serial recall, the word frequency effect was abolished.

Hulme et al.'s (1997) findings across their experiments demonstrated an important interaction between word frequency and serial position through the redintegration process. As individuals recalled successive items, the primary memory traces of the later TBR items became increasingly degraded. Such degradation led to an increased reliance on redintegration to recall the later TBR items in the list, leading to a larger recall difference between high and low frequency words in the later serial positions. High frequency words benefit more from redintegration than low frequency words because their respective long-term representations were more accessible in LTM. Hulme et al. therefore concluded from their research that word frequency affects the quality and accessibility of the lexical-phonological representations of spoken words and that access to those representations was crucial for the redintegration of degraded traces held in verbal STM.

A study by Poirier and Saint-Aubin (1996) also emphasised that high frequency words would enhance the probability of rebuilding damaged short-term phonological memory traces, leading to correct recall of the TBR item in its serial position because of the ease of accessing their long-term phonological and semantic representations. In their experiment, participants viewed lists of phonologically similar words of low, medium, and high frequency and lists of phonologically dissimilar words of low, medium, and high frequency in an immediate serial recall task. They found too that at the item level, individuals recalled a significantly higher proportion of high frequency words compared with medium and low frequency words. At the order level, there was no effect of word frequency. Poirier and Saint-Aubin inferred from their findings that much like Hulme et al. (1997), lists that contain high frequency words improved

the probability of retrieving the TBR items from LTM because their phonological representation acted as a form of retrieval cue to help locate the correct candidate in LTM for later verbal STM performance. Word frequency had no impact on recalling the TBR words in their correct serial order.

Other researchers, such as Stuart and Hulme (2000), have offered an alternative explanation of the word frequency effect by means of the associative link hypothesis. Rather than attributing the word frequency effect due to increased access of the long-term representations for later output, this hypothesis proposes that the inter-word associative links between the TBR item and its corresponding long-term semantic representation enhance word recall. In other words, the stronger the associations in LTM, the greater the benefits to short-term recall performance because individuals can utilise the associative links to locate long-term information that would assist with retrieving information for later recall. In terms of the word frequency effect, high frequency words have stronger inter-word connections that can be retrieved more efficiently for later output compared with low frequency words. Saint-Aubin and Poirier (2005) sought to test Stuart and Hulme's explanation for the word frequency effect by manipulating the different familiarisation procedures that establish interconnections between the TBR items that facilitate later recall. In the item familiarisation procedure, participants were presented with each individual TBR item and asked to repeat it. For the pair familiarisation procedure, the TBR words were presented in pairs.

Saint-Aubin and Poirier (2005) found the word frequency effect, where recall was greater for high frequency words compared with low frequency words, with both item and pair familiarisation procedures improving item recall for high and low frequency words. These observations were consistent with the associative link hypothesis (Stuart & Hulme, 2000).

However, if inter-item associations produced the word frequency effect, there would have been an advantage in item recall via the pair familiarisation procedure as opposed to the item familiarisation procedure because presenting the TBR items in pairs would have facilitated associative links between the TBR items. This is in contrast to the item familiarisation procedure, which aimed to minimise the inter-item associations by presenting the TBR items individually. Saint-Aubin and Poirier found their results were best explained through redintegration. That is, the improvement in item recall through the item and pair familiarisation procedures actually resulted from increased knowledge of the TBR items through familiarity. This knowledge then increased access to long-term semantic representations, particularly those for high frequency words because they were more accessible due to the characteristics of the individual item and not because of its relationship with other high frequency items in the list. It was therefore evident from the literature that the redintegration process presented a more compelling account of the word frequency effect in verbal STM tasks.

In conclusion, the word frequency effect, as explained through the redintegration process, is another demonstration of the intrinsic relationship between verbal STM and LTM (Hulme et al., 1997; Saint-Aubin & Poirier, 2005). Recall is greater for high frequency words due to greater accessibility to long-term phonological and semantic representations that can be retrieved to assist with short-term recall (Hulme et al., 1997; Saint-Aubin & Poirier, 2005). The long-term representations for low frequency words are not as accessible and are more difficult to retrieve for later short-term recall, consequently impairing memory performance for these words (Hulme et al., 1997; Saint-Aubin & Poirier, 2005). Despite other explanations, such as the associative-link hypothesis (Stuart & Hulme, 2000) attempting to explain word

frequency in verbal STM, researchers found that redintegration best explained the word frequency effect in addition to other verbal short-term phenomena such as the semantic similarity effect.

**The semantic similarity effect.** There is agreement in the memory literature that studying TBR items that are related to one semantic category improves short-term recall because knowing there is a relationship inherent among the TBR items enhances the efficiency of encoding the TBR items into verbal STM as all of the items are from one semantic category. Such efficient encoding increases the likelihood of retrieving the correct long-term information to recall the TBR items for later output (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b). This is in comparison to studying each TBR item within a list that comes from a different semantic category. Encoding is less efficient because unique information needs to be encoded for each TBR item, decreasing the likelihood of retrieving the correct information to recall the TBR item (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b).

A study by Poirier and Saint-Aubin (1995) demonstrated the influence of long-term semantic knowledge facilitating verbal STM performance using an immediate serial recall task. They compared recall performance of six-item lists containing words from the same semantic category (e.g., *sports*, *musical instruments*) and six-item lists containing words from different semantic categories. In their first experiment, when Poirier and Saint-Aubin scored performance using a free recall criterion (i.e., recall items irrespective of their original presentation order) or a strict order criterion (i.e., recall items in their original presentation order), they found a substantial recall advantage for categorical relatedness. Specifically, participants recalled a significantly higher proportion of items from the category related word

lists compared with items from the category unrelated word lists. To ensure the categorical relatedness advantage was independent of the articulatory loop, in other words, the rate at which the TBR words are rehearsed prior to output, Poirier and Saint-Aubin in experiment two introduced articulatory suppression into the experimental task by instructing participants to repeat the word *mathématiques* while encoding the TBR items into verbal STM. Short-term recall performance still favoured a categorical relatedness advantage under quiet and articulatory suppression conditions. In fact, the categorical relatedness advantage became stronger in the articulatory suppression conditions compared with the quiet conditions. Even when Poirier and Saint-Aubin introduced articulatory suppression during encoding and asked participants to write down their responses, the categorical relatedness continued to emerge during recall.

Poirier and Saint-Aubin (1995) argued that long-term factors facilitated memory performance in their experimental tasks, finding that redintegration best explained their observations. Knowing the TBR items were from the same category, in combination with partial memory information about the TBR item, reduced the number of potential recall candidates individuals retrieved for later output. Articulatory suppression further degraded the short-term phonological representation by interfering with encoding the TBR item into verbal STM, making the reconstruction of these degraded memory traces difficult. However, as Poirier and Saint-Aubin found, if the TBR items were semantically related, the redintegration process would be relatively efficient because recall attempts would be cued to a subsection of LTM as opposed to searching its entire contents. Poirier and Saint-Aubin therefore concluded that long-term knowledge, in the form of the structure of the list of TBR items linked to a semantic category, combined with the degraded short-term phonological memory traces for

those same TBR items, increased the probability of producing the correct TBR items at output, giving rise to the category relatedness advantage observed in their research.

Saint-Aubin and Poirier (1999a) also established facilitative effect of semantic similarity on verbal STM performance, clarifying the nature of semantic information on order recall and positing that semantic similarity would not provide any additional support to remembering the TBR items in their correct serial order. Using a similar methodology to Poirier and Saint-Aubin (1995), Saint-Aubin and Poirier found the semantic similarity effect for item recall. When they used an order reconstruction task, which focused solely on arranging the TBR items in their correct serial order without the need to recall the items, contrary to their expectations, a semantic similarity advantage emerged. Even when they introduced articulatory suppression into the experimental task, despite the semantic similarity advantage increasing under articulatory suppression conditions for item recall, there was no semantic similarity decrement for order recall. Saint-Aubin and Poirier found that the redintegration process also best explained their multitude of findings. Recall was higher for semantically similar items because semantic similarity acted as an additional retrieval cue to facilitate the search for long-term information to reconstruct the degraded short-term phonological memory trace for later output. However, for order recall, it was assumed there would be no difference in recall because the basic retrieval cue for a degraded short-term phonological memory trace for either a semantically similar or dissimilar item is a degraded phonological representation, and thus the nature and number of phonological features would be relatively the same. Saint-Aubin and Poirier therefore concluded that the redintegration process best accounted for their findings of long-term semantic knowledge aiding verbal STM performance at the item and order levels.



In conclusion, the semantic similarity effect continues to explicate the symbiotic relationship between verbal STM and LTM. Recall is higher for lists of TBR items that are from the same semantic category compared with TBR items that are from different semantic categories because the semantic category acts as an additional retrieval cue that narrows the search for recall candidates to a specific section of LTM (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b). The semantic category enhanced the redintegration process by increasing the likelihood of locating the correct long-term representation to match with the remaining information available in verbal STM for the TBR item for later output (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b). It was clear from the literature that semantic representations enhanced verbal STM performance and these reported benefits have also been extended to the quality of semantic representations in LTM through the concreteness effect (Millers & Roodenrys, 2009; Roche et al., 2011; Walker & Hulme, 1999).

**The concreteness effect.** The concreteness effect refers to the finding that highly concrete words (defined as words which relate to objects or materials e.g., *ball*, *ship*) have a recall advantage over less concrete or abstract words (defined as words that cannot be directly experienced that are abstract qualities or actions e.g., *logic*, *conscience*) (Millers & Roodenrys, 2009; Roche et al., 2011; Walker & Hulme, 1999). From the redintegration perspective, the difference in short-term recall performance for concrete and abstract words is reflected through differential processing of long-term semantic information (Millers & Roodenrys, 2009; Roche et al., 2011; Walker & Hulme, 1999). Concrete words are assumed to have richer long-term semantic representations compared with abstract words and as such, their long-term representations would be easier to retrieve and match with the corresponding degraded short-

term phonological memory trace, aiding reconstruction and ultimately facilitating short-term recall (Millers & Roodenrys, 2009; Roche et al., 2011; Walker & Hulme, 1999).

The literature indicates that concreteness affects the quality of semantic information that can be utilised to aid memory performance in a short-term recall task. Walker and Hulme (1999) established through the concreteness effect that long-term semantic information benefited short-term recall. They argued that verbal STM tasks depended on access to lexical-semantic codes and that concreteness would enhance the likelihood of retrieving semantic information to facilitate memory performance. Walker and Hulme compared the recall performance for lists of concrete and abstract words using an immediate serial recall task and found that recall was significantly higher for concrete words than abstract words. Examination of the errors revealed there was no significant difference in the order errors produced between concrete and abstract words, but participants produced a significantly higher proportion of item errors for abstract words than concrete words. Even when participants were required engage in written recall and the experimental task changed to a backward serial recall task, the concreteness effect still emerged. However, when Walker and Hulme used a matching span procedure, where participants were presented with two lists of words and they had to indicate whether the lists contained the same or different words, to minimise the retrieval processing requirements in the task, the concreteness effect was abolished.

Walker and Hulme interpreted their findings on the notion that the quality or strength of the semantic representation of the TBR word contributed directly to how well individuals recalled that word, as evidenced through their error analyses. Moreover, they suggested from the redintegrative perspective that concreteness facilitated the redintegration process for semantic information. Specifically, long-term semantic and phonological information was

utilised to reconstruct the degraded short-term phonological representation of the TBR items and the degraded trace could be matched with the permanent long-term semantic representations. Concreteness facilitated the redintegration process because the representations of concrete words contained more unique information compared with the phonological representations of abstract words, with this unique information facilitating the reconstruction process and enhancing verbal STM performance.

Roche, Tolan, and Tehan (2011) also established the beneficial effects of concreteness on short-term recall through forward and backward serial recall, in a manner similar to Walker and Hulme (1999), along with an item recognition task. In this task, participants were presented with a list of words previously used in the task where they were asked whether they recognised the words during the task. If they recognised any of the TBR items, they were then required to indicate whether they clearly and consciously remembered the TBR item or whether they were familiar or thought they knew the TBR item was in the task. The concreteness effect was observed in the forward serial recall task, the backward serial recall task, and importantly, the item recognition task, where participants recognised a significantly higher proportion of concrete words than abstract words. Roche et al. applied the redintegration account to their findings, where the richer set of interconnections held in LTM for concrete words led to an increased likelihood of reconstructing their short-term phonological memory traces in the forward and backward serial recall tasks compared with abstract words. However, while researchers have not previously applied the redintegration account to item recognition tasks, Roche et al. suggested that the retrieval process involved was similar to the recall tasks, which involved producing an item that had a degraded short-term phonological representation that needed restoration. It was therefore evident that the

concreteness effects observed in the literature represents the beneficial effects of long-term semantic knowledge contributing to verbal STM performance.

In conclusion, the concreteness effect continues to support the redintegration process, further highlighting the intrinsic relationship between verbal STM and LTM. Concrete words have a substantial recall advantage compared with abstract words as they have richer semantic representations that can be utilised to enhance memory performance (Millers & Roodenrys, 2009; Roche et al., 2011; Walker & Hulme, 1999). Observing the concreteness effect in verbal STM has highlighted that individuals rely on their long-term phonological and semantic knowledge to facilitate short-term recall.

## **Conclusion**

To conclude, redintegration is a viable view of explicating the intrinsic relationship between verbal STM and LTM that has been well documented in the memory literature. These stores work in unison to retrieve the correct long-term information to support short-term recall (Neale & Tehan, 2007; Schweickert, 1993). In instances where there was damage to the short-term phonological memory trace for the TBR item, individuals rebuilt the short-term phonological memory trace by matching the remaining information available in the short-term phonological memory trace with the permanent knowledge retrieved from LTM (Neale & Tehan, 2007; Schweickert, 1993). Examples of long-term knowledge include lexicality (Hulme et al., 1991; Hulme et al., 1995), word frequency (Hulme et al., 1997), semantic relatedness (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b), and concreteness of the TBR item (Millers & Roodenrys, 2009; Roche et al., 2011; Walker & Hulme, 1999). These robust effects demonstrated that individuals utilise different aspects of their long-term knowledge, be it phonological (Hulme et al., 1995) or semantic (Hulme et al.,

1991; Nairne et al., 1991) to facilitate short-term recall performance. It was therefore imperative in this thesis to investigate whether redintegration could be extended to other variables such as word length, associate word pairs, and word relatedness. While the literature has demonstrated redintegration effects in verbal STM, no study to date has indicated whether young and older adults differ in their capacity to redintegrate. One study that addressed the question this thesis intended to investigate was conducted by Neale and Tehan (2007). It was important to review their study because they continued to demonstrate the strength of redintegration operating in verbal STM by measuring redintegration differently using Schweickert's (1993) Multinomial Processing Tree Model of Redintegration. Moreover, Neale and Tehan manipulated the reliance on redintegration by creating a measure of task difficulty to investigate where the individual's reliance on redintegration to aid short-term recall performance was at its greatest. Finally, Neale and Tehan examined whether age differences exist in redintegration by comparing the verbal STM performance of young and older adults. Given the uniqueness of Neale and Tehan's study in the context of this thesis, a detailed review of Neale and Tehan's study follows in Chapter three.

### **Chapter three: Neale and Tehan study**

Neale and Tehan (2007) conducted a unique investigation of redintegration using Schweickert's (1993) Multinomial Processing Tree Model of Redintegration. Their study was important in the context of this thesis because Neale and Tehan also advocated for a unitary view of human memory, consistent with previous researchers (e.g., Brown et al., 2000; Melton, 1963; Nairne, 1990) who have proposed that verbal STM and LTM are intrinsically related to facilitate memory performance. The manners in which Neale and Tehan measured redintegration in a verbal STM task and manipulated the reliance on redintegration revealed key findings that continued to inform the processes underlying redintegration. Moreover, Neale and Tehan are the only researchers to this date who have examined whether age differences exist in redintegration. This thesis intended to extend upon their findings in the subsequent empirical studies and provide greater empirical support for the redintegration process at three levels. First, measure redintegration using different variables known to benefit from pre-existing knowledge (i.e., the WLE, associate word pairs, and the false memory effect). Second, create a new measure of task difficulty using a different combination of variables known to interfere with and impair short-term recall performance (i.e., recall interval, study condition, and presentation rate). Finally, examine whether age differences exist in redintegration by using a sample of young and older adults that were different from Neale and Tehan. Given the relevance of Neale and Tehan's study to this thesis, Chapter Three reviews the development and findings that emerged from their study.

#### **Experiment one**

To measure the reliance on redintegration in verbal STM, Neale and Tehan (2007) created a measure of task difficulty following Schweickert et al.'s (1999) logic by using

variables that were assumed to influence different memory processes and were known to impair short-term recall performance. Their measure of task difficulty intended to interfere with encoding the TBR information into verbal STM, which supported previous researchers (e.g., Keppel & Underwood, 1962; Melton, 1963; Waugh & Norman, 1965; Wickens et al., 1963) who explained short-term forgetting through some form of activity interfering with encoding information into verbal STM. However, rather than expressing task difficulty on a single dimension using one variable, Neale and Tehan elected to manipulate task difficulty using a combination of three variables. They believed using a combination of variables would lead to larger disruptions in verbal STM performance and a higher likelihood of individuals relying on redintegration to reconstruct the short-term phonological memory traces for the TBR items than that achieved if they used either of their variables as their measure of task difficulty.

For their task difficulty manipulation, Neale and Tehan (2007) used the following variables: list length (i.e., the number of items contained in a list of TBR items) to influence the storage capacity of verbal STM; presentation modality of the TBR items (i.e., the mode in which the TBR items are presented) to influence the registration of incoming information in a short-term store; and retention interval (i.e., the amount of time between presenting the last TBR item in the list and recall of those same TBR items), to prevent rehearsal of incoming information being encoded into verbal STM. Keeping with the assumption of redintegration, Neale and Tehan derived an index of task difficulty that existed on a continuum by rank ordering their experimental conditions from lower levels of difficulty (i.e., easy) to higher levels of difficulty (i.e., hard). They created 12 unique experimental conditions that varied in difficulty, with difficulty determined by the amount of interference produced by the unique

combination of variables believed to have a detrimental effect when creating the short-term phonological memory trace of the TBR item in verbal STM. For example, the short-term phonological memory trace for a TBR item presented in a four-item list which they read aloud immediately after list presentation was more likely to remain intact in verbal STM. The memory trace would be less susceptible to degradation because there would be minimal interference during the experimental condition. As such, participants would not need to engage in redintegration because it was assumed that they could retrieve the TBR item directly from verbal STM. This is in comparison with the short-term phonological memory trace for a TBR item presented in a six-item list, which was read in silence after a four-second filled retention interval. As the interference from list length, presentation modality, and retention interval were at their highest level, they assumed that the short-term phonological memory traces for the TBR items would be mostly degraded and participants would be largely reliant on redintegration to reconstruct the degraded trace for later output. Neale and Tehan believed that as task difficulty increased, there would be a corresponding increase in the degradation of the short-term phonological memory traces for the TBR item, and thus individuals would call upon redintegration to facilitate memory performance.

Using their manipulation of task difficulty, Neale and Tehan (2007) then measured redintegration by manipulating the similarity of the TBR items. Firstly, they used semantic similarity, where recall is higher for lists comprising of items that share the same taxonomic category (e.g., *hen, duck, goose, chick*) than lists comprising items from different taxonomic categories (e.g., *red, coffee, football, printer*). Neale and Tehan chose to examine semantic similarity based on suggestions Poirier and Saint-Aubin (1995) made that in an immediate serial recall task, the similarity of the TBR items is beneficial during item recall and not for



order recall. Poirier and Saint-Aubin explained their findings from the redintegration perspective, where individuals used their categorical knowledge to narrow the search for long-term information and increase the likelihood of recovering the TBR item for later output (e.g., knowing a list of items were colours could help reconstruct the degraded short-term phonological memory trace for *b\_ue*). At the order level, Poirier and Saint-Aubin also argued that the semantic category would not enhance recall for those items in the correct serial position because the phonological representations for semantically similar and dissimilar items were equally discriminable. Neale and Tehan therefore believed that as task conditions became harder, there would be an increased reliance on long-term knowledge and individuals would use the similarity of the TBR items as an additional cue to facilitate item recovery during retrieval, giving rise to a semantic similarity advantage during output.

Finally, Neale and Tehan (2007) examined whether age differences exist in redintegration, as no study up until that date had conducted such an investigation. Specifically, they wanted to examine whether ageing would reduce the likelihood of the short-term phonological memory traces for the TBR items remaining intact and increase the reliance on redintegration to facilitate short-term recall. Neale and Tehan noted from the ageing and memory literature that there were quantitative age differences in verbal STM tasks, evidenced by Kausler's (1994) review where age differences were present when storage capacity, presentation modality, and retention interval were manipulated in an experimental task. However, Kausler's review also established that there were no qualitative age differences in verbal STM tasks, where patterns of modality and suffix effects remained the same for young and older adults, and forgetting rates remained the same across age. These observations led Neale and Tehan to surmise that there are no fundamental differences in processing during

short-term recall tasks, but general age differences may still surface during their experimental task. Thus, Neale and Tehan hypothesised that ageing would reduce the likelihood of the short-term phonological memory trace for the TBR items remaining intact at the retrieval stage and that individuals would engage in redintegration to facilitate short-term recall. However, once individuals engage in redintegration, they would use the same process, where young and older adults would use their LTM and the semantic category of the TBR items as an additional retrieval cue to reduce the search set in LTM and locate an appropriate recall candidate for subsequent output.

Neale and Tehan (2007) had 20 young adults and 20 older adults view lists of the TBR items on a computer screen at a presentation rate of one item per second. They used an immediate serial recall task and, depending on the experimental condition, participants read the TBR items either aloud or in silence. After viewing the last TBR item, again depending on the experimental condition, participants viewed either a row of question marks or a series of two-digit numbers as they appeared on the screen followed by the row of question marks. If after viewing the last TBR item participants viewed the row of question marks, they were required to recall the TBR items in their serial order. However, if participants viewed either the two two-digit numbers or four two-digit numbers followed by the row of question marks, participants were required to read aloud the numbers followed by recall of the TBR items, all in their serial order. Participants completed four blocks of this experiment across two one-hour testing sessions, each block containing 30 trials, 15 with semantically similar items and 15 with semantically dissimilar items. The 15 trials also included five trials for immediate recall, five trials for recall after a two-second filled delay, and five trials for recall after a four-second delay. In the first session, participants read the first block of four-item lists and read each TBR

item in silence. After a brief break, participants viewed the second block of six-item lists and read each TBR item in silence. A week later, in session two, participants viewed the third block of four-item lists and read each TBR item aloud. Finally, in session four, participants viewed the fourth block of six-item lists and read each TBR item aloud.

Neale and Tehan (2007) decomposed their scores into correct-in-position score, item score, and order accuracy score. They reported several notable findings. Firstly, Neale and Tehan found redintegration effects using semantic similarity, where a similarity advantage emerged as task difficulty increased. In the easier experimental conditions, there was a small similarity effect. The short-term phonological memory traces for the semantically similar and dissimilar items remained relatively intact because there was minimal interference from other factors that interfered with encoding the TBR items into verbal STM. At recall, individuals could retrieve those items directly from verbal STM without the need for redintegration. As task difficulty increased across the experimental conditions, there was a more pronounced similarity advantage, where the size of the recall difference between semantically similar and dissimilar TBR items became larger. The increased interference from the task difficulty manipulation compromised the fidelity of the short-term phonological memory traces for the semantically similar and dissimilar items. In turn, participants called upon redintegration to reconstruct those degraded memory traces. Moreover, participants recalled an increasingly higher proportion of semantically similar TBR items compared with semantically dissimilar TBR items because they used the semantic category of the TBR items as an additional retrieval cue to enhance reconstruction of the short-term phonological memory traces for the semantically similar items. This effect was strong for the correct-in-position score and stronger for the item score. This similarity effect, however, did not emerge for order accuracy.

Secondly, Neale and Tehan established that redintegration effects were equivalent for young and older adults as their analyses revealed no significant difference between the respective relationship between the similarity advantage and task difficulty. Finally, at the short-term recall level, young adults recalled a significantly higher proportion of TBR items compared with older adults. Recall was also higher for lists of four TBR items compared with lists of six TBR items, for TBR items that were read aloud compared with the TBR items that were read in silence, and in immediate conditions compared with after a two-second and four-second filled retention interval. All of these findings were consistent with their original predictions.

Neale and Tehan (2007) inferred from their findings that at the short-term recall level, the performance of young and older adults was consistent with previous research, where young adults significantly outperformed older adults and recall for semantically similar words was significantly higher than for their dissimilar counterparts. At the redintegration level, young and older adults accessed LTM and used the similarity of the TBR items, specifically the taxonomic category, as a cue to search for long-term information and reconstruct the degraded short-term phonological memory traces for later output. These redintegration effects emerged for correct-in-position recall and item recall, but these effects did not emerge for order accuracy. This supported the notion that semantic similarity facilitated item recall and provided no additional assistance with reproducing the TBR items in their correct serial position. In other words, the short-term phonological traces for the semantically similar and dissimilar TBR items were equally discriminable. Their results primarily amounted to a cueing argument that made little reference to the underlying dimensions of the cue.

## Experiment two

Neale and Tehan (2007) wanted to substantiate the cueing effect that emerged in experiment one by measuring redintegration using phonological similarity, where recall is less accurate for lists of items sharing the same rhyme (e.g., *face, mace, race, chase*) than lists of items that do not share the same rhyme (e.g., *day, put, close, pinch*). Neale and Tehan wanted to establish this cueing effect by demonstrating that it was not crucial that the TBR items come from the same semantic category in order to facilitate this effect. Rather even if the TBR items were from the same or different rhyming categories, individuals would use the rhyming nature of the TBR items as an additional retrieval cue to facilitate redintegration of the TBR items. Thus, Neale and Tehan hypothesised that with increasing task difficulty comes a corresponding increase in the phonological similarity advantage during recall, where individuals would recall an increasingly higher proportion of phonologically similar words compared with their dissimilar counterparts.

Using the same methodology as Experiment one, Neale and Tehan (2007) found redintegration effects for phonological similarity. As task conditions became difficult, the size of the recall difference between phonologically similar and dissimilar words increased for item recall, with participants recalling a higher proportion of phonologically similar words compared with phonologically dissimilar words. For correct-in-position recall and order accuracy, a phonological dissimilarity advantage emerged in the easier task conditions, which increased and subsequently reversed into a phonological similarity advantage in the difficult task conditions. There were no significant age differences in redintegration, again indicating that redintegrative processing is age invariant. In contrast to Experiment one, however, no age effects were present at the short-term recall level, with young and older adults recalling a

comparable proportion of phonologically similar and dissimilar words. The robust benchmark effects for list length, presentation modality, and retention interval remained. Neale and Tehan surmised that much like Experiment one, at the correct-in-position and item scores, a phonological similarity advantage emerged as task conditions increased in difficulty and these effects were equivalent for young and older adults.

## **Discussion**

From their two experiments, Neale and Tehan (2007) interpreted their findings in support of redintegration, where a similarity cueing effect emerged during short-term recall. Task difficulty compromised the fidelity of the short-term phonological memory traces for the TBR items that at times, direct retrieval from verbal STM was not possible. In these instances, consistent with Poirier and Saint-Aubin (1995), participants called upon their long-term phonological and semantic knowledge to reconstruct those degraded short-term phonological memory traces. More importantly, participants used the similarity of the TBR items (i.e., items from the same taxonomic category (experiment one) or items sharing the same rhyme (experiment two)) as an additional cue that pointed to a specific section of LTM, narrowing the search in LTM, and enhancing the accessibility of potential recall candidates to retrieve the TBR items from verbal STM for later output. Redintegration effects emerged in their study in the form of the semantic similarity advantage and phonological similarity advantage.

Addressing age effects in their study, Neale and Tehan (2007) established that at the short-term recall level, mixed findings emerged where age differences were found for semantic similarity but not for phonological similarity. Neale and Tehan did not provide a definitive explanation as to why age differences were mixed at the short-term recall level. They speculated that if age interacted with any of the three task difficulty variables, then any

observed age differences might have been due to difficulties with registering the short-term phonological memory traces in verbal STM, storing those same short-term phonological memory traces in verbal STM, or differential rates of forgetting. As no significant interactions emerged between age and any of their task difficulty variables, Neale and Tehan proposed that their findings were consistent with the other ageing and verbal STM literature (e.g., Kausler, 1994) that sometimes age differences are present in verbal STM tasks and sometimes they are absent. At the redintegration level, as predicted, young and older adults took advantage of the similarity of the TBR items to facilitate reconstruction of the degraded short-term phonological memory traces for later output. One explanation Neale and Tehan proposed for their ageing effects was short-term phonological memory traces become noisier with age as there was a corresponding depletion in cognitive resources. Neale and Tehan believed this approach supported their redintegration findings because the increased levels of noise were equivalent to the short-term phonological memory traces losing their fidelity due to the increased interference during the experimental task, with young and older adults calling upon redintegration to aid memory performance. Nonetheless, Neale and Tehan were able to establish that redintegrative processing remains the same across the age spectrum, but its utilisation in a verbal STM task increases with age.

## **Conclusion**

In conclusion, Neale and Tehan (2007) demonstrated the intrinsic relationship between verbal STM and LTM along with interference affecting short-term recall in their investigation of redintegration. They established that increasing the difficulty of encoding the TBR items into verbal STM subsequently increased the reliance on redintegration to facilitate short-term recall. Moreover, item similarity acted as an additional retrieval cue to narrow the search in

LTM for potential recall candidates that were retrieved for later output. Importantly, Neale and Tehan established that redintegration is invariant to age, where young and older adults utilised the taxonomic category and rhyming nature of the TBR items to facilitate reconstruction of a degraded recall candidate for later output. One important question that emerged from their study was whether the cueing effect they found in their study could be generalised to other verbal STM variables. Neale and Tehan proposed that this effect could only be extended to situations where it was plausible that individuals could utilise a form of cue to aid memory performance. This thesis therefore aimed to extend Neale and Tehan's cueing effect by measuring redintegration and manipulating task difficulty using a similar methodology, but using different variables. To conduct this investigation, firstly, this thesis tested the utility of Neale and Tehan's manipulation of task difficulty by creating a new measure using recall interval, irrelevant speech, and presentation rate. It was important to review this unique combination of variables to determine whether these variables would produce the desired levels of interference during the experimental task and subsequently increase the reliance on redintegration to facilitate verbal STM performance, like Neale and Tehan achieved in their study. As this measure of task difficulty was common to the three empirical investigations in this thesis, discussion of this measure follows in Chapter four.



## **Chapter four: Task difficulty and redintegration**

An important prediction of the redintegration process is that the degree of degradation of the short-term phonological memory trace is directly related to the likelihood of reconstructing the memory trace for later output (Neale & Tehan, 2007; Schweickert, 1993; Schweickert et al., 1999). Compromising the memory trace is achieved by manipulating factors that vary the difficulty of the experimental task. Neale and Tehan (2007) created a unique measure of task difficulty using 12 different combinations of list length, presentation modality, and retention interval, variables known to interfere with short-term recall, to increase the degradation of the memory trace and increase the likelihood of engaging in redintegration to aid verbal STM performance. This thesis aimed to extend Neale and Tehan's manipulation of task difficulty using a different combination of variables, each known to interfere with and impair short-term recall: recall interval, study condition, and presentation rate. The premise for this measure was like Neale and Tehan, as the experimental task becomes difficult, phonemic information from the short-term memory traces of the TBR items dissipates. The increased interference produced from the different combinations of variables would compromise the fidelity of the short-term phonological memory traces for the TBR items being encoded into verbal STM. As a result, participants would be largely reliant on redintegration to reconstruct the information missing from the memory trace to retrieve the TBR item from verbal STM and give rise to larger item recall advantages for long-term factors, such as semantic similarity (Neale & Tehan, 2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995). Given the importance of this task difficulty manipulation to the three empirical studies comprising this thesis, Chapter Four reviews the relevant literature for the three variables that comprised task difficulty.

### **Recall interval (immediate, two-second filled retention interval)**

Researchers have established that memory performance is considerably reduced when recall is required after a filled-retention interval compared with immediate recall conditions (Fournet, Juphard, Monnier, & Roulin, 2003; Neale & Tehan, 2007; Tehan, Hendry, & Kocinski, 2001; Tolan & Tehan, 1999). When researchers implement a filled-retention interval during an experimental task, they require participants to engage in a distractor task after they have viewed the last TBR item and prior to recall (Neale & Tehan, 2007). The distractor task may require a verbal or non-verbal response (Tolan & Tehan, 1999), can involve completing a set of mathematical problems (Tehan et al., 2001) or repeating a series of digits (Fournet et al., 2003; Neale & Tehan, 2007), and may vary in length (Neale & Tehan, 2007; Tehan et al., 2001). Engaging in the distractor task interferes with the encoding of the TBR items in verbal STM because individuals have difficulty rehearsing the TBR items to create a strong short-term phonological memory trace that can be encoded into verbal STM, affecting later memory performance. By comparison with immediate conditions, individuals can freely engage in rehearsal without interference to increase the likelihood of retrieving the TBR items from verbal STM for later output.

Tehan, Hendry, and Kocinski (2001) argued that retention interval was an important factor that influenced the degradation of the short-term phonological memory trace of the TBR items for subsequent recall. They believed that distractor periods in an experimental task might result in more damage to the phonological memory trace, thus interfering with encoding the TBR items into verbal STM. Consequently, individuals would then have to access LTM in order to produce the TBR items for later output. Tehan et al. demonstrated the effects of retention interval on short-term recall performance by measuring recall for lists of TBR words

using an immediate serial recall task that was completed in two parts. For part A, after viewing the last TBR item in the list, participants were instructed to immediately recall the TBR items. In the delayed recall conditions, after viewing the last TBR item, participants viewed four mathematics questions and were asked to make a decision as to whether the equation was correct or incorrect prior to recalling the TBR items. In the complex span condition, Tehan et al. presented the TBR items and mathematics equations simultaneously, where participants read the TBR item out aloud and then read the equation silently before answering whether the equation was correct or incorrect. After solving the last equation, participants were then required to recall the TBR items. For part B, participants completed the same activities in each condition as Part A, but rather than solving the mathematics equations silently, participants were required to read aloud the numbers in the equation. (e.g.,  $4 \times 2 + 7 = 15$  would be *four, two, seven, fifteen*).

Tehan et al. (2001) found that for correct-in-position and item recall in both parts of their study, participants recalled a significantly higher proportion of TBR items in the immediate recall condition compared with the complex span and delayed recall conditions. Furthermore, participants produced a significantly higher proportion of errors during recall in the delayed recall condition compared with the complex span and immediate recall conditions, respectively. Tehan et al. inferred from their findings that completing the mathematics equations produced a delay that interfered with encoding the TBR items into verbal STM, affecting short-term recall performance.

Russo and Grammatopoulou (2003) also substantiated the differing effects of immediate and delayed recall on short-term and long-term recall tasks. They firstly examined the WLE using an immediate and delayed free and serial recall tasks by comparing performance for

short (i.e., one-syllable words) and long (i.e., four- and five-syllable words) words. In the immediate conditions, after viewing the last TBR item in the word list, participants were required to recall the TBR items in any order (i.e., free recall) or in their original order of presentation (i.e., serial recall). In the delayed conditions, after viewing the last TBR item in the list, participants were shown a three-digit number and were asked to count aloud forward by threes for 30 seconds (e.g., 456, 459, 462) at a rate of one number per second. Russo and Grammatopoulou found that recall was significantly higher in the immediate condition than the delayed condition. When they re-examined the effects of delayed recall using a 45-second delay in Experiment two and then a 60-second delay in Experiment three, recall was still considerably reduced compared with the immediate recall condition. The research therefore indicates that engaging in a distractor task interferes with the opportunity for individuals to create strong short-term phonological memory traces for the TBR items using rehearsal, rendering those traces more vulnerable to short-term forgetting (Neale & Tehan, 2007; Russo & Grammatopoulou, 2003; Tehan et al., 2001).

From the redintegration perspective, attending to a series of digits prior to recalling the TBR items would compromise the fidelity of the short-term phonological memory trace because engaging in the additional task would interfere with encoding the TBR items into verbal STM. At recall, there would be a greater reliance on redintegration to reconstruct the degraded short-term phonological memory traces of the TBR items for short-term recall, if redintegration is possible (Neale & Tehan, 2007). By comparison, in immediate recall conditions, the short-term phonological memory traces for the TBR item are more likely to be intact because there would be no inherent distraction that could interfere with encoding. As a result, there would be a reduced need for redintegration to assist with short-term recall as the

TBR items could be recalled directly from verbal STM (Neale & Tehan, 2007). It was therefore plausible that recall interval would impair verbal STM performance and increase the reliance on redintegration for later short-term recall. Importantly, the effects of recall interval on memory performance is believed to become stronger in combination with the presence of irrelevant speech.

### **Study condition (silent, irrelevant speech)**

There is agreement in the literature that irrelevant speech interferes with verbal STM performance (e.g., Colle & Welsh, 1976; Jones & Morris, 1992). When presenting the TBR items simultaneously with irrelevant speech, despite the individual's best efforts at ignoring the content of the irrelevant speech, it subsequently interferes with their capacity to encode the TBR items into verbal STM (Buchner & Erdfelder, 2005; Colle & Welsh, 1976; Jones & Morris, 1992; Salame & Baddeley, 1990; Tolan & Tehan, 2002). Consequently, the short-term phonological memory traces for the TBR items become compromised and short-term recall of those same items is problematic. By comparison, when the TBR items are presented in silence, the short-term phonological memory traces are likely to be intact because there is nothing to interfere with encoding. Silent encoding conditions would increase the likelihood of retrieving the TBR items from verbal STM for later output (Buchner & Erdfelder, 2005; Colle & Welsh, 1976; Jones & Morris, 1992; Salame & Baddeley, 1990; Tolan & Tehan, 2002).

Colle and Welsh (1976) initially demonstrated the effects of irrelevant speech interfering with short-term recall performance when participants viewed lists of eight phonologically distinct (e.g., *F, H, K*) or phonologically similar (e.g., *B, C, D*) consonants that were presented in silence or simultaneously with German Speech. Colle and Welsh found that recalling the letters was higher in the silent conditions (i.e., no irrelevant speech) as there was no

interference, which resulted in memory performance for the consonants being relatively unimpaired. This is in comparison with the considerable lower recall performance in the irrelevant speech conditions, as evidenced by the increased number of errors produced during recall (i.e., where participants heard German speech). Colle and Welsh suggested that the phonemes from the irrelevant speech entered the phonological store and interfered with the information about the visually presented items participants encoded into verbal STM. They argued that irrespective of whether the irrelevant speech was a single phoneme, a narrative, or a multisyllabic word, it was the similarity of the phonemes in the irrelevant speech to the phonemes in the TBR items that produced interference in the verbal STM task.

Buchner and Erdfelder (2005) demonstrated the unique effects of irrelevant speech on immediate serial recall performance using Schweickert's (1993) Multinomial Processing Tree Mode of Redintegration. Buchner and Erdfelder compared short-term recall performance across conditions where there was silence, a non-acoustic distractor of low frequency words, and a non-acoustic distractor of high frequency words. They demonstrated that low and high frequency distractor words produced a greater amount of impairment in recall performance compared with no distractor. Importantly, when modelling their data using Schweickert's model, the non-acoustic distractor, irrespective of its form, selectively affected the probability of the short-term phonological representation of the TBR item remaining intact and the probability of successfully reconstructing the TBR item based on the available information that remained in the degraded short-term phonological memory trace.

Neath's (2000) simulation of irrelevant speech using Nairne's (1990) Feature Model offers a unique interpretation of irrelevant speech interfering with short-term recall, noting that this effect stems from individuals adopting the features of the irrelevant speech while creating

a short-term phonological representation for the TBR items into verbal STM. Essentially, individuals amalgamate the content of the irrelevant speech with the phonological information in the short-term memory trace. Doing so corrupts the short-term phonological memory trace such that when retrieving the TBR item from verbal STM, there is no form of cue to aid retrieval of information from LTM that would assist with later short-term recall. The Feature Model proposes that a matching process occurs where a degraded (i.e., corrupted) short-term phonological memory trace in primary memory is matched to a set of traces in LTM (i.e., secondary memory), where all the traces consist of a specific set of features. The long-term representation that produces the best match with the short-term phonological memory trace in verbal STM is selected for later recall. Through the various simulations of the Feature Model using irrelevant speech, Neath firmly established that short-term recall was considerably lower in irrelevant speech conditions compared with the silent conditions because the presence of irrelevant speech facilitated the feature adoption process. Specifically, when individuals amalgamates the features of the irrelevant speech with the short-term phonological memory trace of the TBR item being encoded into verbal STM, the irrelevant speech subsequently compromised the integrity of the short-term phonological memory trace, making retrieval of the TBR item from verbal STM problematic. Thus, the presence of irrelevant speech during the experimental task reduced the probability of successfully reconstructing a partially degraded cue in primary memory, further reducing the probability of producing that same TBR item for later output.

Tolan and Tehan (2002) found similar effects that Neath (2000) articulated in his study by manipulating the phonemic features of the irrelevant speech: whether the irrelevant speech was a steady-state, where participants would hear continuous repetition of a single item (i.e., a

nonword) or a changing-state, where participants would hear continuous repetition of different words (i.e., phonologically similar and dissimilar words). They also manipulated the timing of the presentation of the irrelevant speech to determine where its effects would be most disruptive: simultaneous presentation of the irrelevant speech with the TBR items (i.e., encoding phase) or for two seconds after presenting the last TBR item in the list and prior to recall (i.e., rehearsal phase). Tolan and Tehan found that correct recall was significantly higher in the quiet condition compared with the steady-state and changing-state irrelevant speech conditions. Secondly, irrespective of whether the irrelevant speech remained steady or changed, the irrelevant speech effects had its greatest impact during rehearsal compared with during encoding. Tolan and Tehan established that irrelevant speech interfered with verbal STM performance, where features of the irrelevant speech interacted with features of the phonological representations individual created for the TBR items retained in verbal STM to impair later memory performance. Thus, there was sound evidence to consider irrelevant speech as a task difficulty variable as it would interfere with encoding and produce detrimental effects on verbal STM performance.

Based on the literature, it was reasonable to believe that irrelevant speech would make an important contribution to the task difficulty manipulation for this thesis because irrelevant speech has the capacity to interfere with encoding the TBR items into verbal STM (Buchner & Erdfelder, 2005; Colle & Welsh, 1976; Jones & Morris, 1992; Neath, 1999, 2000; Salame & Baddeley, 1990; Tolan & Tehan, 2002). Once the irrelevant speech has gained access to the contents of verbal STM, it would damage the phonemic content of the trace, compromising its fidelity and increasing the reliance on redintegration to reconstruct the trace. By comparison, in silent conditions, there would be a higher probability of the short-term phonological



memory traces being intact because there would be no interference from other auditory input that could gain access to the verbal STM store and affect the fidelity of the memory trace. As a result, there would be a decreased reliance on redintegration as the TBR item could be retrieved directly from verbal STM. Further disruption to the fidelity of the memory traces for the TBR items would be achieved if recall interval and study condition were combined with manipulating the presentation rate of the TBR items to interfere with registering the memory trace into verbal STM.

### **Presentation rate (one second, two seconds)**

The research has demonstrated that short-term recall is higher for words presented at a slower presentation rate (i.e., one word every two seconds) because it allows individuals additional time to register, encode, and create stronger short-term phonological memory traces for the TBR items in verbal STM (Bhatarah, Ward, Smith, & Hayes, 2009; Coltheart, 1999; Coltheart & Langdon, 1998). This is in comparison with words presented at a faster presentation rate (i.e., one word every second), as the amount of information individuals could encode into verbal STM is considerably reduced. Specifically, faster presentation rates may not allow individuals opportunities to rehearse and subsequently create a strong short-term phonological memory trace, consequently decreasing likelihood of retrieving the short-term phonological memory traces of those TBR items from verbal STM for later output (Bhatarah et al., 2009; Coltheart, 1999; Coltheart & Langdon, 1998; Tan & Ward, 2008).

Manipulating presentation rate gives valuable insight into the memory processes individuals use to retain the short-term phonological memory traces of the TBR items for later output. Coltheart and Langdon (1998) demonstrated the effects of varying presentation rates when measuring the phonological similarity effect. Specifically they found that recall

performance was greater during the slower presentation rates (i.e., 500 milliseconds per item) compared with the medium presentation rate (i.e., 243 milliseconds per item) and faster presentation rate (i.e., 114 milliseconds per item). They argued that individuals were able to create stronger phonological codes at slower presentations rates that were then used for accurate recall performance. Conversely, faster presentation rates increased the difficulty associated with retrieving information to assist with producing the TBR items for later short-term recall. Coltheart (1999) corroborated Coltheart and Langdon's (1998) finding about the effects of presentation rate on short-term recall performance in a follow-up study across two experiments by manipulating phonological similarity using pictures.

The literature has also established that slower presentation rates allow individuals to engage in activities to help strengthen the short-term phonological memory trace and retain the TBR items in verbal STM (Bhatarah et al., 2009; Tan & Ward, 2000, 2008). Tan and Ward (2008) found that individuals often attempted to engage in cumulative forward-ordered rehearsal during slower presentation rates to make the TBR items more accessible to retrieve for later recall. Individuals would rehearse the first item in a list (e.g., *dog*), then after presenting the second item (e.g., *cat*), individuals sub vocally repeat the two items consecutively (e.g., *dog, cat*). They repeat this process until they have viewed all the items in the list. During faster presentation rates, however, Tan and Ward purported individuals are not afforded time to engage in cumulative forward-ordered rehearsal as they would only have enough time to register the first TBR item in verbal STM. As a result, because there are no further attempts to strengthen the short-term phonological memory traces, this decreases access to the TBR item's phonological representation stored in verbal STM. In their study, Tan and Ward manipulated presentation rate of the TBR items during an immediate serial

recall task in either the silent or overt rehearsal condition. In the silent condition, participants read the TBR items aloud but remained silent after reading the word. In the overt rehearsal condition, Tan and Ward instructed participants to rehearse aloud any TBR items from the list that they were thinking of. Participants viewed each TBR item in the six-item lists at either a rate of one word every second (i.e., fast presentation rate, 0.25s on/0.75s off), one word every two and a half seconds (i.e., medium presentation rate, 1.75s on/0.75s off), or one word every five seconds (i.e., slow presentation rate, 4.25s on/0.75 s off).

Tan and Ward (2008) found a significant effect of presentation rate, where recall was superior during the slower presentation rate compared with the medium and faster presentation rates, respectively. Tan and Ward analysed the pattern of rehearsals obtained at each of the presentation rates and found that there were fewer rehearsals during the faster presentation rate, suggesting there was little time to rehearse each TBR item after presentation. Furthermore, during the medium and slower presentation rates, participants engaged in cumulative rehearsal early in the list, where they rehearsed the maximum possible sequence of items in a forward serial order. However, towards the end of the list, participants engaged in more fixed rehearsal. Tan and Ward inferred from their findings that increased rehearsal had a positive effect on recall accuracy of the TBR items by strengthening the phonological codes into verbal STM so that they were more accessible. The literature has therefore indicated that varying presentation rate interferes with the amount of phonological information that can be registered and encoded into verbal STM, along with opportunities to strengthen short-term phonological representations of the TBR items to be retrieved for later memory performance.

It was therefore evident from the literature that manipulating the presentation rate of the TBR items would interfere with verbal STM performance. Presenting the TBR items at a

faster presentation rate (i.e., one word every second) would compromise the fidelity of the short-term phonological memory traces for the TBR items as there would be a reduced opportunity for individuals to engage in rehearsal and strengthen the memory trace being encoded into verbal STM (Coltheart, 1999; Coltheart & Langdon, 1998; Tan & Ward, 2000). Consequently, there would be a corresponding need to engage in redintegration to rebuild the memory trace. Conversely, presenting the TBR items at a slower presentation rate (i.e., one word every two seconds) would allow individuals to rehearse the TBR items and create a stronger short-term phonological memory trace that could be easily retrieved from verbal STM for later output. Therefore, it was reasonable to believe that in combination with recall interval and study condition, presentation rate would interfere with encoding and retrieval, and increase the reliance on redintegration to facilitate verbal STM performance.

### **A new measure of task difficulty**

The literature has ascertained that recall interval (Fournet et al., 2003; Neale & Tehan, 2007; Russo & Grammatopoulou, 2003; Tehan et al., 2001), study condition (Colle & Welsh, 1976; Jones & Morris, 1992; Neath, 2000; Tolan & Tehan, 2002), and presentation rate (Coltheart, 1999; Coltheart & Langdon, 1998; Tan & Ward, 2008), exert their own detrimental effect on verbal STM performance. Recall interval, study condition, and presentation rate could also be considered as task difficulty variables in their own right. However, it was reasonable to believe that consistent with the redintegration literature, it was assumed that combining these variables across eight different conditions that varied on a continuum from easy to difficult would produce great disruption to the short-term phonological memory traces of the TBR items than if each task difficulty variable was presented on its own. Knowing how each variable affects different memory processes in their own right, Table 4.1 presents a

summary of the hypothesised task difficulty conditions from easy to difficult using eight different combinations, which were used for the three empirical studies of this thesis.

Table 4.1

*Summary of Task Difficulty Conditions used in the Experimental Task for the Three Empirical Studies*

Condition	Task difficulty variable		
	Recall interval	Study condition	Presentation rate
1	Immediate	Silence	2 seconds
2	Immediate	Silence	1 second
3	Immediate	Irrelevant speech	2 seconds
4	Immediate	Irrelevant speech	1 second
5	Delayed	Silence	2 seconds
6	Delayed	Silence	1 second
7	Delayed	Irrelevant speech	2 seconds
8	Delayed	Irrelevant speech	1 second

As identified by Neale and Tehan (2007), the empirical literature has clearly shown that the variables comprising task difficulty impair short-term recall performance. Recall is better in immediate conditions compared with after a filled-retention interval, when words are presented in silence as opposed to irrelevant speech, and when words are presented at a slower presentation rate compared with a faster presentation rate. However, previous literature had not examined the relative impact of each of these task manipulations to identify the order of difficulty presented by these manipulations. As such, apart from the easiest (silence; 2 second presentation; immediate recall) and most difficult (irrelevant speech; 1 second presentation; filled retention interval) conditions, the rank order of the task difficulty conditions was based on the outcomes of the study directly from verbal STM.

## Conclusion

In conclusion, it was reasonable to believe that this unique manipulation of task difficulty using eight different combinations of recall intervals, study conditions, and presentation rates for the measurement of redintegration in this thesis would gradually

interfere with encoding the TBR items in verbal STM by affecting the fidelity of the short-term phonological memory traces. Particularly during the difficult task conditions, this unique manipulation of task difficulty would increase the reliance on redintegration to reconstruct and subsequently retrieve the degraded short-term phonological memory traces for the TBR items for later output. Rather than simply using Neale and Tehan's (2007) variables, recall interval, irrelevant speech, and presentation rate were purposely selected to determine whether this combination of variables would also increase the reliance on redintegration to aid short-term recall, particularly in the difficult task conditions, given their reported effects in the verbal STM literature. Furthermore, by using word length, associate word pairs, and false memory to measure redintegration, it was also important to ascertain whether this new and unique manipulation of task difficulty would produce the cueing effects expected to be observed during short-term recall. As manipulating task difficulty has been shown to influence the use of redintegration during recall, it was also important to extend Neale and Tehan's findings regarding age-related differences in redintegration. Neale and Tehan established using their measure of redintegration and manipulation of task difficulty that young and older adults engage in the same redintegrative processing to facilitate short-term recall. More importantly, they used item similarity as an additional retrieval cue to enhance redintegration of the TBR items for later output. Neale and Tehan attributed their findings to noisier memory traces because of depleted cognitive resources that increase the reliance on redintegration to facilitate recall. Given Neale and Tehan's notable findings, this thesis continued to examine age differences by using a different sample of young and older adults to Neale and Tehan and ascertain the relationship between age and redintegration in verbal STM. Discussion of the ageing literature follows in Chapter five.

## **Chapter five: Age differences in verbal STM**

The relationship between ageing and cognition has been extensively documented in the memory literature (Grady & Craik, 2000; Luo & Craik, 2008). It is acknowledged that ageing is a continuous process of change that is generally associated with cognitive slowing and these changes extend to memory-related performance (Grady & Craik, 2000; Luo & Craik, 2008; Salthouse, 1996). However, age-related differences depend on the type of information and the processes involved. Some experimental tasks show substantial loss with age compared with other experimental tasks that remain relatively unaffected by age (Grady & Craik, 2000; Luo & Craik, 2008). Neale and Tehan (2007) demonstrated that age-related differences in verbal STM extend to redintegration, where they found that young and older adults engage in the same redintegration process to facilitate short-term recall, using additional retrieval cues to enhance memory performance. They attributed their finding to noisier memory traces that became degraded because of a gradual depletion in cognitive resources with increasing age. As Neale and Tehan are the only researchers to this date who have conducted such an examination between ageing and redintegration, this thesis continued examining this relationship and extend upon their findings to continue articulating the mechanisms underpinning redintegrative processing in verbal STM across the age spectrum. As ageing was relevant to the three empirical studies of this thesis, Chapter five reviews the literature that informs why age-related differences surface in verbal STM tasks.

### **Theoretical accounts of age differences in verbal STM**

Ageing and verbal STM is a complex relationship and the various manipulations made in experimental tasks can either modulate or moderate the magnitude of observed age differences in verbal STM tasks (Balota, Dolan, & Ducheck, 2000; Luo & Craik, 2008).

Researchers have proposed different explanations to account for the theoretical mechanisms underlying these age-related differences include general cognitive slowing, reduced processing resources, loss of inhibitory functions, lack of cognitive control, and the amount of contextual/environmental support provided in an experimental task.

**General cognitive slowing.** The general cognitive slowing account attributes age-related differences in experimental tasks to the reduced speed with which individuals carry out every day cognitive operations as opposed to specific changes in memory processing (Balota et al., 2000; Luo & Craik, 2008; Salthouse, 1996). It is evident that processing speed has an important role in cognitive functioning, as Salthouse (1996) postulated when explicating the relationship between cognitive slowing and age. Salthouse developed the Processing Speed Theory of Ageing that contained two core assumptions. Firstly, factors that limit performance on an array of cognitive tasks include constraints in general processing, restricted declarative, procedural, and strategic knowledge and variations in either the efficiency or effectiveness of engaging in specific cognitive processes. Limitations in one or a combination of these factors may place greater demands upon the individual's capacity to process incoming information and, as a result, may have negative consequences on performance in memory-related tasks. Secondly, the speed of processing is a critical constraint that is associated with advancing age and is not based on the processing required to perform that activity. Rather, it reflects the individual's ability to carry out many different types of cognitive operations. More frequent processing results in higher levels of performance and the opportunities to accomplish a larger amount of processing is greater when processing speed is faster.

Salthouse (1996) also proposed there are two mechanisms that underlie the relationship between processing speed and age in cognitive-based verbal STM tasks. The limited time



mechanism suggests that the time required to perform the latter part of a task is restricted as a large proportion of the available time is occupied by executing the early operations of a task. This is primarily relevant when there are external time limits or other restrictions on the time available for processing information in order to complete the task (e.g., reading numbers prior to recalling a list of words). The simultaneity mechanism suggests that there is a decrease in the availability of earlier processed information due to the amount of time afforded to later processing. The relevant information needed to complete a task may no longer be available as it is lost through either decay or displacement. Support for the processing speed theory comes, in part, from studies in which the age-related deficit in memory is greatly attenuated when a simple measure of perceptual motor speed is statistically taken into account. Across a series of path analyses, Salthouse argued that after controlling for speed, the independent contribution of age to measures of memory is relatively weak, with age only indirectly related to memory performance.

While the general cognitive slowing theory accounts for age-related differences in memory-based tasks as a function of processing speed, it is not a consistent explanation for why age differences are present in some memory-related tasks and not others (Balota et al., 2000; Luo & Craik, 2008). Age-related declines have been found in free recall tasks that do not have a speed component and ageing is associated with differential effects on tasks that do not involve different amounts of processing. For example, source recognition tasks require a greater amount of processing compared with an item recognition task (Balota et al., 2000; Luo & Craik, 2008). It seems likely that other factors contribute to the age-related declines observed in memory-related tasks, such as declines in one's processing resources.

**Declines in processing resources.** Researchers advocating for declines in processing resources attribute age-related differences in verbal STM to declines in resources that are available for cognitive processing (Craik & Byrd, 1982). Depending on the difficulty of the cognitive task, some tasks may require more processing resources than other tasks (Balota et al., 2000; Craik & Byrd, 1982; Luo & Craik, 2008). Deficits in processing resources have been able to account for much of the age-related decrements observed in memory-related tasks. For example, older adults may experience greater difficulty with working memory tasks because a greater amount of attention is required to manipulate and retain information for later output in comparison with simple span tasks that do not require a large amount of processing resources to complete the task (Balota et al., 2000; Luo & Craik, 2008). Similarly, greater processing resources are required to remember specific names as opposed to remembering general facts because these tasks require more resources to engage in deep and elaborative processing to facilitate retrieval and subsequent output. Having to engage in such self-initiated processing may be particularly difficult for older adults when the environment in which the event is being processed does not provide many cues at either encoding or retrieval (Balota et al., 2000; Luo & Craik, 2008).

A study by Rabinowitz, Craik, and Ackerman (1982) demonstrated age-related memory difficulties associated within deficits in attentional processing by focusing on encoding processes as they hypothesised that the amount of detail encoded to remember an event assists with differentiating it from other events that have been encoded. However, this level of encoding requires a substantial amount of processing resources that may be depleted because of age. If such processing resources are not readily available to encode the specific details of an event, it is likely that individuals would engage in a general level of encoding that might

affect their capacity to retrieve that event for later output. With reference to age-related differences, Rabinowitz et al. further argued that the amount of processing resources that are available to complete a memory-related task diminishes with age. Therefore, when a task requires a greater amount of processing resources in order to complete it, the performance of older adults was expected to reduce considerably relative to young adults.

To test these notions, Rabinowitz et al. (1982) compared the effectiveness of general and specific retrieval cues between young and older adults. They gave participants a list of TBR items and instructed them to generate an associate for each item. At recall, participants were given either a specific cue (i.e., the participant's own previously generated associate in response to the TBR items) or a general cue (i.e., the category label of the list of TBR items) and were asked to recall the original list of TBR items. They found that young adults recalled a significantly higher proportion of items when provided with the specific cues relative to the general cues. However, for older adults, there was no significant difference in recall performance when the researchers provided them with the specific or general cue, tentatively suggesting that the provision of cues reduced the cognitive demands of the experimental task and facilitated memory performance.

Rabinowitz et al. (1982) then had young and older adults learn the word pairs where half of the words were paired with a strong associate and the remaining half were paired with a weak associate and at recall, the researchers provided them with the cue for which they had to produce the target item. While the young and older adults completed this task under full attention conditions, a second group of young adults completed the same task under divided attention conditions, where they performed a digital monitoring task while learning the word pairs. Rabinowitz et al. found that in the full attention conditions, older adults were

significantly poorer in their recall for the weak cue-target pairs relative to the young adults, but there was a smaller age deficit for recall of the strong cue-target pairs. When the cues and targets were exchanged in strength, older and young adults performed at a comparable level. When comparing recall performance in the full and divided attention conditions, recall performance for the second group of young adults reduced considerably under divided attention conditions, particularly for the weak cue-target pairs, with their recall performance mirroring the performance of the older adults under full attention conditions.

Finally, Rabinowitz et al. (1982) compared the recall performance of young and older adults using specific (i.e., item) and general (i.e., descriptive phrases) retrieval cues under full and divided attention conditions. Consistent with their two previous experiments, Rabinowitz et al. proposed that the effectiveness of item cues would reduce under divided attention conditions because integrating and encoding the TBR cue-target pairs required attentional resources. Under such conditions, individuals may not be able to encode the core semantic features of each item in the pair as effectively as they would under full attention conditions. For the general retrieval cues, however, divided attention conditions may not affect its overall effectiveness because, according to Rabinowitz et al., cues are effective when the general semantic aspects individuals encode from the cue are also contained in the general semantic information encoded for the TBR item. They also manipulated the relatedness of the cue-target pair, hypothesising that as the relatedness between the cue-target pairs decreases, individuals would need to use more processing resources to form a meaningful relationship between the two items in order to produce the target item at recall. Thus, under divided attention conditions, the unrelated cue-item targets would suffer in recall performance relative to the related cue-target pairs. For the general cue (i.e., the descriptive phrase), divided attention

would have less effect on cued recall performance because individuals still encode the general semantic aspects of both the cue and target item. Their findings supported their predictions. They inferred from their findings that reductions in one's attentional capacity might have led to surface level encoding of the TBR information, which contributed to poorer memory performance, particularly for older adults. Having to integrate contextual specific features of the TBR information may be deemed as effortful for older adults and require substantial processing resources which they may not have at the time of the task, impairing their cued recall performance relative to young adults.

Therefore, although the reduced processing resources account attributes age-related differences in memory performance to the amount of processing resources required to complete a memory-related task (Balota et al., 2000; Craik & Byrd, 1982; Luo & Craik, 2008), it is not without its limitations. Researchers have criticised this account as not being able to identify the resource itself that contributes to these age-related decrements in memory-related performance and have postulated that other factors, such as those concerning one's capacity to inhibit irrelevant information, may account for the age-related differences observed in verbal STM tasks.

**Reduced inhibition.** Other researchers have proposed that ageing is associated with a reduction in the efficiency of inhibition processes, where efficient processing systems must activate information that is relevant to the task and inhibit the partially activated information that is irrelevant to the task demands (Balota et al., 2000; Hasher & Zacks, 1979; Luo & Craik, 2008). Stemming from their theoretical framework of age differences in working memory and comprehension, Hasher and Zacks (1988) proposed that older adults have less inhibitory control over the contents of their memory compared with young adults. According to their

view, inhibition serves two primary functions. Firstly, prevent unrelated, distracting, or goal irrelevant information from entering working memory. Secondly, delete information from memory that is no longer relevant. With impaired inhibitory functioning occurring in older age, the contents of verbal STM is assumed to be different for young and older adults as the contents of verbal STM for older adults may contain irrelevant information that detracts from encoding and retrieving the TBR information for later output.

Hasher and Zacks (1988) developed their framework from a series of experiments they conducted to initially examine the relationship between working memory capacity and the ability to form inferences. Hasher and Zacks purported that this ability was critical to establishing a coherent and integrated representation of the TBR information but it could also place great demand on the capacity of working memory. With specific reference to age differences, they purported that older adults would experience greater difficulty with making inferences, which may place greater strain on their working memory compared with young adults because of irrelevant information interfering when making inferences.

Hasher and Zacks (1988) tested a group of young and older adults on their capacity to encode an inference about a central target event using three different types of paragraphs. The explicit version clearly stated the target event directly. The expected version gave participants strong contextual support for the target inference. The unexpected version gave no information to support making an inference about the target event. Participants read one example of each paragraph across three different presentation modes: oral presentation, where the experimenter read the paragraph out to the participant, the written condition/noncumulative presentation, where the paragraph appeared on a computer screen and the participant read the passage at their own pace, and the written/cumulative presentation, where each sentence of the paragraph

appeared on the screen one at a time in a consecutive manner. Hasher and Zacks (1988) found that across the three presentation modes, young and older adults were comparable in the percentage of correctly recalled target information for the explicit version, indicating they can encode and retrieve important target information. Under the oral presentation mode, significant age differences emerged for the expected and unexpected versions, where young adults recalled a significantly higher percentage of correct target information than did older adults. Under the noncumulative presentation mode, age differences were only present for the unexpected condition, where young adults significantly outperformed older adults in correctly recalling the target information. For the cumulative presentation mode, no significant age differences were present for either the expected or unexpected version, where young and older adults were equal in their percentage of correctly recalling the target information. Hasher and Zacks tentatively concluded from these three experiments that unless conditions were optimal (i.e., supportive), older adults had greater difficulty with retrieving sufficient information from working memory to form inferences in verbal STM.

To address these potential age-related deficits in retrieving prior information, Hasher and Zacks (1988) then used a priming task to examine young and older adults' respective abilities for a word to cue (or prime) the retrieval of another word from a recently presented sentence. A second group of participants were presented with six unrelated noun-verb-noun sentences (e.g., the *scientist nudged* the *sheriff*). Participants then completed a recognition test on the nouns from the preceding sentence. The test noun was paired with either another noun from the same sentence (i.e., within prime) or paired with another noun from one of the previous five sentences (i.e., between prime). The delay between presenting the prime and the noun was either 300 milliseconds or 1000 milliseconds in duration. Hasher and Zacks

hypothesised that if the prime cues the retrieval of its sentence, then the participant should be able to recognise the noun more quickly using the within prime than the between prime. They found significant priming effects for both age groups at both time delays, where young and older adults reported significant faster recognition times to the within prime compared with the between prime. Young and older adults' respective performances were faster under the 300-millisecond condition compared with 1000-millisecond condition. Hasher and Zacks concluded that older adults, much like young adults, retrieve information from working memory if the information is short in duration and accessible in LTM. Hasher and Zacks inferred that the difficulties older adults experienced across their studies resulted from them being more distracted by other irrelevant information (e.g., personal memories, environmental details) and as such, this reduced inhibitory control allowed these irrelevant ideas to enter memory and remain active, thereby making the experimental task more difficult. Older adults became more reliant on the information in their immediate environment to facilitate memory performance as opposed to searching for information in memory that may aid later output.

Thus, the inhibition account does well to explain age-related deficits in experimental tasks through difficulties in dealing with distractions and interference inherent in a memory task. Moreover, the inhibition account explains how ageing is associated with an increase in the rate of false recognitions and false recalls produced during an experimental task (Balota et al., 2000; Luo & Craik, 2008). However, the downfall of the inhibition account is its inability to explain decreases in veridical recall and veridical recognition, where difficulties lie in initiating as opposed to inhibiting the execution of planned intentions.

**Contextual/environmental support.** Finally, in contrast to the previously reported frameworks, the contextual/environment framework provides a more functional perspective on



age-related deficits in verbal STM (Balota et al., 2000; Craik & Byrd, 1982; Luo & Craik, 2008). The extent to which age differences surface in an experimental task depends upon the requirements of the task itself. If during the experimental task there is some form of environmental (i.e., contextual) support where the demands of the memory task are stimulus-driven rather than having to be self-initiated, age differences are minimal because the support provided during the task reduces the amount of cognitive effort expended (Balota et al., 2000; Craik & Byrd, 1982; Luo & Craik, 2008). However, if during the experimental task there is no form of support provided and individuals are required to engage in self-initiated processes, cognitive demands of the task increase and age differences become larger (Balota et al., 2000; Craik & Byrd, 1982; Luo & Craik, 2008).

This framework adequately accounts for large age differences in free recall tasks compared with cued recall or recognition tasks through the amount of context given to support verbal STM performance. Contextual support provides older adults with assistance to guide information processing in the experimental task (Balota et al., 2000; Hasher & Zacks, 1979; Luo & Craik, 2008). For example, during a free recall task, there is no form of contextual support to assist with recall, other than what individuals may generate to facilitate memory performance. However, in cued recall and recognition tasks, contextual support is provided in the form of either a cue or being presented with the TBR items that would assist with retrieval. A study by Craik, Swanson, and Byrd (1987) demonstrated the effects of aging and contextual support by comparing the memory performance of young and older adults using a recall task under different conditions that varied in the amount of contextual/environmental support. Craik et al. wanted to determine at which stage of memory contextual/environmental support would benefit recall performance of young and older adults.

In their experiment, Craik et al. (1987) created four different testing conditions. In condition one, where there were no cues, the demands on encoding and retrieval were high because there was a greater reliance on self-initiated processing to facilitate recall of the TBR items. In condition two, where cues were provided at encoding and retrieval, there was greater environmental support. In the third and fourth conditions, cues were only provided during encoding or retrieval, respectively. During these conditions, environmental support is minimal because it was only provided at either the beginning or the end of the experimental task. Craik et al. found that older adults performed poorly in the free recall condition compared with the young adults because there was no form of cue that was present. However, when learning and recall were cued or partly cued, recall performance between the young and older adults was comparable. Craik et al. suggested that the greater the amount of environmental support provided in the experimental task (i.e., less of a need to engage in self-initiated processing) improved older adults' memory performance to the extent it almost matched the memory performance of young adults. However, when environmental support is absent from an experimental task, more processing resources are afforded to complete the experimental task, thus diverting away from recall performance and, in turn, resulting in larger age differences at recall, in favour of young adults. Thus, the contextual/environmental support framework provided a more functional view of age differences observed in verbal STM tasks.

To conclude, each theoretical framework offers a unique perspective on explaining age-related deficits in verbal STM tasks, has its advantages and disadvantages, and can explain some empirical data better than other frameworks (Balota et al., 2000; Grady & Craik, 2000; Luo & Craik, 2008). While some researchers consider the reduced speed of processing as best accounting for age-related deficits in memory performance (Salthouse, 1996), it lacks any

specification of decrements in exact cognitive operations that contribute to these age-related deficits (Balota et al., 2000; Craik & Byrd, 1982; Luo & Craik, 2008). Similarly, the reduced inhibition account explains age-related differences in managing the interference and distractions inherent in a memory task (Hasher & Zacks, 1988; Rabinowitz et al., 1982).

Moreover, other researchers have postulated that it is the amount of contextual/environmental support provided in the experimental task that explains age-related differences in verbal STM performance, particularly when environmental support is provided at encoding and at retrieval (Craik et al., 1987). In the context of this thesis, a number of these theoretical accounts could explain the predictions regarding age-related performance across the various task conditions in the three empirical studies.

### **Empirical findings**

Numerous studies have established that age-related differences in verbal STM emerge across various experimental tasks, for example free recall, associative learning, source memory, prospective memory, and working memory tasks. Conversely, tasks that remain relatively stable across age include tasks of long-term knowledge (i.e., vocabulary, knowledge of words and their meanings, and well-learned facts), recognition, priming, and primary memory tasks (Grady & Craik, 2000; Luo & Craik, 2008; Salthouse, 1996). At a specific level, researchers have established that age-related deficits in verbal STM can be attributed to deficiencies in encoding and retrieving the TBR information for later recall (Balota et al., 2000; Luo & Craik, 2008). The literature has typically conveyed that older adults experience greater difficulty with such encoding and retrieval processes relative to their young counterparts because they are deemed as being effortful and demanding of processing

resources, which may then impair later memory performance (Balota et al., 2000; Hasher & Zacks, 1979; Luo & Craik, 2008).

However, researchers have also found that older adults can compensate for difficulties experienced with the encoding and retrieval demands of a task through the provision of effective encoding techniques and support provided at retrieval (Howard, Fry, & Bruce, 1991; Luo & Craik, 2008). Effective encoding strategies include creating meaningful associations between the TBR items, organising the TBR items in verbal STM, and elaborating on the TBR information by integrating it with previously stored long-term knowledge. Effective retrieval processes include searching for relevant cues in LTM to aid with recalling the TBR information for later output, along with monitoring the information produced at output. Howard, Fry, and Bruce (1991) compared the recall performance of young and older adults when they were required to complete indirect and direct tests of memory to ascertain effective encoding and retrieval of the TBR information. By definition, for indirect tests of memory, participants respond based on their inferences due to changes in behaviour resulting from previous experiences. In contrast, for direct tests of memory, participants are required to verbally report information from memory.

In their study, Howard et al. (1991) had participants view sentences where two nouns that were unrelated were extracted to create a word pair. For example, in the sentence, “*the queen fell down the stairs*”, the nouns “*queen*” and “*stairs*” were extracted to create a word pair. In another sentence, “*the author dismissed the project*”, the nouns “*author*” and “*project*” were extracted to create another word pair. In the indirect test, participants viewed the stem of one word from a word pair and were asked to complete the stem with the first word that came to mind. The word stem was paired with the noun from the same sentence

(e.g., *queen-sta*, *author-pro*) and then paired with the noun from a different sentence (e.g., *queen-pro*, *author-sta*). To reduce the cognitive demands of the memory task and determine whether this additional cue increased or decreased memory performance, participants then completed direct tests of memory, where they were given one word from the pair (e.g., *queen*) and the first three letters of the second word in the pair (e.g., *queen-sta*) to recall. Howard et al. found young adults outperformed the older adults in both experimental conditions. Interestingly, however, when participants were given the additional cue (i.e., the first three letters of the second word) in the direct test, although young adults still outperformed older adults, recall performance improved dramatically across both groups. Howard et al. purported that the cued recall task reduced the amount of cognitive effort required to complete the task because the support provided during the task in the form of cues may have alleviated the demands on encoding and retrieving the TBR items from verbal STM. This would allow individuals to allocate those cognitive resources to recalling the word pairs and improve their memory performance.

Similarly, Paired-Associate Learning (PAL) tasks (Lowndes, Saling, Ames, Chiu, & Gonzalez, 2008) have also been reported as being demanding on encoding and retrieval processes given that memory performance in the PAL tasks is dependent on the individual's ability to create new associations between unrelated pieces of TBR information for later short-term recall. The PAL literature suggests that older adults perform poorly on these types of memory tasks compared with young adults because older adults experience difficulty with learning associations between items for which there is no pre-existing semantic knowledge to draw upon (Lowndes et al., 2008).

Lowndes et al. (2008) used a PAL task to compare recall performance of young and older adults across two different tasks. Participants learned a list of word pairs (e.g., *apple-chair*, *foot-phone*) and were then required to complete a cued recall task, where they viewed the word pairs and were shown the cue word (i.e., *apple*) to prompt recall of the target word (e.g., *chair*). Participants then completed the associate recognition task, where they viewed the list of word pairs and were later asked to differentiate between word pairs that remained intact (e.g., *apple-chair*) from word pairs that had been rearranged (e.g., *chair-phone*). Lowndes et al. found that whilst there were no significant differences in memory performance between young and older adults on the cued-recall and associate-recognition tasks, overall memory performance was significantly higher in the associate-recognition task relative to the cued recall task. Lowndes et al. suggested there was greater retrieval support in the associate-recognition test because participants received the content of the word pair (i.e., the words in the pair) and the context in which the word pair was presented (i.e., the original word pair combination). At recall, participants only needed to discriminate between the contexts in which the word pairs appeared, namely whether they were the original word pairs or whether the words had been rearranged. In contrast with the cued-recall task, where participants were given the content of the word pair, there were additional retrieval demands in the form of recalling the word pair along with the context in which the word pair appeared, since one word was missing from the pair. Ultimately, Lowndes et al. suggested the potentially higher retrieval demands of the cued-recall task contributed to the reduced recall performance compared with associate-recognition task, which used more supportive retrieval conditions.

Naveh-Benjamin, Craik, and Shaul (2002) also displayed the effects of support provided at encoding and retrieval on the verbal STM performance of young and older adults. The

support provided at encoding was in the form of two words that were semantically related or unrelated to a presented picture. Participants were shown 10 pictures of everyday scenes with two words that related to objects in the picture (i.e., related words) and also shown the same 10 pictures but with two words that referred to objects that were not depicted in the picture (i.e., unrelated words). Participants then completed a cued-recall task where they were presented with each picture in a randomised order and were asked to write down the four words associated with that picture.

Naveh-Benjamin et al. (2002) found that young adults recalled a significantly higher proportion of words compared with older adults and cued-recall performance was superior for the supportive (i.e., related) condition relative to the unsupportive (i.e., unrelated) condition. However, in a reverse trend on memory performance, young adults benefited more in the supportive conditions relative to the older adults. Believing that older adults may require support at retrieval and encoding, during retrieval Naveh-Benjamin et al. provided participants with the first three letters of the TBR item as a cue. Importantly, while young adults recalled a significantly higher proportion of words compared with older adults and recall performance was significantly higher for the supportive condition than unsupportive condition, older adults appeared to benefit more from the supportive conditions compared with young adults, based on the extra cue provided during retrieval. To ascertain whether it was the provision of the three-letter cue which improved older adults' recall performance, Naveh-Benjamin et al. varied the type of support at encoding (i.e., related or unrelated picture word pairs) and at retrieval (i.e., the presence or absence of the three-letter cue). Predictably, Naveh-Benjamin et al. found young adults recalled a significantly higher proportion of words compared with older adults, recall performance was significantly higher in the supportive condition compared with

the unsupportive condition, and recall performance was significantly higher when the three-letter cue was provided during retrieval compared with no three-letter cue. They explained their results through the provision of good cognitive support at encoding and retrieval. The literature therefore supports the notion that older adults do have deficits with encoding and retrieval processes relative to their young counterparts. However, when there is appropriate support inherent in the experimental task, the encoding and retrieval demands of the task become more manageable for older adults to perform at a level that closely resembles that of young adults.

## **Conclusion**

To conclude, the literature has ascertained that there is considerable variability in the performance of young and older adults across different experimental tasks and these age-related differences have been attributed to both global (e.g., speed) and specific (e.g., executive control) cognitive mechanisms (Balota et al., 2000; Craik & Byrd, 1982; Erber, 2005; Grady & Craik, 2000; Luo & Craik, 2008). When memory tasks require holding information actively in verbal STM for a brief amount of time, age-related deficits are minimal. However, when there are interruptions between the time taken to register the TBR information and later output or when information in verbal STM must be actively processed and reorganised in order to retrieve and recall the information, age-related deficits are more pronounced (Balota et al., 2000; Craik & Byrd, 1982; Erber, 2005; Luo & Craik, 2008). The consensus among researchers is the processes to store or manipulate information in older adults are somewhat compromised relative to their young counterparts that, in turn, influence short-term recall performance. However, when there is some form of environmental support inherent in the experimental task, these age-related differences in memory performance are



alleviated (Balota et al., 2000; Craik & Byrd, 1982; Erber, 2005; Luo & Craik, 2008). In this thesis, several of the theoretical accounts of ageing and verbal STM could explain the relationship between ageing and redintegration in the three empirical studies and extend Neale and Tehan's original position of noisier memory traces affecting verbal STM performance. From the general cognitive slowing and reduced processing resources perspectives, older adults may experience greater difficulty with encoding incoming information, particularly as interference would increase in the experimental task during the difficult task conditions. From the reduced inhibition perspective, older adults may experience greater difficulty combating the interference produced by the manipulation of task difficulty during encoding that the short-term phonological memory traces of the TBR items become degraded and difficult to retrieve directly from verbal STM. Presumably, in these instances, young and older adults would call upon redintegration to aid memory performance. From the contextual/environmental support perspective, older adults largely than young adults would benefit from the additional retrieval cues inherent in the TBR items in the form of lexicality, association, or relatedness to enhance the redintegration process and facilitate short-term recall. Given that Neale and Tehan (2007) are the only researchers to date who have examined age-related differences in redintegration, it was important to extend their research using a different sample of young and older adults to examine whether redintegration is age invariant using different measurements of redintegration and a different manipulation of task difficulty to manipulate the reliance on redintegration. Chapter six is the first empirical study of this thesis that investigates this relationship between ageing and redintegration using the WLE (Hulme et al., 1991; Hulme et al., 1995).

## **Chapter six: First empirical study-Word length and redintegration**

The word length effect (WLE) is one of the cornerstone verbal STM phenomena and is the consistent finding that the immediate serial recall for lists of short words (defined in terms of their spoken duration) is superior to the immediate serial recall for lists of long words (Baddeley et al., 1975; Henry, 2012; Neath & Suprenant, 2003). The decay explanation of short-term forgetting has been primarily used to account for the WLE, with Baddeley, Thomson, and Buchanan's (1975) seminal investigation of the WLE establishing that recall was significantly higher for words with a 'short' spoken duration than items with a 'long' spoken duration. They inferred from their study that short words are rehearsed quicker before their short-term phonological memory traces begin to decay from verbal STM compared with long words that take longer to rehearse and, as a result, their respective short-term phonological memory traces are subject to a greater rate of decay. However, researchers have since challenged Baddeley et al.'s account of the WLE and have established that it is an item-based phenomenon, where the recall advantage for short words stems from differential processing of the TBR words into verbal STM that influences their later retrieval (Caplan, Rochon, & Waters, 1992; Hulme, Surprenant, Bireta, Stuart, & Neath, 2004; Neath & Nairne, 1995) and in some instances, researchers have found a reverse WLE (Baker, Tehan, & Tehan, 2012). Specifically, these researchers have acknowledged that there is a long-term contribution to the WLE, where individuals access their long-term phonological representations that assist with retrieving the TBR words and this process is highly efficient for short words compared with long words. From the redintegration perspective, the WLE would emerge because of a reciprocal relationship that exists between the information held in verbal STM and the permanently stored lexical information held in LTM (Neale & Tehan,

2007; Schweickert, 1993). Reconstructing the short-term phonological memory traces for short words would be highly efficient as they contain fewer elements that require reconstruction than long words that contain more elements, which may need a greater amount of reconstruction. This empirical study sought to investigate the relationship between the WLE and redintegration to articulate whether the item-based explanation of the WLE would extend to redintegrative processing.

### **Current explanations for the word length effect**

Baddeley et al. (1975) conducted the earliest demonstration of the WLE in verbal STM. They were primarily interested in examining memory span as researchers of the time proposed that verbal STM was a speech-based system and it was possible to measure verbal STM capacity using speech-based units such as syllables and phonemes. Baddeley et al. aimed to determine the influence of word length on memory span, determine whether verbal STM capacity was based on either the number of TBR items held within verbal STM or the length of time of retaining the TBR items in verbal STM, and examine the implications of whether the system underlying verbal STM is time-based or item-based. Several key findings emerged from their study: Firstly, when they held the number of syllables and number of phonemes in the TBR items constant and were matched for word frequency or semantic category, there was a substantial recall advantage for lists of short words compared with lists of long words. Secondly, when the TBR items were visually presented, the WLE was abolished. Thirdly, they identified a systematic relationship between the time taken to articulate the TBR items and memory span, where memory span was equivalent to the number of TBR items individuals could read in approximately two seconds. Fourthly, memory span was correlated with the rate at which individuals read the TBR items. Finally, when they introduced articulatory

suppression into the experimental task, the WLE was abolished under visual presentation conditions and not auditory presentation conditions. However, Baddeley et al.'s explanation has since been challenged and time is no longer an adequate explanation of the WLE in verbal STM. Researchers have been able to establish that the WLE is an item-based phenomenon. These researchers focused their attention on the properties of the TBR words and have demonstrated this word length advantage in verbal STM using the characteristics of the TBR items such as the number of consonants and vowels (Caplan et al., 1992; Hulme et al., 2004), the number of features of the TBR items (Neath & Nairne, 1995), and through processing differences between short and long words that is reflected through a trade-off between attending to the TBR word at the expense of recalling that same word in its correct serial position (Baker & Tehan, 2008; Hendry & Tehan, 2005).

**Phonological complexity.** Phonological complexity refers to the phonological structure of the TBR word (Caplan et al., 1992; Hulme et al., 2004). Researchers who ascribe to this view believe the WLE emerges during short-term recall because the increasing phonological complexity of the TBR word limits the capacity of the individual's memory span to retain the respective short-term phonological memory traces of those words for later output (Caplan et al., 1992; Hulme et al., 2004). This subsequently affects the individual's ability to discriminate the TBR words among the other information remaining in verbal STM (Caplan et al., 1992; Hulme et al., 2004). Caplan, Rochon, and Waters (1992) explicated this relationship between the WLE and phonological complexity as they believed that the phonological structure of the TBR items dictated the WLE. Caplan et al. used lists containing words matched for the number of syllables and phonemes, but defined word length in terms of the vowel duration of the TBR item. Short words contained two lax vowels of short duration (e.g., *bullet*) and long

words contained two tense vowels or two tense vowels and one lax vowel of long duration (e.g., *balloon*). Using a memory span task and presenting the items either auditory or visually, Caplan et al. found a reverse WLE, where participants recalled a significantly higher proportion of words with a long articulatory duration compared with words with a short articulatory duration.

Further substantiating their position on phonological complexity explaining the WLE, Caplan et al. (1992) then defined word length using articulatory complexity (i.e., the ease with which individuals could articulate the TBR word). The short ‘easy to articulate’ words contained a consonant-vowel-consonant structure, a lax vowel, and had an average spoken duration of 475 milliseconds (e.g., *rat*). The long ‘difficult to articulate’ words began with two consonants, ended with a tense vowel, and had an average spoken duration of 571 milliseconds (e.g., *tree*). Interestingly, there was no significant difference between the number of TBR items correctly recalled in the lists of ‘easy-to-articulate’ (71.4%) and ‘difficult-to-articulate’ (71.3%) words. Caplan et al. inferred from their findings that it was the phonological structure and not the features pertaining to articulating the TBR word that determined the size of the WLE in verbal STM. They believed that individuals used the phonological structure of the TBR word to engage in a level of phonological planning that activated the lexical representations needed to produce the TBR word. These processes then fed back to the activated long-term lexical representations to assist with retrieving and subsequently recalling the TBR word held in verbal STM to enhance their retrieval for later output. In their study, the phonological processes were easier to activate the representations for short words because the structure of these words were less phonologically complex compared with long words. Thus, the WLE required the activity of phonological output

planning processes that operated on accessing long-term lexical phonological representations of the TBR words that facilitated short-term recall.

Hulme, Suprenant, Bireta, Stuart, and Neath (2004) also established that phonological complexity best accounted for the WLE in verbal STM, as demonstrated through their use of a serial reconstruction task to equate the output time for the lists of short words and lists of long words. Participants viewed lists of short words (i.e., monosyllabic), long words (i.e., three to five syllables) along with alternating lists beginning with either a short word (i.e., short-long) or a long word (i.e., long-short) and were instructed to indicate which of the words were present in the trial and then allocate those words to their original serial position. Hulme et al. observed a significant WLE for the pure lists of words, but that same WLE was abolished in the alternating lists. Hulme et al. interpreted the presence and absence of WLEs as reflecting limitations in the individual's ability to retain the short-term phonological representation of a list of TBR words, which individuals can later use to differentiate from other TBR words that may be active in the search set. The WLE emerged because according to Hulme et al., lists of long words have a greater level of phonological complexity that made it difficult to maintain all of the phonological information at one point in time to retrieve for later recall. Furthermore, given lists of short words have a considerably reduced level of phonological complexity, maintaining their respective phonological representations in verbal STM in a retrievable state would be easier which facilitated their higher recall. It was therefore evident from the literature that phonological complexity served as one plausible alternative account for the WLE by attributing this effect to item-based characteristics that enhanced and hindered encoding and retrieval of those items for subsequent output.

**Feature model of memory.** The Feature Model of Memory conceives the TBR words as being made up of multiple segments, each of which need to be assembled correctly to identity the TBR word. The number of segments do not correspond with the number of features of the TBR word (Nairne, 1990; Neath & Nairne, 1995). Rather, successful recall relies upon matching the segments in the degraded primary memory trace with groups of relevant intact secondary memory traces. To achieve this, the primary memory trace for the TBR word needs to be discriminated not only from the other primary memory traces created for the remaining TBR words, but also from other secondary memory traces that have been internally accessed in LTM. However, if errors occur during the assembly process, then the primary memory trace may lose important features that could assist with matching it with its undamaged secondary memory trace. Neath and Nairne therefore purported that the WLE stemmed from short words having fewer segments that need to be reassembled in verbal STM compared with long words that contain a greater number of segments.

Neath and Nairne (1995) emphasised that the application of their framework to the WLE is only sound if it is assumed that the WLE works in a similar manner to the list length effect. That is, as the length of the list of TBR words increases, the total number of TBR words that are recalled systematically decreases because there are a greater number of opportunities to produce an error during recall. Applying this logic to the WLE, as the number of segments in the TBR word increases (i.e., long words), the probability of recalling that word systematically decreases. The segments of the degraded short-term phonological memory traces for the TBR words must be assembled in primary memory into useful retrieval cues to (a) identify the TBR word in secondary memory and (b) reproduce the TBR word at output. However, there is a small probability that errors may occur in the reassembly process due to the increasing number

of segments contained in the TBR word. The probability of making an assembly error for a particular segment is the same for short and long words but given that long words contain more segments, there is a greater overall probability of producing errors when recalling long words compared with short words. Consequently, this reduces the usefulness of the primary memory trace for the TBR item acting as a retrieval cue to assist with later output. For example, *candle* contains two segments /*can*/ and /*dle*/, and *amphitheatre* contains four segments, /*am*/, /*phi*/, /*thea*/, and /*tre*/. Should there be difficulties with retrieving the short-term phonological memory trace to recall *candle* or *amphitheatre*, the probability of making an error when reassembling the TBR words would be smaller for *candle* because it contains fewer segments than *amphitheatre*.

In their various simulations of the Feature Model, Neath and Nairne (1995) used the WLE to explicate the relationship between the number of segments in the TBR word and correct item recall. Participants viewed trials containing short words (i.e., monosyllabic) and long words (i.e., five-syllables). After presenting the last word in the trial, participants were presented with an array of pictures and they were required to point to pictures of the TBR words. Neath and Nairne found that correct item recall decreased as the number of segments in the TBR item increased from one to 13. They inferred that the WLE surfaced because long items contained more segments and they have a greater probability of making an assembly error due to the compounding of error that is associated with each segment in the TBR word. The Feature Model therefore substantiated the item-based perspective of the WLE by demonstrating that the WLE stems from difficulties in reassembling the properties of the TBR words to locate information in LTM and facilitate short-term recall.



**Item-order framework.** The item-order framework proposes that the WLE surfaces because of differences in processing the short and long words into verbal STM. Specifically, there is a trade-off between processing item information and processing order information when presented with lists of short and long words in an immediate serial recall task (Baker & Tehan, 2008; Hendry & Tehan, 2005; Nairne et al., 1991). Individuals spend a large amount of cognitive resources processing the item information for the TBR words that it is at the expense of processing the corresponding order information (Baker & Tehan, 2008; Hendry & Tehan, 2005; Nairne et al., 1991). Researchers have applied the item-order framework to the WLE, postulating that in an order-based task, individual process lists of short words faster than long words, leading to a greater short word advantage. Conversely, long words require additional processing time that would be a detriment to an order-based task but advantageous to an item-based task, leading to a reverse WLE in verbal STM. Hendry and Tehan (2005) demonstrated the WLE using the item-order trade-off to show the dissociation in recall between verbal STM tasks that utilise item information and verbal STM tasks that utilise order information. Hendry and Tehan believed that in the recognition task, due to the fast presentation rates, individuals would require more time to identify long words compared with short words, resulting in more time to processing the item information for short words. Furthermore, the additional time given to identify long words meant that they would receive additional item processing. In effect, the typical WLE found in immediate serial recall tasks (i.e., order memory), where recall is higher for short words than long words, would reverse in an item recognition task (i.e., item memory), where recognition is higher for long words than short words.

To test these predictions, in their first experiment, Hendry and Tehan (2005) had participants view 15 six-word lists containing short monosyllabic words containing three

phonemes, and 15 six-word lists containing long words comprising two to three syllables and seven phonemes. Using a serial recall task and then a recognition task, Hendry and Tehan found the ubiquitous WLE across all conditions, where recall was significantly higher for short words than long words. However, this word length advantage predictably reversed in the recognition task, where participants recognised a significantly higher number of long words than short words. These initial robust findings suggested there were processing differences for the short and long words during the serial recall task that strongly reversed in the recognition task.

Hendry and Tehan (2005) then introduced articulatory suppression, positing that the easy items (i.e., short words) would be more affected when articulatory suppression was introduced because item processing may become more difficult under such conditions and therefore easy items would be more affected by these changes. In contrast, the difficult items (i.e., long words) already require substantial item processing and therefore articulatory suppression would have little effect on recall and recognition performance for long words. Hendry and Tehan believed that introducing articulatory suppression would reduce the size of the WLE in a serial recall task but the reverse WLE would remain in the recognition task. Using the same experimental paradigm, Hendry and Tehan found that under articulatory suppression conditions, there was no significant recall difference between short and long words. However, participants recognised a significantly higher proportion of long words compared with short words. Hendry and Tehan suggested that short words were encoded with more order information at the detriment of encoding the item information because short words required less time to identify and process in verbal STM, hence the recall advantage in an order-based task. Long words, on the other hand, were encoded with more item information at

the detriment of order information because long words required more time to identify and process in verbal STM. Although this resulted in longer identification times, the additional processing ultimately led to their better recognition in an item-based recognition task. Thus, the WLEs observed in their study are based at the item level and the opposing WLEs reflected differences in processing short and long words.

Baker and Tehan (2008) extended Hendry and Tehan's (2005) findings by using a backward serial recall task and incorporated the remember/know procedure (Tulving, 1985) to substantiate the notion of the WLE resulting from processing differences between short and long words and determine whether individuals engaged in more elaborate processing for the long words. Using lists containing five short words (i.e., monosyllabic with two to four phonemes) and lists containing five long words (i.e., two to five syllables with six to 11 phonemes), Baker and Tehan found the two opposing WLEs. For the backward serial recall task, participants recalled a significantly higher proportion of short words in their reverse serial position than long words. For the recognition test, participants recognised a significantly higher proportion of long words than short words. Importantly, for the remember/know task, Baker and Tehan also found a significant interaction between word length and the two levels of responses. For long words that were recognised, participants recorded a significantly higher proportion of "remember" responses than "know" responses. However, for short words, there was no significant difference in the proportion of "remember" and "know" responses. Baker and Tehan suggested the WLEs observed in their study reflected a trade-off between item and order information in the backward serial recall task and the recognition task. More importantly, the findings from the remember/know task reflected differences in the type of information encoded during the backward serial recall and recognition tasks. The higher

proportion of “remember” responses for long words suggested that individuals encoded the long words with more episodic information than for short words, thereby enhancing their retention in verbal STM. Furthermore, short words were presumably not as richly encoded as long words and, as a result, they were more easily forgotten over the retention intervals from the backward serial recall task to the remember/know task. The literature has therefore strengthened the notion that the recall advantage for short words over long words stems from differential processing into verbal STM that increased the efficiency with which individuals encoded, retrieved and subsequently recalled the TBR words from verbal STM.

Together, the literature has indicated that the WLE is an item-based phenomenon, with phonological complexity (Caplan et al., 1992; Hulme et al., 2004), word features (Neath & Nairne, 1995), and differential processing for short and long words (Baker & Tehan, 2008; Hendry & Tehan, 2005) influencing their encoding and subsequent retrieval for short-term recall. An important interaction exists between the previously stored representations in LTM with the temporarily stored representations in verbal STM for short and long words, which dictated processing differences between short and long words that subsequently led to the recall advantage for short than long words in verbal STM tasks. The redintegration literature closely aligns with these explanations of the WLE as redintegration focuses solely on utilising item information to facilitate the reconstruction process and aid recall for those forgotten items. While using long-term representations to begin reconstruction of the degraded short-term phonological memory trace, individuals may cue the search for long-term information by using the lexical properties (i.e., number, of syllables, letters, phonemes) of the TBR word to enhance the redintegration process, particularly for short words, as contain fewer features to identify and reconstruct. In turn, redintegration may be more efficient in comparison to long

words that may have a greater number of features that require reconstruction. It was therefore reasonable to believe that when measuring redintegration using the WLE, a redintegration effect in the form of the word length advantage would emerge, where the recall difference between words in the short and long words would become greater with increasing task difficulty.

### **Age differences and the word length effect**

Few studies to date have compared the WLE between young and older adults under verbal STM conditions. The available investigations have examined their performance in terms of the functionality of different components of memory, mainly the phonological loop, because the WLE has been previously established as being associated with the articulatory mechanism (Belleville, Peretz, & Malenfant, 1996; Peters et al., 2007). Only one study to date has conducted a direct examination of age differences in the WLE in verbal STM. Baker, Tehan, and Tehan (2012) examined age effects in the WLE in forward and backward serial recall to determine in which task would age effects be present and in which direction of recall would age effects be most pronounced. They expected that age effects would be more pronounced during the backward serial recall task compared with the forward serial recall task, as the backward task is more cognitively demanding.

Baker et al. (2012) had 20 young adults aged 18 to 26 years and 20 older adults aged 60 to 75 years complete four different experimental tasks: a forward-ordered immediate serial recall task, a forward-ordered order reconstruction task, a backward-ordered immediate serial recall task, and a backward-ordered order reconstruction task. They manipulated word length for all tasks using short monosyllabic words containing two to four phonemes and long words with two to three syllables containing between four to 10 phonemes. Baker et al. found verbal

STM performance was significantly higher for the order reconstruction task compared with the standard immediate serial recall task, for forward than backward recall, and for short than long words. No significant main effect of age was observed. There were no significant age effects for forward recall but, as predicted, there was a significant age effect for backward serial recall, where young adults recalled a significantly higher proportion of words in their reverse presentation order compared with older adults. They tentatively concluded that the only age difference in this experiment might have resulted from differences in the cognitively demanding nature of the task, which resulted in differences in item processing for the TBR words.

Baker et al. (2012) included an item recognition task to reduce the cognitive demands of the experimental task and examine differential effects in item processing. They found in a reverse trend on memory performance, there was no significant WLE in the backward serial recall task but a strong age effect, where young adults recognised a significantly higher number of short and long words than older adults. While there was a long-word recognition advantage, no age effects were present. Baker et al. explained the pattern of WLEs that emerged across their two experiments that the processes occurring for the WLE are common to adults across the age spectrum and that the pattern of overall age differences is consistent with levels of task difficulty and/or environmental support in the experimental task (Tulving, 1985).

In conclusion, examinations of age-related performance for the WLE have revealed insight into the functionality of memory (Belleville et al., 1996; Peters et al., 2007), but little research has provided insight into how young and older adults process short and long words in a verbal STM task. Only Baker et al. (2012) have suggested that the processes underlying the

WLE are consistent for young and older adults when using different verbal STM tasks and that young and older adults benefit when there is some form of contextual or environmental support to reduce the cognitive demands of the experimental task. From the redintegration perspective, it was reasonable to believe that given there was no form of contextual or environmental support to facilitate short-term recall performance, young adults may outperform older adults given that the TBR items are based purely on their lexical characteristics. However, young and, to a greater extent, older adults, would engage in the same redintegration process to facilitate short-term recall as older adults may be more reliant on redintegration to aid verbal STM performance as they may find it problematic managing the varying levels of interference produced across the eight different task conditions.

## **Aims**

This study aimed to examine the redintegration process by uniquely measuring redintegration using the WLE. The literature has established that the time-based explanation of the WLE (Baddeley et al., 1975) is no longer tenable and there is increasing support in the verbal STM literature that the WLE is an item-based phenomenon. Researchers have explained the WLE through factors such as phonological complexity (Caplan et al., 1992; Hulme et al., 2004), word features (Neath & Nairne, 1995), and differential processing of information for the TBR words (Baker & Tehan, 2008; Hendry & Tehan, 2005). These accounts of the WLE allude to some form of reliance on long-term knowledge to produce the TBR words during output that facilitates the recall advantage of short words over long words. It was reasonable to believe that the item-based advantages of the WLE in verbal STM would extend to the redintegration process, where individuals would focus on the characteristics of the TBR word and subsequently use the length of the TBR word as an additional retrieval cue

to enhance redintegration process and aid short-term recall, particularly during the difficult task conditions. As no researchers have conducted such an examination between redintegration and word length using a unique manipulation of task difficulty, this relationship represented an important area of inquiry.

This study also aimed to examine whether age-related differences exist in redintegration when measured using the WLE. Previous investigations of age and the WLE have explained this effect in terms of the functionality of the phonological loop (Belleville et al., 1996; Peters et al., 2007) and only one study to this date has given some indication as to how young and older adults process short and long words in a verbal STM task. These researchers found that young and older adults recalled and recognised a comparable proportion of short and long words across the serial order reconstruction and item recognition tasks, respectively (Baker et al., 2012). This observation may give some indication as to how young and older adults process short and long words across a range of memory conditions that vary in their level of difficulty. It was believed that when individuals engage in redintegration, particularly during the difficult task conditions, young and older adults would engage in the same process to aid short-term recall. However, older adults would be more reliant on redintegration to counter the effects of the task difficulty manipulation interfering with encoding the TBR items into verbal STM to benefit their memory performance. Given that Neale and Tehan (2007) are the only researchers to date who have examined age differences in redintegrative processing, this study also aimed to add to this body of literature.

## **Hypotheses**

The predictions of this study were made in terms of correct-in-position recall with additional analyses conducted for item recall and order accuracy to establish whether these



two further analyses would produce similar patterns of performance. Furthermore, this study predicted that as the experimental task became more difficult, redintegration would be required to support short-term recall. The level of each difficulty for each task condition was based on the outcome of the study and not on predictions. This was the case for all studies in this thesis. Therefore, it was hypothesised that for correct-in-position recall, item recall, and order accuracy, at the short-term recall level across all task difficulty conditions, young adults would recall a significantly higher proportion of short and long words compared with older adults. Given the varied level of interference produced across the conditions in the experimental task, young adults would be more efficient in combating the interference during encoding relative to their older counterparts.

It was hypothesised that for correct-in-position recall, item recall, and order accuracy, there would be a significant positive relationship between the word length advantage and task difficulty. In the easier task conditions, the recall difference between short and long words would not be present. Consistent with the redintegration process, recall for short and long words would be comparable because the short-term phonological memory traces would be relatively intact that they would have sustained little damage from the interference produced from the manipulation of task difficulty. As a result, the short and long words could be retrieved directly from verbal STM. In the difficult task conditions, redintegration effects would emerge, where participants would recall an increasingly higher proportion of short words than long words. Consistent with the redintegration process, the increased interference in the experimental task would compromise the fidelity of the short-term phonological memory traces for the TBR words. As a result, individuals would call upon redintegration to assist with retrieving those words for later output. Individuals would locate long-term

information to amalgamate it with the remaining information that was available in verbal STM. Furthermore, individuals would use the length of the TBR words as an additional retrieval cue to enhance the search for long-term information a specific section of LTM that would increase the likelihood of retrieving the correct information to reconstruct the degraded short-term phonological memory trace. Redintegration effects, in this study, would emerge in the form of the word length advantage, where the size of the recall difference between short and long words would increase, in favour of short words.

It was hypothesised that for correct-in-position recall, item recall, and order accuracy, at the most difficult level of the task, the size of the recall difference between short and long words would be greater for older adults than young adults. In the condition where interference in the experimental task was at the highest level, older adults would be more susceptible to the interference produced during encoding that they would be largely reliant on redintegration to reconstruct the degraded short-term phonological memory traces for the TBR words. Furthermore, older adults would utilise the length of the word to facilitate the reconstruction process because they contain fewer elements that would need to be rebuilt relative to long words as well as reduce the cognitive demands of the experimental task to improve their memory performance.

## **Method**

### **Participants**

The sample consisted of 40 adult volunteers that comprised two groups: Twenty young adults (35% men and 65% women,  $M_{\text{age}} = 24.10$  years, age range 18-35 years) were recruited from undergraduate psychology courses at an Australian university (70%) for partial course

credit and the general community (30%). Participants from the general community did not receive incentives for their participation. Twenty independent living older adults (25% men and 75% women,  $M_{\text{age}} = 75.70$  years, age range 62-86 years) were recruited from a retirement village in Australia, local community groups, and the general community. Participants in the older adult group did not receive incentives for their participation. The age ranges for young and older adults were consistent with the sample Neale and Tehan (2007) recruited for their study and these age groups are similar to those groups that are typically used in ageing research (e.g., Balota & Duchek, 1988; Craik et al., 1987; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2002). All participants spoke English as their first language. Participants were recruited using expression of interest posters and spoken advertisement (see Appendices B-1 and B-2). Interested participants received an information letter and a consent form to complete (see Appendices A-1 to A-4). Those individuals who provided informed consent participated in the study. This research received full ethics approval by the Human Research Ethics Committee at the Australian Catholic University (approval number V 2009 31) (see Appendix A-5). Table 6.1 presents a summary of the remaining demographic characteristics of the sample.

Table 6.1  
*Demographic Characteristics across Age*

Characteristic	Young ( <i>n</i> = 20)		Older ( <i>n</i> = 20)		<i>t</i>	<i>df</i>	<i>p</i>	<i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>				
Health on testing day <sup>a</sup>								
Good to excellent	100%		95%					
Not very good	0%		5%					
Vision								
Normal	80%		25%					
Corrected-to-normal	20%		75%					
Hearing								
Normal	95%		25%					
Corrected-to-normal	5%		75%					
Mill Hill <sup>b</sup>	13.50	2.01	15.15	2.03	-2.58	38	.014	0.82
Education (years)	15.53	2.71	11.55	2.76	4.59	38	<.001	1.46

*Note.* *n* = number of participants.

<sup>a</sup> was self-rated on a five point Likert Scale from 1 (Excellent) to 5 (Poor).

<sup>b</sup> refers to the Mill Hill Vocabulary Scale (Raven, 1989).

## Design

This study used a 2 x 2 x 2 x 2 x 2 mixed factorial design. The four within-subjects independent variables were: (1) word length (short, long), (2) recall interval (immediate, delay), (3) study condition (silence, irrelevant speech), and (4) presentation rate (one second, two seconds). The between-subjects independent variable was age (young, older).

The primary dependent variables were: (1) correct-in-position recall, which was measured as the number of TBR words recalled in their correct serial position, (2) item recall, which was measured as the number of TBR words recalled, irrespective of the original order of presentation, and (3) order accuracy, which was measured as the proportion of TBR words recalled in their correct serial position, given that the word was initially recalled. The secondary dependent variables of interest were the errors the participant made during recall: (1) transpositions, which were measured as the number of instances the participant recalled

two TBR words in their transposed serial position and (2) omissions, which were measured as the number of instances the participant omitted the TBR words during recall.

## Materials

**Background measures.** The background measures used in this study were a biographical questionnaire and the Mill Hill Vocabulary Scale (Raven, 1989).

***Biographical questionnaire.*** A brief biographical questionnaire obtained demographic data from the participant. Questions related to the participant's gender, age (in years), marital status, year level of secondary school completed, and the number of years of post-secondary education completed. Questions relating to the participant's state of health over the last month and the current day of completing the study were rated on a five point Likert Scale from 1 (Excellent: No problems) to 5 (Poor: Persistent serious problems). The final two questions asked the participant to respond "Yes" or "No" if they had received a diagnosis related problems with vision or hearing. If their response was "Yes", the participant described their diagnosis in the space provided (see Appendix B-3).

***Mill Hill Vocabulary Scale.*** The Mill Hill Vocabulary Scale (Raven, 1989) is a 21-item pencil and paper multiple-choice vocabulary test that the participant completes in the presence of the researcher. The Mill Hill assesses synonym recognition, is considered to be a reliable indicator of general intelligence, and has been frequently used in ageing research to ascertain that a sample of participants are of a healthy ageing population (Bopp & Verhaeghen, 2007; Raven, 1989; Slessor, Phillips, & Bull, 2007). The 21 test words are in uppercase and increase in difficulty; the first word is a practice item. Each test word has six accompanying words in lower case letters. For example, the practice word *CONNECT* has six accompanying words *accident, lace, flint, join, bean, and field*. Participants underlined or circled the word that was

closest in meaning to the test word; in this example, the answer is *join*. Correct responses are given one point and incorrect responses are given zero. The responses are summed to calculate the total Mill Hill score that ranges from zero to 20. The Mill Hill is reported to have high test-retest reliability, with Pearson's Product Moment Correlation Coefficient ranging from .87 to .98 (Bortner, 1958) (see Appendix B-4).

**Word stimuli.** The experimental materials used in this study consisted of word stimuli and word trials. Three hundred and twenty words were generated and selected from the Medical Research Council (MRC) Psycholinguistic Database (Quinlan, 1992) to create two separate word pools based on word length (short and long). The restrictions for selecting the short and long words were consistent with the Baker and Tehan (2008) study, where they generated word pools to examine WLEs in forward and backward serial recall. The short word pool contained 160 monosyllabic words, between three and five letters in length, and consisted of two to four phonemes, for example, *mane*, *dad*, *vase*, *meal*, *patch* (see Appendix B-5). The long word pool contained 160 words, between two and five syllables, between four and 11 letters in length, and consisted of four to nine phonemes, for example, *wholesaler*, *magazine*, *algebra*, *envelope*, *triangle* (see Appendix B-5). Word frequency was controlled by selecting words with a low frequency. As defined by the Kucera and Francis (1967) written frequency norms, words with a low frequency have a rating of five per one million in the English language. There was no significant difference in the mean frequency between the short ( $M = 48.85$ ,  $SD = 86.15$ ) and long words ( $M = 41.40$ ,  $SD = 73.44$ ),  $t(699) = 1.24$ ,  $p = .217$ ,  $d = 0.09$ . All words were concrete nouns that had a minimum rating of 500 and a maximum rating of 700 for concreteness and imagery because words that are rated higher on these characteristics

improve recall whereas words that are rated lower on these characteristics decrease recall (Sadoski, Goetz, & Fritz, 1993; Sadoski, Goetz, & Rodriguez, 2000).

**Word trials.** All words were imported into an excel program that was designed in accordance to the constraints of this study and generated the word trials the participant viewed in the experimental task. This program generated one unique block of word trials for each participant, where they viewed five different word trials in each of the eight memory conditions.

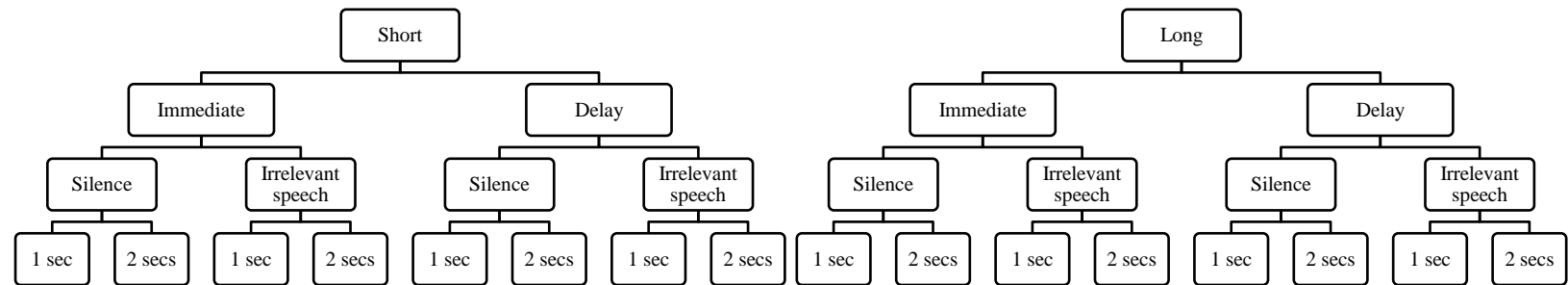
Figure 6.1 presents the configuration of the word trials used in the study. For each word trial, the program selected four short words without replacement to ensure no word appeared more than once throughout the experiment. Using only four words per trial would place less cognitive demand on the individual to retain the words using rehearsal and help explicate the true effects of recall interval, study condition, and presentation rate to increase the reliance on redintegration and aid short-term recall. This process occurred 40 times to create 40 individual short word trials. Twenty of the short word trials were randomly allocated to the immediate recall condition. The remaining 20 word trials were allocated to the delayed recall condition, where 40 pairs of two digit numbers between 10 and 99 were randomly selected and imported into the computer program to serve as distractor items during the two-second interval after list presentation and before recall. The program then allocated 10 of the short word trials from the immediate recall condition to the silence condition and the remaining 10 trials were allocated to the irrelevant speech condition with an audio wave file containing German speech synchronised to each trial. German speech was used as Colle and Welsh (1976) established interference effects in recall performance using German speech as the irrelevant speech component in their study. Ten of the short word trials from the delayed recall condition were

allocated to the silence condition and the remaining 10 trials were allocated to the irrelevant speech condition, with a different audio wave file containing German speech synchronised to each trial. A row of five question marks (?????) was synchronised to the end of all word trials. Together, the eight different combinations of word length, recall interval, and study condition were tested five times. The entire process was repeated to create the 40 individual long word trials (see Appendix B-6 for an example block of word trials).

The unique block of 80 word trials was counterbalanced on presentation rate, where individuals began viewing the words in 40 of the trials at a rate of either one word every second or one word every two seconds. Finally, each block of trials was exported into a notepad document and then loaded into a program called Cue Speech.

To ensure comparability between the young and older adults, participants in each age group were matched to receive the same block of word trials. That is, participant one from the young adult group received the exact same set of trials as participant one in the older adult group and so forth.





*Figure 6.1.* Composition of the task difficulty conditions using recall interval, study condition, and presentation rate across word length.

## Procedure

Each participant was tested individually in a quiet room in one session at a mutually convenient time. Participants were randomly assigned to one of the two conditions (i.e., begin with the one-second presentation rate or begin with the two-second presentation rate) and testing took approximately 45 to 60 minutes to complete. The program Cue Speech was loaded onto the computer and participants viewed all of the trials on a yellow background in black size 36 Courier New Font on a 1680 x 1050 pixel resolution 22" LCD Monitor. Prior to testing, the researcher explained the experimental task and provided the participant with four practice trials representing each experimental condition. On completion of these trials, the participant had the opportunity to ask questions prior to completing the experimental trials or repeat the practice trials if necessary.

At the beginning of each trial, the word READY appeared in capital letters to cue the participant that the word trial was about to commence. The participant viewed the experimental stimuli one at a time in lowercase letters in the middle of the computer screen. For the one-second presentation rate, words were displayed for 1,000ms on/0ms off and for the two-second presentation rate, words were displayed for 2,000ms on/0ms off. Depending upon the experimental condition, half of the word trials were presented in silence while the other half of the word trials began with irrelevant speech playing simultaneously as the participant viewed each word in the trial and ceased once the last item was presented. The participant was directed to ignore the irrelevant speech when they heard it playing during the word trial. In all conditions, if a pair of two-digit numbers (e.g., 26, 79) appeared on the screen, which were presented a rate of one digit per second, participants were required to say the numbers aloud first (e.g., “*twenty-six*”, “*seventy-nine*”). At the end of all trials,

immediately after presenting the last item, a row of question marks (?????) appeared on the screen that indicated to the participant they were required to recall aloud the words they viewed in the same order of presentation. The participant had 12 seconds to respond before the next word trial appeared on the screen. The participant was instructed to substitute “pass” or “something” when they could not remember a word to preserve the serial order of the recalled words. The participant was given a 10-minute break after completing the first set of 40 trials and before commencing the experimental task for the second set of 40 trials that were viewed in the reverse presentation rate. That is, if the participant viewed the words in the first set of 40 trials at the one-second presentation rate, the participant viewed the items in the second set of 40 trials at the two-second presentation rate. The individual sets of 40 trials in the block of 80 trials were counterbalanced on presentation rate to avoid confounds such as fatigue and practice effects.

The researcher recorded the participant’s responses on a hard copy of the 80 experimental trials. At the end of the testing session, the participant completed the biographical questionnaire and the Mill Hill Vocabulary Scale (Raven, 1989). The participant was debriefed about the nature of the research and thanked for their participation and time.

### **Scoring**

The following scores were computed across the five trials in each memory condition: the total number of TBR words recalled in their correct serial position (correct-in-position score), the total number of TBR words recalled, irrespective of the serial position (item score), the proportion of TBR words the participant recalled, given the participant initially recalled the TBR word (order accuracy), the total number of instances when two TBR

words were recalled in their transposed serial positions (transposition score), and the total number of instances the participant omitted the TBR word at recall (omission score). A proportion score was then calculated by dividing the total score by the number of trials in the memory condition (i.e., 20 trials) for correct-in-position, item, transposition, and omission scores.

## **Results**

### **Data screening**

All data for correct-in-position recall, item recall, order accuracy, transposition errors, and omission errors were screened prior to data analysis. The screening process was consistent with the procedures outlined by Tabachnick and Fidel (2007) and Field (2009) using the Statistical Package for the Social Sciences (SPSS), Version 20.0. This involved checking the accuracy of data input, missing data, outliers, tests of homogeneity of variance, and tests of normality. Screening revealed no extreme data that would represent inaccurate data input and no missing data. Examining box plots and histograms, there were outliers present in all of the memory conditions but these outliers were retained as they were deemed part of the intended population. Examining the Levenes Test of Equality of Variances, there were no violations of the assumption of homogeneity of variances for correct-in-position recall, item recall, transposition errors, and omission errors. However, for order accuracy, four of the eight memory conditions violated the homogeneity of variances assumption, where  $p < .05$ . In studies where the assumptions of an Analysis of Variance (ANOVA) are violated, Keppel (1991) argues the  $F$  test is not affected when the distribution of scores is asymmetrical, is not normal, and when the sample size for each

group is greater than 12. Therefore, given the sample size for each group is 20, violation of the ANOVA assumptions would not affect the interpretation of the results. Furthermore, as the dependent variables of correct-in-position recall, item recall, order accuracy, transposition errors, and omission errors were split across 16 cells, transforming the data to improve these violations was not plausible because this would cause additional problems with the other variables. Therefore, the decision was made to retain the data in its original form.

### **Data analysis**

To investigate the WLE, means, standard deviations, and 95% confidence intervals were calculated to compare recall performance between young and older adults for short and long words across the eight different memory conditions using correct-in-position recall, item recall, and order accuracy. Separate  $2 \times 2 \times 2 \times 2 \times 2$  Mixed Factorial Analyses of Variances (ANOVAs) were calculated to confirm that each of the variables that operationalised task difficulty (i.e. word length, recall interval, study condition, and presentation rate) produced the hypothesised influence on memory performance for correct-in-position recall, item recall, and order accuracy, respectively. Significant interactions (i.e., 2-way, 3-way, and 4-way) between the variables were followed up with tests of simple effects using a feature within SPSS that takes into account the overall error term. Using this procedure reduces both the possibility of running multiple *t*-tests and reduces the increase of Type 1 errors. No post-hoc comparisons were completed because all variables had two levels. It is important to note that memory performance for each participant was collapsed across serial positions because the present study was not interested in serial position effects and serial position was not reported in any of the hypotheses. To measure whether the WLE

was a true redintegration variable, two different analyses were calculated. Firstly, Spearman's Rank Order Correlation Coefficient ( $r$ ) were calculated between the average memory performance for all task difficulty conditions for lists of short and long words across word length and across young and older adults to confirm or disconfirm that task difficulty was equivalent across the word length conditions. Secondly, linear regressions were calculated using the word length advantage as a function task difficulty (defined as the proportion of baseline errors participants made when recalling lists of long words) to determine whether the word length advantage (i.e., the size of the recall difference between short and long words) increased with task difficulty (i.e., the proportion of errors made during recall). Young and older adults were also compared to determine whether there were any significant age differences in redintegrative processing. Finally, to examine the errors made during recall, in a similar manner to measuring the word length advantage, means, standard deviations, and 95% confidence intervals were calculated to compare the mean proportion of transposition and omission errors young and older adults produced across the eight different memory conditions. In addition, separate  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVAs were calculated to confirm whether the task difficulty variables influenced the proportion of transposition and omission errors produced during recall. Again, significant interactions (i.e., 2-way, 3-way, and 4-way) were followed up with tests of simple effects using the same feature within SPSS.

It is important to note there were significant age differences in the total years of education and score on the Mill Hill (Raven, 1989), as outlined in the Participants section for this study. (Bopp & Verhaeghen, 2007; Slessor et al., 2007). It was never the intention of this thesis to conduct covariate analyses. The Mill Hill was used to establish participants

were of a healthy ageing population. However, in the interests of completing a thorough data analysis, the same  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVAs that were calculated for this study were recalculated using years of education and the Mill Hill score as covariates. There were no differences in the main effects reported and therefore, the original mixed factorial ANOVAs without the covariates are reported. This applied to correct-in-position recall, item recall, order accuracy, transposition errors, and omission errors.

A complete analysis of the data was conducted for Study one, however, only the results pertinent to the hypotheses of this study are reported. All significant interactions are reported in Appendix C-2.1 and all non-significant interactions are reported in Appendix C-2.2.

### **Correct-in-position recall**

**Descriptive statistics.** Table 6.2 presents the mean proportions of short and long words recalled in correct serial position across young and older adults in the eight memory conditions.

Table 6.2

*Means With Confidence Intervals (CIs) and Standard Deviations for Proportions of Correct-in-Position Recall across Task Difficulty, Word Length, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Short			Long			Short			Long		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.91	.11	[.86, .96]	.83	.17	[.75, .91]	.85	.14	[.78, .91]	.64	.22	[.53, .74]
		1 sec	.90	.13	[.83, .96]	.84	.15	[.77, .90]	.80	.17	[.72, .88]	.79	.16	[.71, .86]
	Speech	2 sec	.86	.17	[.78, .94]	.79	.17	[.71, .87]	.84	.15	[.76, .91]	.63	.14	[.57, .70]
		1 sec	.92	.10	[.87, .97]	.80	.19	[.71, .89]	.91	.09	[.86, .95]	.68	.18	[.60, .77]
Delay	Silence	2 sec	.67	.21	[.57, .77]	.52	.21	[.42, .61]	.50	.19	[.41, .59]	.42	.20	[.32, .51]
		1 sec	.60	.20	[.51, .69]	.49	.20	[.40, .59]	.56	.22	[.45, .66]	.37	.21	[.27, .46]
	Speech	2 sec	.65	.20	[.55, .74]	.52	.22	[.41, .62]	.51	.21	[.41, .61]	.44	.18	[.35, .52]
		1 sec	.64	.19	[.55, .73]	.51	.18	[.42, .59]	.52	.22	[.42, .62]	.40	.17	[.32, .48]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Short = short words, Long = long words.



The general trend of the data in Table 6.2 appeared to support a word length advantage. Participants recalled a higher proportion of short words in serial position compared with long words and this word length advantage appeared consistent for young and older adults across the eight memory conditions. Overall, young adults seemed to recall a higher proportion of short and long words compared with older adults.

**Inferential statistics.** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for correct-in-position recall. The within-subjects variables were word length, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Significant main effects.** A significant main effect was found for word length, where participants recalled a significantly higher proportion of short words in serial position ( $M = .73$ ,  $SD = .12$ ) compared with long words ( $M = .60$ ,  $SD = .15$ ),  $F(1, 38) = 163.59$ ,  $MSE = 2.43$ ,  $p < .001$ ,  $\eta_p^2 = .81$ , *observed power* = 1.00. A significant main effect was found for recall interval, where participants recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .81$ ,  $SD = .12$ ) compared with after a delayed interval ( $M = .52$ ,  $SD = .16$ ),  $F(1, 38) = 342.30$ ,  $MSE = 13.60$ ,  $p < .001$ ,  $\eta_p^2 = .90$ , *observed power* = 1.00. Finally, there were significant age differences, where young adults recalled a significantly higher proportion of words in serial position ( $M = .71$ ,  $SD = .13$ ) compared with older adults ( $M = .61$ ,  $SD = .12$ ),  $F(1, 38) = 6.56$ ,  $MSE = 1.58$ ,  $p = .015$ ,  $\eta_p^2 = .15$ , *observed power* = .70.

**Item recall**

**Descriptive statistics.** Table 6.3 presents the mean proportions of short and long words young and older adults recalled in the eight memory conditions.

Table 6.3  
*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Item Recall across Task Difficulty, Word Length, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Short			Long			Short			Long		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.94	.08	[.90, .98]	.88	.13	[.82, .93]	.89	.11	[.84, .94]	.78	.16	[.71, .85]
		1 sec	.93	.10	[.88, .98]	.88	.13	[.82, .94]	.88	.13	[.81, .94]	.88	.10	[.83, .92]
	Speech	2 sec	.90	.12	[.84, .96]	.87	.11	[.81, .92]	.89	.12	[.83, .94]	.76	.14	[.70, .83]
		1 sec	.92	.10	[.87, .97]	.87	.15	[.80, .93]	.91	.09	[.86, .95]	.80	.11	[.75, .85]
Delay	Silence	2 sec	.76	.16	[.69, .84]	.65	.18	[.56, .73]	.66	.14	[.60, .73]	.59	.12	[.53, .64]
		1 sec	.71	.17	[.63, .79]	.59	.17	[.51, .67]	.70	.16	[.62, .77]	.51	.19	[.41, .60]
	Speech	2 sec	.75	.14	[.68, .81]	.65	.17	[.57, .73]	.63	.18	[.55, .71]	.57	.15	[.50, .64]
		1 sec	.72	.15	[.65, .79]	.64	.17	[.56, .72]	.63	.18	[.54, .71]	.54	.15	[.47, .61]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Short = short words, Long = long words.

As evident from Table 6.3, irrespective of serial position, participants appeared to recall a higher proportion of short words compared with long words. This pattern of memory performance was consistent for young and older adults. As well, young adults recalled a higher proportion of short and long words compared with older adults.

**Inferential statistics.** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for item recall. The within-subjects variables were word length, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Significant main effects.** A significant main effect for word length was evident, where participants recalled a significantly higher proportion of short words ( $M = .80$ ,  $SD = .09$ ) than long words ( $M = .71$ ,  $SD = .11$ ),  $F(1, 38) = 156.76$ ,  $MSE = 1.17$ ,  $p < .001$ ,  $\eta_p^2 = .81$ , *observed power* = 1.00. A significant main effect for recall interval emerged, where participants recalled a significantly higher proportion of words during immediate conditions ( $M = .87$ ,  $SD = .08$ ) compared with after a delayed interval ( $M = .64$ ,  $SD = .12$ ),  $F(1, 38) = 295.97$ ,  $MSE = 8.33$ ,  $p < .001$ ,  $\eta_p^2 = .89$ , *observed power* = 1.00. Finally, the main effect for age was significant, where young adults recalled a significantly higher proportion of words ( $M = .79$ ,  $SD = .10$ ) compared with older adults ( $M = .72$ ,  $SD = .08$ ),  $F(1, 38) = 5.02$ ,  $MSE = 0.68$ ,  $p = .031$ ,  $\eta_p^2 = .12$ , *observed power* = .59.

### Order accuracy

**Descriptive statistics.** Table 6.4 presents the mean proportions for order accuracy of short and long words for young and older adults across the eight memory conditions.

Table 6.4

*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Order Accuracy across Task Difficulty, Word Length, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Short			Long			Short			Long		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.97	.06	[.94, .99]	.94	.10	[.89, .99]	.95	.08	[.91, .99]	.81	.20	[.72, .90]
		1 sec	.96	.07	[.93, 1 ]	.95	.08	[.92, .99]	.91	.11	[.86, .96]	.89	.12	[.84, .95]
	Speech	2 sec	.94	.10	[.90, .99]	.91	.11	[.86, .96]	.94	.09	[.90, .98]	.83	.11	[.78, .88]
		1 sec	1	.00	[1, 1]	.92	.09	[.87, .96]	1	.00	[1, 1]	.85	.15	[.78, .92]
Delay	Silence	2 sec	.86	.16	[.79, .94]	.78	.18	[.70, .87]	.75	.18	[.67, .84]	.70	.27	[.57, .83]
		1 sec	.83	.12	[.77, .89]	.82	.18	[.73, .90]	.78	.18	[.69, .86]	.70	.24	[.59, .81]
	Speech	2 sec	.85	.14	[.78, .91]	.76	.21	[.66, .86]	.79	.16	[.72, .87]	.74	.23	[.63, .85]
		1 sec	.88	.12	[.82, .94]	.79	.15	[.72, .86]	.81	.17	[.73, .88]	.72	.18	[.64, .80]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Short = short words, Long = long words.

At a mean level, Table 6.4 shows that the probability of recalling a word from the trial in serial position, given the participant initially recalled the word, was higher for short words than for long words. This word length trend was consistent for young and older adults across the eight memory conditions. Regarding age differences, order accuracy was higher for young adults compared with older adults.

**Inferential statistics.** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for order accuracy. The within-subjects variables were word length, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Significant main effects.** A significant main effect was found for word length, where order accuracy was significantly higher for short words ( $M = .89$ ,  $SD = .07$ ) compared with long words ( $M = .82$ ,  $SD = .12$ ),  $F(1, 38) = 31.10$ ,  $MSE = 0.77$ ,  $p < .001$ ,  $\eta_p^2 = .45$ , *observed power* = 1.00. A significant main effect was evident for recall interval, demonstrating a significantly higher order accuracy for words during immediate conditions ( $M = .92$ ,  $SD = .06$ ) compared with after a delayed interval ( $M = .78$ ,  $SD = .12$ ),  $F(1, 38) = 121.43$ ,  $MSE = 3.08$ ,  $p < .001$ ,  $\eta_p^2 = .76$ , *observed power* = 1.00. Finally, there was a significant main effect of age, where order accuracy was significantly higher for young adults ( $M = .88$ ,  $SD = .07$ ) compared with older adults ( $M = .82$ ,  $SD = .10$ ),  $F(1, 38) = 5.36$ ,  $MSE = 0.04$ ,  $p = .026$ ,  $\eta_p^2 = .12$ , *observed power* = .62.

## **Transposition errors**

**Descriptive statistics.** Tables 6.5 summarises the mean proportion of transposition errors young and older adults produced when recalling short and long words across the eight memory conditions.

Table 6.5

*Means with Confidence Intervals (CIs) and Standard Deviations for Proportions of Transposition Errors across Task Difficulty, Word Length, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Short			Long			Short			Long		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.03	.05	[.00, .06]	.05	.07	[.02, .08]	.04	.06	[.01, .06]	.12	.13	[.06, .18]
		1 sec	.03	.05	[.00, .06]	.05	.06	[.02, .07]	.05	.07	[.02, .09]	.07	.08	[.03, .11]
	Speech	2 sec	.03	.06	[.00, .06]	.04	.05	[.02, .06]	.04	.06	[.01, .07]	.10	.08	[.06, .14]
		1 sec	.05	.07	[.02, .08]	.06	.07	[.03, .09]	.08	.07	[.04, .11]	.09	.09	[.05, .14]
Delay	Silence	2 sec	.07	.09	[.03, .11]	.10	.07	[.06, .13]	.13	.10	[.08, .17]	.12	.10	[.07, .16]
		1 sec	.07	.07	[.04, .10]	.06	.05	[.03, .08]	.10	.08	[.06, .13]	.08	.06	[.05, .11]
	Speech	2 sec	.08	.07	[.04, .11]	.09	.08	[.05, .12]	.08	.07	[.04, .11]	.08	.08	[.04, .11]
		1 sec	.06	.08	[.02, .09]	.09	.07	[.06, .12]	.07	.07	[.04, .10]	.08	.07	[.05, .12]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Short = short words, Long = long words.



It was evident from Table 6.5 that at a mean level, the proportion of transposition errors participants produced during recall appeared to increase with task difficulty. Specifically, participants produced a higher proportion of transpositions errors when recalling long words than short words. Examining performance across age, across six of the eight memory conditions, older adults seemed to have produced a higher proportion of transposition errors during recall compared with young adults.

**Inferential statistics.** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for the transposition errors produced during recall. The within-subjects variables were word length, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Significant main effects.** A significant main effect for word length emerged, where participants produced a significantly higher proportion of transposition errors when recalling long words ( $M = .08$ ,  $SD = .04$ ) than short words ( $M = .06$ ,  $SD = .04$ ),  $F(1, 38) = 12.87$ ,  $MSE = 0.05$ ,  $p = .001$ ,  $\eta_p^2 = .25$ , *observed power* = .94. A significant main effect for recall interval was evident, where participants produced a significantly higher proportion of transposition errors when recall was required after a delayed interval ( $M = .08$ ,  $SD = .04$ ) compared with immediate conditions ( $M = .06$ ,  $SD = .05$ ),  $F(1, 38) = 15.07$ ,  $MSE = 0.10$ ,  $p < .001$ ,  $\eta_p^2 = .28$ , *observed power* = .97. Finally, a significant main effect for age emerged, where older adults ( $M = .08$ ,  $SD = .04$ ) produced a significantly higher proportion of transposition errors compared with young adults ( $M = .06$ ,  $SD = .03$ ),  $F(1, 38) = 4.14$ ,  $MSE = 0.08$ ,  $p = .049$ ,  $\eta_p^2 = .10$ , *observed power* = .51.

**Omission errors**

**Descriptive statistics.** Table 6.6 summarises the mean proportion of short and long words that young and older adults omitted during recall across the eight memory conditions.

Table 6.6

*Means With Confidence Intervals (CIs) and Standard Deviations for Proportion of Omission Errors across Task Difficulty, Word Length, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Short			Long			Short			Long		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.04	.05	[.01, .06]	.09	.08	[.05, .13]	.09	.11	[.04, .14]	.18	.14	[.11, .24]
		1 sec	.06	.10	[.01, .10]	.08	.08	[.04, .12]	.08	.11	[.03, .13]	.09	.07	[.06, .13]
	Speech	2 sec	.06	.07	[.03, .09]	.11	.11	[.06, .16]	.09	.11	[.03, .14]	.20	.13	[.13, .26]
		1 sec	.06	.08	[.02, .09]	.11	.12	[.05, .16]	.08	.09	[.03, .12]	.15	.10	[.10, .19]
Delay	Silence	2 sec	.17	.13	[.11, .23]	.28	.15	[.21, .35]	.28	.16	[.20, .35]	.34	.13	[.28, .40]
		1 sec	.21	.15	[.14, .28]	.30	.16	[.22, .37]	.23	.15	[.16, .29]	.42	.19	[.33, .50]
	Speech	2 sec	.20	.12	[.14, .25]	.28	.15	[.21, .35]	.30	.14	[.23, .36]	.34	.13	[.28, .40]
		1 sec	.21	.13	[.14, .27]	.29	.15	[.22, .35]	.28	.18	[.20, .37]	.39	.16	[.31, .46]

*Note.* *n* = number of participants, Recall interval = recall interval, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Short = short words, Long = long words.

As can be seen in Table 6.6, during recall, participants appeared to have omitted a higher proportion of long words than short words. Regarding age differences, older adults omitted a higher proportion short and long words during recall across all memory conditions compared with young adults.

**Inferential statistics.** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for the TBR words participants omitted during recall. The within-subject variables were word length, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Significant main effects.** A significant main effect was evident for word length, where participants omitted a significantly higher proportion of long words ( $M = .23$ ,  $SD = .10$ ) during recall than short words ( $M = .15$ ,  $SD = .08$ ),  $F(1, 38) = 128.99$ ,  $MSE = 0.93$ ,  $p < .001$ ,  $\eta_p^2 = .77$ , *observed power* = 1.00. The main effect for recall interval was also significant, where participants omitted a significantly higher proportion of words when recall was required after a delayed interval ( $M = .28$ ,  $SD = .12$ ) compared with immediate conditions ( $M = .10$ ,  $SD = .07$ ),  $F(1, 38) = 189.26$ ,  $MSE = 5.43$ ,  $p < .001$ ,  $\eta_p^2 = .83$ , *observed power* = .83. Finally, there was a significant main effect for age where older adults ( $M = .22$ ,  $SD = .08$ ) omitted a significantly higher proportion of words during recall compared with young adults ( $M = .16$ ,  $SD = .08$ ),  $F(1, 38) = 5.26$ ,  $MSE = 0.60$ ,  $p = .026$ ,  $\eta_p^2 = .12$ , *observed power* = .62.

### **Task Difficulty and redintegration**

**Task difficulty.** The  $2 \times 2 \times 2$  (recall interval, study condition, and presentation rate) design produced eight estimates of task difficulty. Spearman's Rank Order Correlation

Coefficients ( $r$ ) were calculated between the average memory performance for all task difficulty conditions for lists of short and long words across word length and across young and older adults. With the exception of the easiest and difficult task conditions, there were no firm predictions regarding the remaining conditions. The remaining rankings of task difficulty conditions were created as a result of the findings. Table 6.7 presents the rank order correlations for the eight task difficulty levels across word length (short, long) and across age (young, older) for correct-in-position scoring, item scoring, and order scoring.

Table 6.7

*Spearman's Rank Order Correlations for Task Difficulty as Function of Word Length and Age*

Age	Word Length	Young ( <i>n</i> = 20)	Older ( <i>n</i> = 20)
		Short	Long
Correct-in-Position Scoring			
Young	Short	1.00	
	Long	.90	1.00
Older	Short	.74	.61
	Long	.91	.97
Item Scoring			
Young	Short	1.00	
	Long	.96	1.00
Older	Short	.74	.68
	Long	.93	.92
Order Scoring			
Young	Short	1.00	
	Long	.76	1.00
Older	Short	.91	.71
	Long	.76	.76

*Note.* *n* = number of participants.

The rank order correlations in Table 6.7 were generated to demonstrate that the task difficulty levels (ranked from easiest to hardest) were comparable for the short word lists and the long word lists and for young adults and older adults. For correct-in-position scoring, the ranking between the easy and hard difficulty conditions for short words and long words appears to be stronger for young adults ( $r = .90$ ) than older adults ( $r = .64$ ). This same pattern emerged for item scoring, where the correlation was higher for young adults ( $r = .97$ ) compared with older adults ( $r = .71$ ). However, this trend was reversed for order scoring where the correlation was higher for older adults ( $r = .81$ ) than for young adults ( $r = .76$ ). In addition, there appears to be more variability when comparing the correlations between young adults and older adults across correct-in-position scoring and item scoring for long words than for short words. Yet this trend was reversed for order scoring, where more variability was

evident for the ranking of task difficulty for short words than for long words. Therefore, while the rank order correlations appeared to be equivalent across item similarity and age for Neale and Tehan (2007), there appeared to be more variability across word length and age for this study.

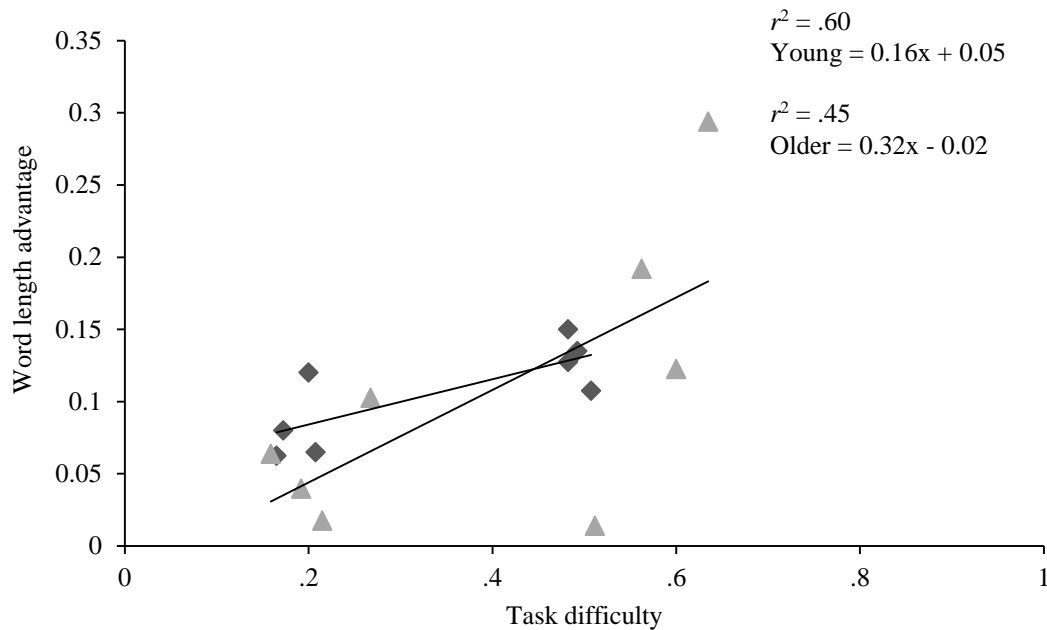
**Redintegration.** Redintegration effects are displayed in the following graphs using the word length advantage as a function of task difficulty for correct-in-position recall, item recall, and order accuracy. The word length advantage (y-axis) is represented by the size of the recall difference between the proportion of short and long words participants recalled in each of the eight memory conditions. Task difficulty (x-axis) is represented by the proportion of transposition and omission errors participants made when recalling lists of long words across the eight memory conditions. The zero point on the x-axis indicates the participant did not produce any errors during recall for lists of long words. However, if for example, the participant scored .4, this means that on average, 40% of the participant's performance on the list of long words were either transposition or omission errors. It was assumed that the short-term phonological representations for long words are more difficult to reconstruct using long-term knowledge because they contain a higher number of segments to reassemble in order to identify the phonological trace as representing the TBR word for later recall. This is consistent with Neale and Tehan's (2007) rationale and the predictions of redintegration (Schweickert, 1993).

Redintegration outcomes are represented by the relationship between the size of the word length advantage (i.e., the size of the recall difference between short and long words) and task difficulty (i.e., the proportion of errors produced when recalling lists of long words).

To explain, a positive relationship is represented by an increase in the size of the word length advantage as task difficulty increased. That is, as the memory task became more difficult, the recall difference between short and long words increased, where participants recall a higher proportion of short words than long words. A negative relationship is represented by a decrease in the size of the word length advantage as task difficulty increased. That is, as task difficulty increased, the size of the recall difference between short and long words decreased. Essentially, there is no word length advantage during short-term recall and participants recalled a comparable proportion of short and long words. Redintegration outcomes were analysed at the group mean level to compare the recall performance of young adults and older adults across the eight different memory conditions that increased in difficulty.

***Correct-in-position recall.*** Figure 6.2 presents the redintegration outcomes using the group mean levels of performance across the eight memory conditions for young adults and older adults.





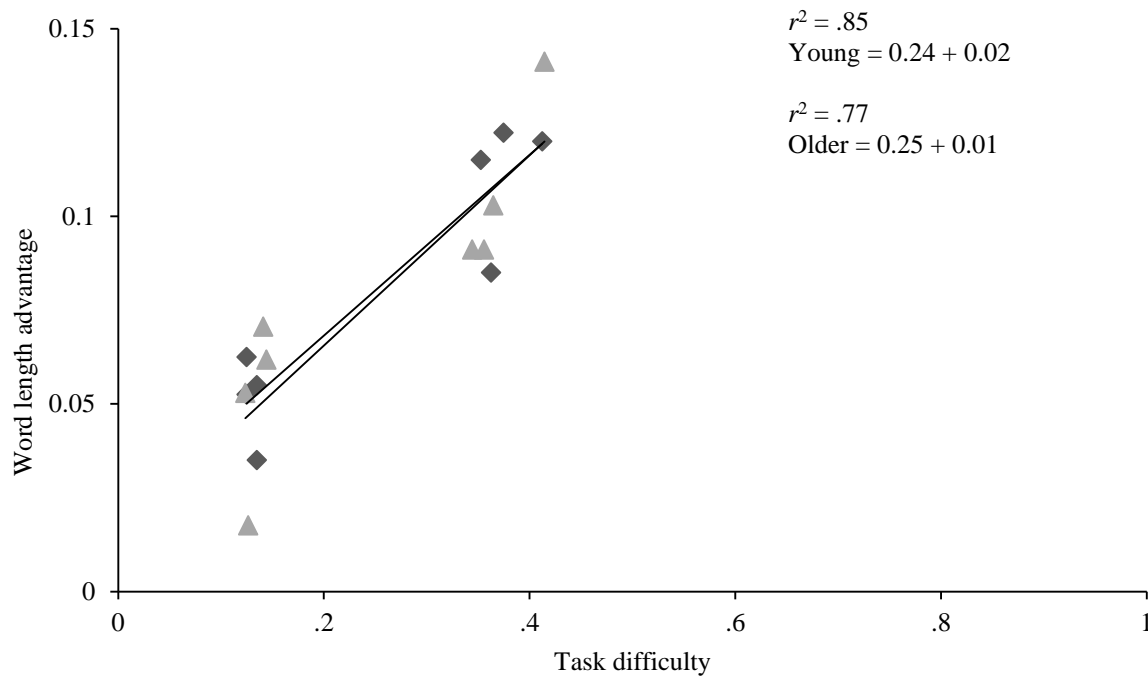
*Figure 6.2.* Word length advantage as a function of task difficulty for correct-in-position recall for young adults (diamonds) and older adults (triangles)

It was evident from Figure 6.2 that there was a moderately strong relationship for young ( $r^2 = .60$ ) and older ( $r^2 = .45$ ) adults, where the word length advantage increased with task difficulty. These results indicate that word length assisted with recalling the TBR words in their correct serial order. Further regression analyses revealed there was no significant difference between the slopes of the older ( $b = -0.32$ ) and young adults ( $b = 0.16$ ),  $t(12) = -0.98$ ,  $p = .556$ . There was also no significant difference between the intercepts of the older ( $c = -0.02$ ) and young adults ( $c = 0.05$ ),  $t(12) = 1.15$ ,  $p = .215$ . These results indicated that the processes underlying redintegration were comparable for young and older adults.

Additional analyses were calculated for redintegration outcomes at the sample level (i.e., young and older adults, respectively) to demonstrate their respective use of redintegration and are located in Appendix C-2.3. Additional analyses were also calculated at the individual level

(i.e., each participant in the young and older adult samples, respectively) to demonstrate how each participant engaged in redintegration during the experimental task. These analyses are located in Appendices C-2.4 and C-2.5.

**Item recall.** Figure 6.3 presents the redintegration outcomes using the group mean levels of performance for item recall across the eight memory conditions for young and older adults.



*Figure 6.3.* Word length advantage as a function of task difficulty for item recall for young adults (diamonds) and older adults (triangles)

For item recall, there was evidence of a word length advantage for young and older adults. Figure 6.3 shows there was a strong relationship for the young ( $r^2 = .85$ ) and older ( $r^2 = .77$ ) adults, where the length of the TBR word facilitated item recall. Further regression analyses revealed there was no significant difference between the slopes for the older ( $b = 0.25$ ) and young adults ( $b = 0.24$ ),  $t(12) = -0.01$ ,  $p = .954$ . There was also no significant

difference between the intercepts for the older ( $c = 0.01$ ) and young adults ( $c = 0.02$ ),  $t(12) = 0.01$ ,  $p = .898$ . These results indicated that young and older adults utilised the same redintegrative processing for short-term recall. Redintegration outcomes at the sample level are presented in Appendix C-2.6. Redintegration outcomes at the individual level are presented in Appendices C-2.7 and C-2.8.

**Order accuracy.** Figure 6.4 presents the redintegration outcomes for order accuracy using the group mean levels of performance across the eight memory conditions for young and older adults.

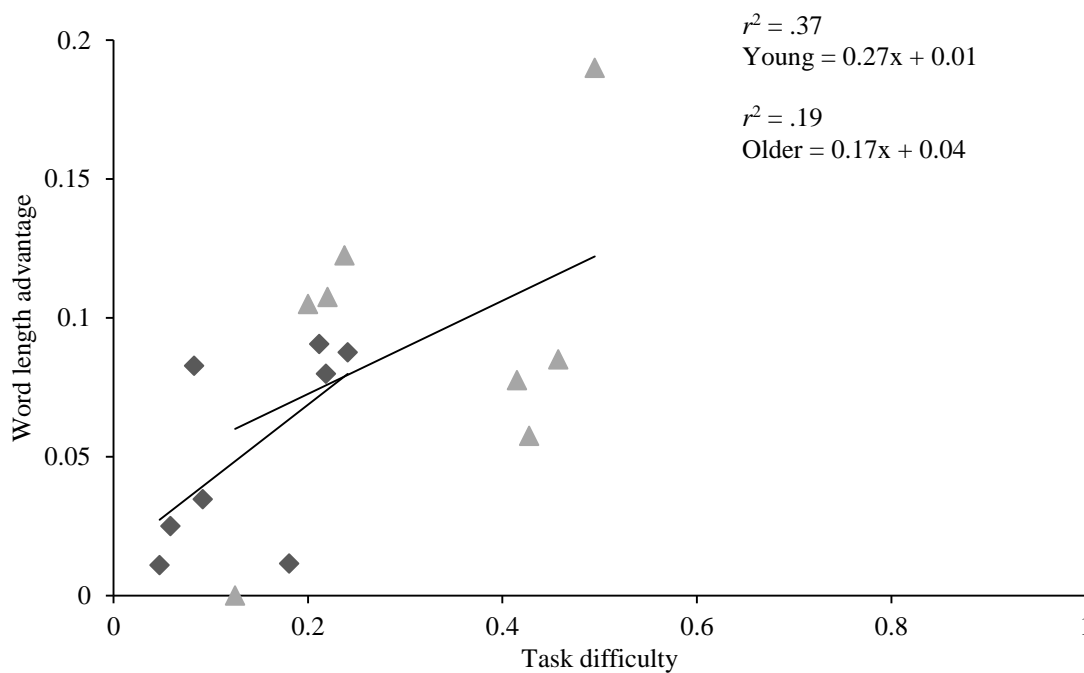


Figure 6.4. Word length advantage as a function of task difficulty for order accuracy for young adults (diamonds) and older adults (triangles)

As demonstrated in Figure 6.4, there was a moderately strong relationship between the word length advantage and task difficulty for the young adults ( $r^2 = .37$ ). However, there was a weak relationship between the word length advantage and task difficulty for older adults ( $r^2$

= .04). Word length increased the probability of young and older adults recalling the TBR word in its correct serial position. Further regression analyses revealed there was no significant difference between the slopes of the older ( $b = 0.21$ ) and young adults ( $b = 0.27$ ),  $t(12) = 1.68, p = .255$ . There was also no significant difference between the intercepts of the older ( $c = 0.04$ ) and young adults ( $c = 0.01$ ),  $t(12) = 2.65, p = .506$ , indicating redintegration was comparable for young and older adults. Redintegration outcomes at the sample level are presented in Appendix C-2.9. Redintegration outcomes at the individual level are presented in Appendices C-2.10 and C-2.11.

## **Discussion**

### **Study overview**

The primary aim of this study was to continue examining the redintegration process by measuring redintegration using the WLE through Schweickert's (1993) Multinomial Processing Tree Model of Redintegration. Researchers have identified that the WLE operates at the item level, with the WLE resulting from differences in how individuals encode short and long words in verbal STM and utilise their long-term knowledge to assist with later output (Baker & Tehan, 2008; Caplan et al., 1992; Hendry & Tehan, 2005; Hulme et al., 2004; Neath & Nairne, 1995). Given that the redintegration framework closely aligns with the item-based framework and the interaction that occurs between long-term knowledge and short-term recall, it was important to examine whether these word length advantages extend to redintegrative processing.

This study also aimed to continue examining age differences in the redintegration framework. To date, Neale and Tehan (2007) are the only researchers who have examined age differences in redintegration, finding that redintegration is invariant to age. It was important to examine whether measuring redintegration using the WLE may reveal new insight into different processes that may be underlying redintegration or whether redintegration remains consistent across age, irrespective of its measurement. Given the importance of the relationship between ageing and redintegration in this thesis, this relationship also warranted further investigation.

### **The word length effect and redintegration**

This study has demonstrated the utility of the redintegration framework by defining redintegration using the WLE (Baddeley et al., 1975) through Schweickert's (1993) Multinomial Processing Tree Model of Redintegration. The manipulations of task difficulty developed for this thesis gradually interfered with encoding across the task conditions, such that individuals became more reliant on redintegrative processing to assist with retrieving the TBR items for later short-term recall. Redintegration effects in this study were in the form of the word length advantage, where the positive correlation between the word length advantage and task difficulty for correct-in-position recall and item recall revealed that participants recalled an increasingly higher proportion of short words compared with long words. Specifically, during the easier task conditions, the size of the recall difference between short and long words was relatively small. In accordance with the redintegration literature and Schweickert's redintegration model, as there was little disruption from the manipulation of task difficulty to interfere with encoding the TBR items into verbal STM, the short-term

phonological memory traces for the TBR items remained relatively intact. At recall, individuals did not have to rely on redintegration to facilitate recall because they could retrieve the TBR items directly from verbal STM. As task difficulty increased, redintegration effects emerged in the form of the word length advantage, where the size of the recall difference between short and long words increased in favour of short words. The increasing level of interference produced from the task difficulty manipulation compromised the fidelity of the short-term phonological memory traces for the TBR words being encoded into verbal STM. To retrieve the TBR words for later output, depending on the amount of damage sustained to the short-term phonological memory trace, individuals called upon redintegration to facilitate the retrieval process. The results of this study support the notion that individuals used their long-term lexical and phonological knowledge to help reconstruct the degraded short-term phonological memory traces for those TBR words and the available information remaining in the short-term phonological memory trace. Moreover, individuals enhanced the search process by cueing the search for long-term information only to those words that contained the specified lexical characteristics (i.e., length, syllables, and phonemes) in the TBR word. As short words contained fewer segments to reconstruct compared with long words, this further enhanced the redintegration process and lead to their subsequent recall advantage over long words. It can be surmised with confidence that the WLE has been substantiated as a redintegration variable and has provided increasing support for individuals engaging in redintegrative processing to facilitate verbal STM performance.

The findings from this study support the notion that a cueing effect may be occurring when redintegration is operating in verbal STM. The increasing size of the word length

advantage indicates that individuals used the lexical characteristics of the TBR word such as the length of the word (i.e., number of syllables), letters, and phonemes as additional retrieval cues to guide the search to a specific section of LTM and locate potential recall candidates to match with the remaining information available in verbal STM. This cueing effect is consistent with other redintegration studies that advocate for characteristics of the TBR items enhancing their subsequent recall performance. Neale and Tehan (2007) found that individuals used the similarity shared between the TBR words (i.e., semantic or phonological) to guide the redintegration process and limit the search only for information that was either semantically or phonologically similar or dissimilar to the TBR word. These additional retrieval cues increased the likelihood of redintegrating the degraded short-term phonological memory trace of those items for later output. Poirier and Saint-Aubin (1995) also confirmed this cueing notion in their study, where knowing the TBR items were from a specific category delimited the number of potential recall candidates and enhanced the probability of recalling the correct items at output. Together, these findings demonstrate that the cueing effect extends any property of the TBR item, be it lexical, phonological, or semantic in form, which facilitates the redintegration process and benefits verbal STM performance.

At a broader level, the findings from this study indicate that an important interaction exists between pre-existing knowledge in LTM and the temporarily stored information held in verbal STM. The WLE emerged in this study because of how individuals encoded the TBR words across the task conditions that varied in their level of inherent interference that subsequently affected their capacity to retrieve those same items from verbal STM for later output. These findings are consistent with other accounts of the WLE that advocate for this

important relationship between verbal STM and LTM. Neath and Nairne (1995) found using the Feature Model of Immediate Memory that individuals experienced difficulties with retrieving the phonological representations of long words from secondary memory because they were required to reassemble and match a greater number of segments in order to recall the TBR word. Neath and Nairne further purported that because short words contain fewer segments, there is a greater likelihood of reassembling those segments and matching the correct features that are available in primary memory with those that have been retrieved from secondary memory. Caplan et al. (1992) along with Hulme et al. (2004) also established that individuals engage in a level of phonological planning to maintain the phonological representations of the TBR words in a retrievable state in verbal STM so they can locate the correct representations that have been activated in LTM to recall them for later output. A feedback process occurs between the information in verbal STM and LTM that allowed the individual to recall the TBR items. The findings from this study along with previous research confirm that the WLE operates at the item level, and that individuals utilise their long-term lexical and phonological knowledge to support short-term recall performance.

Together, this study has firmly established that redintegration operates in verbal STM through its measurement using the WLE (Baddeley et al., 1975). As task difficulty increased, individuals recalled an increasingly higher proportion of short words than long words. Importantly, these findings continue to suggest that individuals utilise different cues (i.e., the lexical characteristics of the TBR words) to enhance the redintegration process and facilitate recall. These findings also continue substantiate the notion that an important interaction exists between long-term knowledge and verbal STM (Brown et al., 2000; Melton, 1963; Neath &



Nairne, 1995) and this interaction extends to items based on their lexical characteristics. In other words, irrespective of the lexical properties of the TBR items, a spreading activation occurred in LTM that continued to guide the search for long-term information and increase the likelihood of reintegrating the short-term phonological memory traces for the TBR items for later output.

### **Age differences, the word length effect, and redintegration**

This study has also made a unique contribution to the ageing and redintegration literature by continuing to explicate the mechanisms underpinning redintegration across the age spectrum. Young adults recalled a significantly higher proportion of short and long words compared with older adults and this recall difference was consistent across the eight memory conditions for correct-in-position recall, item recall, and order accuracy. At the redintegration level, young and older adults did not significantly differ in their capacity to reintegrate, where they relied on the length of the word to support verbal STM performance during the difficult task conditions. Whilst all participants demonstrated a word length advantage, young adults recalled a significantly higher proportion of short and long words compared with older adults across correct-in-position recall, item recall, and order accuracy. These findings are consistent with previous findings that young adults outperform older adults in verbal STM tasks measuring the WLE (Baker et al., 2012; Belleville et al., 1996; Peters et al., 2007) and appear to suggest that older adults experience considerable difficulty with managing the cognitive demands of the experimental task, which ultimately affects their verbal STM performance. However, the examination of age differences at the redintegration level revealed that young and older adults did not significantly differ in reintegrative processing for correct-

in-position recall, item recall, and order accuracy. This is an important finding, as this study has established that redintegration is invariant to age, and is consistent with Neale and Tehan's (2007) study that young and older adults utilise the same redintegrative processing to facilitate verbal STM performance. One suggestion for this finding is that there could potentially be differences when encoding information that is based purely on lexical characteristics. While retrieval processes are consistent across age, the respective performance of young and older adults in this study indicates that as the memory task became difficult, encoding the item information and order information became difficult. The relationship between the word length advantage and task difficulty appears to suggest that due to the cognitive demands of the experimental task, particularly in the difficult conditions where interference was at its greatest, participants concentrated on encoding and retaining the TBR item in verbal STM at the expense of encoding the serial position of that same TBR word. Consequently, recalling the TBR words at the item level reflected the robust WLE but they experienced considerable difficulty with recalling the TBR words in their correct serial position, irrespective of word length.

It is reasonable to believe that the increased interference from the measure of task difficulty affected verbal STM performance in two ways. Firstly, it affected the resources available to encode the TBR word and output that same TBR item in its correct serial position. Secondly, the fidelity of the memory traces was compromised from the increased interference inherent in the task conditions. These findings are consistent with the findings Baker et al. (2012) observed in their research, where they attributed the only significant age difference in

their study to difficulties with managing the demands of the cognitive-based task. Thus, the processes underlying the WLE are consistent across age.

In conclusion, the respective performances of young adults and older adults in this study have substantiated that redintegration is invariant to age. Although age differences were found at the short-term recall level, when redintegration was required to facilitate verbal STM performance, young and older adults alike engaged in the same redintegrative processing. Individuals utilised their long-term lexical knowledge to retrieve the correct information that would assist in reconstructing the degraded short-term phonological memory traces of the TBR words for later output.

### **Recall errors and redintegration in verbal STM**

Of secondary interest in this study were the transposition and omission errors participants produced during recall in the experimental task. From the redintegration perspective, individuals produce errors during recall for two reasons. Firstly, the short-term phonological memory traces for the TBR items were degraded to the extent that they have difficulty interpreting the traces based on the available information that remained in verbal STM (Neale & Tehan, 2007; Schweickert, 1993; Thorn et al., 2004). Secondly, the short-term phonological memory traces for the TBR items were damaged to the point there was no more useable information to reconstruct the short-term phonological memory trace for later output (Neale & Tehan, 2007; Schweickert, 1993; Thorn et al., 2004). In this study, participants produced a significantly higher proportion of transposition and omission errors for lists of long words than lists of short words. As well, older adults produced a significantly higher proportion of transposition and omission errors during recall than young adults. The

prevalence of errors during recall indicated there was an increased level of interference during encoding that hindered attempts at reintegrating the damaged short-term phonological memory trace for the TBR items, rendering reintegration unsuccessful (Neale & Tehan, 2007; Schweickert, 1993; Thorn et al., 2004). These findings have important implications for understanding the processes underlying reintegration occurring in verbal STM.

**Transposition and omission errors in reintegration.** The reintegration literature purports that different cognitive processes are involved when transposition and omission errors emerge during short-term recall. Transposition errors are primarily associated with order recall and occur because individuals experience problems with discriminating between the short-term phonological memory traces of two TBR items (Saint-Aubin & Poirier, 2000). Older adults produced a significantly higher proportion of transposition errors during short-term recall compared with young adults. This finding suggests that as task conditions became difficult, older adults, to a greater extent than young adults, had difficulty with encoding the short and long words into verbal STM. They had particular difficulty with the serial position of the TBR word, due to the increasing interference produced by the task difficulty manipulation. Given there was sufficient degradation to the short-term phonological memory trace, it appears that there was a greater tendency for transposition errors to occur for long words as they contain more segments that required reconstruction in comparison to short words that contain fewer segments, reducing the likelihood of transposing those items at output. With respect to age-related performance, older adults had a greater propensity than young adults did to confuse the serial position of the two TBR items at output. This finding appears to suggest that, consistent with their reintegrative processing at the correct-in-

position level, older adults primarily focused on producing the TBR words at recall that encoding the corresponding order information due to the cognitively demanding nature of the experimental task. Furthermore, given the TBR items in this study were selected based on their lexical properties, there was no form of environmental or contextual support that could have supported encoding and create a meaningful episodic association among the TBR items to facilitate their later retrieval.

Omission errors are primarily associated with item recall and they occur when individuals have difficulty with reconstructing the missing features of the degraded short-term phonological memory trace for the TBR item (Saint-Aubin & Poirier, 2000). The extent that participants omit the TBR items at recall depends on the amount of information remaining in the short-term phonological memory trace that can assist with searching for long-term information to reconstruct the short-term phonological memory trace (Saint-Aubin & Poirier, 2000). The higher proportion of omission errors in this study suggests that the unique manipulation of task difficulty produced a substantial level of interference when encoding the short and long words into verbal STM. When individuals called upon redintegration to assist with retrieving the TBR items from verbal STM for subsequent output, there was sufficient degradation to those traces that redintegration attempts were unsuccessful. Specifically, as the short-term phonological memory traces of the long words contain a greater number of segments compared with short words, they were presumably more difficult to redintegrate as there contained more missing segments compared with short words that contain fewer segments. Moreover, the TBR words for this study were selected purely on their lexical characteristics and as such, there were no other forms of environmental support or contextual

support to facilitate the redintegration process for long as well as short words. As a result, this lead to subsequent difficulties at recall. More importantly, in relation to age-related performance, older adults also produced a significantly higher proportion of omission errors during recall compared with young adults, suggesting that older adults were more susceptible to the increasing interference during the experimental task. As the cognitive demands of the task increased, older adults had considerable difficulty locating the long-term phonological information to support reconstruction of the degraded short-term phonological memory traces. This is in comparison to young adults who, although susceptible to the interference during the experimental task, were more efficient and effective at redintegrating the degraded short-term phonological memory traces of the TBR words in order to retrieve them for later short-term recall. Overall, the prevalence of transposition and omission errors during short-term recall is indicative of difficulties experienced with encoding and retrieval when recalling list of short and long words.

## **Conclusion**

To conclude, this study has established that redintegration occurs in verbal STM, as measured using the robust WLE (Baddeley et al., 1975) in accordance with Schweickert's (1993) Multinomial Processing Tree Model of Redintegration. As task difficulty increased, redintegration effects became evident during short-term recall, where the size of the recall difference between short words and long words increased in favour of short words. The redintegration process was more efficient for short words because they contained fewer elements that require reconstruction using their long-term lexical knowledge to retrieve the degraded short-term phonological memory trace for later short-term recall. This is in

comparison with long words that contain more elements to reconstruct, decreasing the probability of rebuilding the short-term phonological memory trace to produce the TBR item and producing an error at recall. Secondly, this study found that although young adults predictably outperformed older adults during short-term recall, the groups did not significantly differ in their capacity to reintegrate when short-term recall was problematic, particularly during the difficult task conditions, consistent with Neale and Tehan's (2007) study where reintegrative processing was found to be comparable across the age spectrum. Older adults did demonstrate a greater reliance on reintegrative processing compared with young adults to facilitate short-term recall, as evident by the greater size of the WLE relative to young adults. These observations are consistent with the ageing literature that indicates older adults experience greater difficulty at managing the cognitive demands of the experimental task. Older adults focused on encoding the item information pertaining to the TBR word that it was at the expense of encoding the corresponding order information in order to recall the TBR item in its correct serial position. Finally, participants produced extra-list intrusions during short-term recall for lists of short and long words. The prevalence of these intrusions indicate that individuals relied on some form of semantic association to encode the short and long words into verbal STM that induced spreading activation of the corresponding representations in LTM. The reliance on the semantic associations was so great that individuals erroneously recalled the semantic associates instead of the originally presented TBR item. This study has provided substantial evidence that a reciprocal and symbiotic relationship exists between verbal STM and LTM, where there is an increased reliance on long-term lexical knowledge to aid verbal STM performance. Individuals can cue the search for this long-term information by using the lexical characteristics of the TBR word to enhance the likelihood of reintegrating

the degraded short-term phonological memory trace of the TBR word in order to retrieve it for later output. However, there is also increasing support for the notion that individuals call upon others forms of long-term knowledge, for example semantic knowledge, to enhance the redintegration process and facilitate verbal STM performance. Therefore, to examine this proposition, this thesis continued examining redintegration in Chapter Seven using Schweickert's (1993) Multinomial Processing Tree Model of Redintegration along with the unique manipulation of task difficulty by uniquely measuring redintegration using associate word pairs.



## Chapter seven: Second empirical study-Associate word pairs and redintegration

Long-term information is organised in a highly sophisticated manner, allowing individuals to retrieve this information systematically to aid short-term recall (Baddeley & Hitch, 1974). Much of the information is organised on the word's conceptual meaning, for example clusters (Bousfield, 1953) and hierarchies (Bower, Clark, Lesgold, & Winzenz, 1969). Studies have demonstrated that short-term recall is consistently higher when there is some level of organisation amongst the TBR items because a spreading activation occurs amongst previously stored semantic representations in LTM, which then assists with retrieving the correct information for later output (Collins & Loftus, 1975; MacKay & Burke, 1990). This is in comparison with TBR items that are not presented in an organised manner, where a spreading activation cannot readily occur, especially if the TBR items are unrelated (Collins & Loftus, 1975; MacKay & Burke, 1990). There is evidence to suggest that the benefits of semantic knowledge may extend to redintegration when measured using associate word pairs. From the redintegration perspective, the semantic relationship inherent among the words in the associate pair would cue individuals to narrow the search for information to a specific section of their LTM. Participants would then retrieve long-term phonological and semantic representations relevant to the words in the associate pair in order to reconstruct the degraded short-term phonological traces for the TBR items for later output (Neale & Tehan, 2007; Schweickert, 1993). For example, the words in the associate pair *dog-cat* are associated with the semantic category *animals*. At recall, if the short-term phonological traces become degraded for either *dog* or *cat*, individuals would engage in redintegration and cue the search in LTM for items only associated with *animals*. In comparison, for the words in the non-

associate pair *apple-chair*, there is no inherent semantic association between the items to guide the redintegration process. If the short-term phonological memory traces became degraded for either *apple* or *chair*, individuals would have to search all of the contents in LTM to reconstruct the short-term phonological memory traces for *apple* and then *chair* in order to retrieve them for later output. This empirical study sought to examine this relationship between associate word pairs and redintegration to determine with the benefits of association may extend to the redintegration process.

### **Semantic factors facilitating verbal STM performance**

Researchers have identified that semantic factors have a unique role in assisting short-term recall and have found that factors such as semantic relatedness (Neale & Tehan, 2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b) and the inter-item associate strength shared between two TBR items (Badham, Estes, & Maylor, 2012; Tse, 2009) contribute substantially to improved short-term recall performance.

**Semantic relatedness.** The benefits of association and semantic knowledge in memory performance have been widely demonstrated using recognition tasks and free recall tasks and their reported benefits extend to verbal STM tasks (Neale & Tehan, 2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b). One such example is semantic relatedness, where items that are semantically related (e.g., *pear-banana* belong to the category *fruits*) already have a pre-existing association in LTM, which enhances their encoding and retrieval for later recall. The association narrows what would ordinarily be an exhaustive search of LTM that would occur for semantically unrelated items (e.g., *paper-flower* are related to two different semantic categories, *stationery* and *plants*) (Neale & Tehan,

2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b). These findings can be understood from the redintegration perspective, where knowing the TBR items were from the same semantic category delimited the number of potential recall candidates retrieved from LTM, increasing the likelihood of retrieving the correct item to be produced for later output (Neale & Tehan, 2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b). This is in contrast to the TBR items that were from different semantic categories as there was no type of cue to enhance the search for long-term information to facilitate retrieval and subsequent output (Neale & Tehan, 2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b).

However, the redintegration explanation for the Poirier and Saint-Aubin (1995) and Saint-Aubin and Poirier (1995; 1999a; 1999b) findings may not necessarily account for the semantic relatedness effects observed in verbal STM tasks. Briefly, these researchers examined the effects of semantic categories on immediate serial recall performance by comparing short-term recall for lists of items related to the same semantic category with lists of items related to different semantic categories. They found that short-term recall was significantly higher for items from the same semantic category than for items from different semantic categories, even after introducing articulatory suppression into the experimental task. The conclusion drawn from these studies was semantic relatedness cued the search for information to a specific subsection of LTM that increased the likelihood of individuals retrieving the correct information to produce the TBR items for later output. Given the verbal nature of immediate serial recall, the processes underlying language representations may better account for these effects. Stuart and Hulme (2000) have suggested certain items co-occur more

frequently in natural language and as such, they share strong inter-item associative links. For example, items from the same category such as *blue* and *black* would share strong associative links. Likewise, the items *eye* and *black* would also share strong associative links, even though they do not share category membership because they co-occur frequently in the English language. Poirier, Dhir, Saint-Aubin, Tehan, and Hampton (2011) speculated that when a list of semantically similar items is presented, co-activation of items that share associative links may occur, and this activated network then aids recall of semantically similar items.

Furthermore, this increase in recall performance for semantically similar items transpires because the activated network makes these items more accessible at recall or because the retrieval set is restricted to the items that are available in the activated network. Poirier et al. argued that this activated network of semantically similar items during the encoding process might be responsible for better recall performance observed for semantically similar items rather than the redintegration process whereby the category membership acts as an additional cue to aid the reconstruction process. The aim of Poirier et al.'s study therefore, was to examine whether strong associative links between items would support recall performance or whether recall performance is the result of category membership. They manipulated the category membership and the associative strength between pairs of words. They argued that if verbal STM performance relied on an activated semantic network, individuals would recall pairs of words that have strong associative links compared with pairs of words that have weak associative links, irrespective of category membership.

Poirier et al. (2011) presented participants with 24 six-item lists for immediate serial recall. Each list contained a critical pair of words. The lists were comprised of either: words

pairs from a different category with strong associative links (e.g., *eye-black*); word pairs from the same category with strong associative links (e.g., *blue-black*); word pairs from different categories with weak associative links (e.g., *blue-feet*); or word pairs from the same category with weak associative links (e.g., *eye-feet*). Irrespective of semantic category, individual recall performance for pairs of words that were strongly associated (e.g., *eye-black* and *blue-black*) was higher than for pairs of words that were weakly associated (e.g., *blue-feet* and *eye-feet*). However, individual recall performance for pairs of words from the same category (e.g., *blue-black* and *eye-feet*), irrespective of their associative link strength, was higher than for pairs of words that were from different categories (e.g., *eye-black* and *blue-feet*). Poirier et al. argued that given category membership and strength of association both played a role in improving memory performance, the effect of associative strength on its own could not explain the semantic similarity advantage. They suggested a more plausible explanation for this recall advantage was that during encoding, participants processed the knowledge that the TBR items were from the same category and at recall, they used this information to serve as an additional cue when retrieving the TBR items. According to Poirier et al., this interpretation cannot be applied to the associative link effect, as it is difficult to argue frequency of co-occurrence between pairs of words would provide a common cue to aid the retrieval process. Rather, strong associations between pairs of words would result in a more readily available set of items at recall. Therefore, increased memory performance was due to the additive effects of associative links and category membership because they served as additional retrieval cues, making those items readily available to retrieve for later output. Given these findings, the redintegration account for the semantic relatedness effects under short-term recall procedures remained a viable explanation.

**Inter-item associative strength.** The benefit of semantic knowledge on verbal STM performance has also been demonstrated through examining the theme-item associative strength (i.e., the strength of the TBR items such as *banana*, *apple*, *lime*, *strawberry* to the category of *fruit*) and the inter-item associative strength of the TBR items (i.e., the strength of the TBR items to one another e.g., *honey*, *sugar*, *sour*). The literature indicates that the semantic relatedness effect (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b) may also extend to an associate relatedness effect. From the redintegration perspective, much like using the category shared amongst the TBR items as a form of retrieval cue, individuals can also extract a common theme shared amongst a list of associate items as an additional cue to also facilitate short-term recall (Tse, 2009). In other words, the stronger the theme-item association between the TBR items and their category or common theme, the more likely it is that the category name or theme activates the phonological and semantic representation of the TBR item in LTM. This activation then delimits the number of potential recall candidates, making redintegration more effective to produce the TBR item for later output. The importance of this possible associate relatedness effect to the redintegration framework was paramount as Tse (2009) believed that the association shared among the TBR items may further facilitate the redintegration process. The aim of Tse's study was to investigate how the associative strength among the TBR items and the associative strength between the TBR items and their shared theme could modulate the effects of categorical and associative relatedness on immediate serial recall performance.

To examine this proposition, Tse (2009) had 25 participants view 12 category related lists containing six items that were typical exemplars of the category and 12 category

unrelated lists containing six items. Another 25 participants viewed 12 associatively related lists containing six strong associates and 12 associatively unrelated lists. Finally, 20 participants viewed a mixture of lists, where 12 lists were a combination of category and associatively related lists and 12 lists were a combination of category and associatively unrelated lists. Using an immediate serial recall task, Tse found a relatedness effect emerged for recall of associatively and category related lists, where participants recalled a significantly higher proportion of categorically related items and associatively related items relative to their unrelated counterparts. When the results were analysed using Schweickert's (1993) Multinomial Processing Tree Model of Redintegration, Tse also found having items under the same category enhanced item redintegration and having the items associated with each other further facilitated item redintegration. Consistent with previous studies (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b), Tse interpreted these findings through the redintegration process, where a spreading activation occurred among the TBR items that strengthened their pre-existing associations during encoding. This pre-activation then guided the search process to those potential recall candidates from a specific category or theme through activation of their semantic representations in LTM, increasing the efficiency of redintegrating the short-term phonological representations of the TBR items that were degraded in the memory task and enhancing memory performance. The effectiveness of these cues, according to Tse, depended on the theme-item associative strength as opposed to the inter-item associative strength, as the redintegration process assumes that redintegration is not dependent upon the properties of other items in the list.

Conversely, researchers have also suggested that the TBR items do not necessarily need to be semantically related (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b) or share a level of associative strength to a particular theme (Tse, 2009) in order to facilitate short-term recall performance. Badham, Estes, and Maylor (2012) investigated whether the recall differences observed for semantically or associatively related items could extend to other experimental stimuli that lacked a pre-existing semantic association, but could be linked by integration. Specifically, Badham et al. used integrative word pairs consisting of two items that were dissimilar, and were not associated with each other, but were linked together to form a coherent phrase (e.g., *red-apple*). These integrative word pairs lacked pre-existing relations, each item was from a different semantic category, and the two items were rarely spoken or written together in the English language. Badham et al. proposed these integrative word pairs could be easily encoded together much like semantic word pairs, because individuals could use their pre-existing long-term semantic associations to guide encoding, which then facilitates retrieval of those items for later output. In this instance, *red-apple* is a *red fruit*, so individuals would cue the search for long-term information only pertaining to *fruits* that were *red* to retrieve *red* and *apple* for later output.

Badham et al. (2012) had participants view three sets of 45 cue-target pairs, with each target word paired with an integrative, semantic, and unrelated cue. For example, the target, *tooth*, was paired with the cues *gold* (integrative), *tongue* (semantic), and *lecture* (unrelated). Once participants viewed the last item in the list, they were required to complete a one-minute delay task where they were required to count backwards in threes from 200. Following the delay task, participants viewed the cue (i.e., *gold*, *tongue*, or *lecture*) and were asked to recall



the target word (i.e., *tooth*). Badham et al. found that participants recalled a significantly lower proportion of unrelated cues compared with the integrative and semantic cues. They also measured the proportion of intrusions participants produced during recall, where intrusions were categorised as either congruent to the target item (i.e., a relation between the intrusion and the cue) or incongruent to the target item (i.e., no relation between the intrusion and the cue). Participants produced a significantly higher proportion of intrusions for the unrelated cues compared with the integrative and semantic cues but, more importantly, they produced a significantly higher proportion of congruent intrusions during recall compared with incongruent intrusions. These findings provided Badham et al. with evidence that participants were aware of the relations between the TBR items they recalled at output, which indicated they used their pre-existing knowledge to benefit recall of the target from its respective cue.

Badham et al. (2012) argued their findings highlighted the importance of semantic associations improving short-term recall performance, purporting the integrative relationship among the TBR items assisted with encoding and retrieving the TBR word pairs that ultimately benefited verbal STM performance. The relation in the word pair, irrespective of whether it was integrative or semantic, allowed for more meaningful encoding. At retrieval, knowing there were relations among the TBR items, irrespective of whether the relation was integrative or semantic, provided additional support to cue the search for long-term information that would facilitate later output. From the redintegrative perspective, one would assume that individuals used the coherent phrase or the semantic category, depending on the TBR item being retrieved, to cue the search for long-term information and guide the retrieval process. Thus, the underlying link between the word pairs would create an additional

advantage to the redintegration process by further enhancing the accessibility of LTM representations to benefit short-term recall performance (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b; Tse, 2009).

To conclude, the research has provided strong evidence that long-term semantic factors, in the form of semantic relatedness (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b), inter-item associative strength (Tse, 2009), and integrative relations (Badham et al., 2012) shared among the TBR items facilitated verbal STM performance. Essentially, individuals initially encoded these semantic associations into verbal STM. At recall, these semantic associations then directed the search process to a specific section of LTM, increasing the likelihood of retrieving the correct recall candidates for later output. If the short-term phonological memory traces of the items in the TBR word pairs sustained damage, identifying a relationship inherent in the word pair would act as an additional retrieval cue to retrieve the correct long-term representations to match with the remaining information available in the trace and recall the TBR items. Thus, it was plausible that when measuring redintegration using associate word pairs, a redintegration effect would emerge in the form of the associate advantage, where the recall difference between words in the associate and non-associate pairs would become greater as difficulty increased in the experimental task. Much of the research on the importance of semantic knowledge on verbal STM performance has primarily been conducted with young adults with few studies comparing their performance with older adults. Given the research has clearly acknowledged that individuals can cue the search for long-term information using the semantic or associate relationship inherent in the

TBR items, it was important to ascertain whether these advantages in short-term recall would also benefit the memory performance of older adults.

### **Age differences in associate memory tasks**

There is general agreement in the literature that age-related deficits are not present in all experimental tasks. This has been established in studies that have measured lexicality (Hulme et al., 1991; Hulme et al., 1995), word frequency (Hulme et al., 1997), word length (Baddeley et al., 1975), and irrelevant speech effects (Colle & Welsh, 1976; Jones & Morris, 1992).

However, in memory tasks that measure the use of long-term semantic associations, a different recall trend emerges. Although recall performance of young adults is superior to older adults when remembering two unrelated pieces of information (Naveh-Benjamin, 2000), there is a substantial reduction in this recall difference when the two pieces of information appear to have an associate relationship, semantic relationship, or when two words are related to each other. Older adults have been found to utilise the relationship among the TBR items to benefit their short-term recall performance and, in some instances, age differences in short-term recall are abolished (Kausler & Lair, 1966; Naveh-Benjamin, 2000; Zaretsky & Halberstam, 1968).

Researchers have explained these age-related differences in associate memory tasks through the associative strength shared among the TBR items as older adults capitalise on their long-term knowledge to help match the performance of young adults to benefit their memory performance (Kausler & Lair, 1966; Naveh-Benjamin, 2000; Zaretsky & Halberstam, 1968). There is evidence that suggests when a strong association exists between two words, age differences no longer exist in memory performance because older adults use their pre-existing semantic knowledge to assist with short-term recall performance (Kausler & Lair, 1966;

Naveh-Benjamin, 2000; Zaretsky & Halberstam, 1968). Earlier research by Kausler and Lair (1966) confirmed this assertion when examining recall performance of young and older adults for recalling paired associates of varying associative strength. They proposed that with increasing age comes a corresponding increase in the variability of word associates in response to a stimulus item because of language acquisition and changes across the lifespan. One consequence of this, particularly for older adults, is that they may find it difficult to produce the correct responses in the memory task because of other competing responses, particularly when the degree of associative strength is medium or even weak, as the words may be difficult to acquire from LTM.

Kausler and Lair (1966) tested their proposition by presenting participants with nine paired stimulus-response associates: three pairs were of high associative strength, three pairs were of low associative strength, and three control pairs had no associative strength. With each word pair, Kausler and Lair paired each stimulus item with a different response item: a high associate, a low associate, and an unrelated item. For example, the stimulus item *eagle* was paired with *bird* (high associate), *fly* (low associate), and *happy* (unrelated item). Participants were presented with the paired associates and, after viewing the last paired associate, they were given the stimulus item (i.e., *eagle*) for which they were required to produce the response item (i.e., *bird*, *fly*, or *happy*). Measuring memory performance using the errors participants produced during recall, Kausler and Lair found young and older adults did not significantly differ in the number of errors produced for the control word pairs and the high associate word pairs. However, older adults produced a significantly higher number of errors when recalling the low associate pairs than young adults.

Kausler and Lair (1966) suggested that acquiring the word pairs in memory differed as a function of associative strength and age. That is, older adults experienced more difficulty with the low associate pairs compared with young adults because activating the relevant semantic representations may have been difficult due to the low level of activation for the semantic representations of those items in LTM. This is compared with the high activation of the semantic representations for word pairs sharing a high association. Kausler and Lair interpreted their findings as indicating that older adults largely relied on their long-term semantic associations in order to acquire the TBR items from verbal STM for later recall.

Zaretsky and Halberstam (1968) also confirmed this observation in a later study where participants viewed paired associates of low, medium, and high associate strength. Using a similar experimental paradigm to Kausler and Lair (1966), no significant age differences emerged in recall for word pairs of medium and high associate strength. However, there was a marked age difference for recall of paired associates with low associate strength, where young adults recalled a significantly higher number of words pairs compared with older adults. Zaretsky and Halberstam also inferred that older adults benefit in an experimental task when there is a high level of associative strength among the TBR items because they utilised their long-term knowledge to enhance the retrieval of these items for later output. These earlier studies have clearly identified that young adults outperformed older adults in recall tasks only when there was a weak associative strength among the TBR items. Despite postulating that older adults have more established connections and associative links in memory because of their years of experience with the English language in comparison to young adults (Kausler & Lair, 1966; Zaretsky & Halberstam, 1968), it was the application of this knowledge that

contributed to differences in recall performance. These pre-existing associations among the word pairs, particularly if they had a high associative strength, were beneficial to all ages, but they were particularly helpful to older adults as they contributed to minimising the age differences observed in associate memory tasks. It was therefore plausible that within the context of redintegration, older adults would be largely reliant on their long-term semantic knowledge to facilitate redintegration of the damaged short-term phonological memory traces of the TBR items, particularly in the difficult task conditions compared with their young counterparts.

A study by Naveh-Benjamin (2000) also substantiated the notion that age significantly influenced the reliance on pre-existing semantic associations to facilitate verbal STM performance. Specifically, Naveh-Benjamin posited that previous long-term knowledge can support performance in a memory task where one needs to create and retrieve associations for items in the memory task using pre-existing semantic associations (e.g., semantically related word pairs). Naveh-Benjamin hypothesised that older adults would benefit the most from using semantically related word pairs, particularly in the cued recall task, because this type of task relies heavily on encoding and retrieving associate information.

To examine his proposition, Naveh-Benjamin (2000) presented participants with three lists of word pairs, each containing 16 word pairs with four of the word pairs used as buffers. Naveh-Benjamin used each list in one of three different memory tasks: a cued recall task, a free recall task, and a recognition task. There were two separate conditions: semantically related word pairs and semantically unrelated word pairs. Participants were given one specific instruction that carried across the three tasks when they were presented with the word pairs:

pay close attention to the second word in the word pair (i.e., the target word). For the cued recall-task, participants were given the cue word and they were asked to write down the corresponding target word. For the free recall task, participants were asked to memorise the word pairs and write down as many of the targets as they could remember. Finally, for the recognition task, participants were presented with a list of words and they were required to organise as many of the targets as possible into their original word pairs.

One of the prominent findings from Naveh-Benjamin's (2000) research was the significant interaction between age and the memory task performed. For each test, young adults recalled a significantly higher number of target words compared with older adults. However, the largest age difference between young and older adults was for the cued-recall test, compared with the free recall and recognition tasks, respectively. The second significant interaction between age and the type of word pair revealed a significant age difference for the semantically unrelated word pairs, where young adults recalled a significantly higher proportion of semantically unrelated word pairs compared with older adults; however, there was no significant age difference for the semantically related word pairs. Naveh-Benjamin inferred that older adults demonstrated a significant disadvantage in memory for the unrelated word pairs because they needed to create a new episodic association between the TBR items in order to encode them correctly and retrieve the short-term phonological representations for later recall. In contrast, for the semantically related word pairs, as older adults could rely on previously learned associations, these items were less difficult to encode and retrieve for later output. Thus, there was further evidence to strengthen the position that older adults to a greater

degree than young adults rely largely on their long-term semantic knowledge to facilitate short-term recall performance in a verbal STM task.

In conclusion, the multitude of research has demonstrated that young and older adults benefit greatly when there is an inherent relationship among the TBR information to facilitate verbal STM performance. For older adults, when there is a strong association shared among the word pair, they utilise their pre-existing long-term semantic knowledge to assist with encoding and retrieving the TBR items from verbal STM for later output (Kausler & Lair, 1966; Naveh-Benjamin, 2000; Zaretsky & Halberstam, 1968). This is in comparison to their reduced recall performance for word pairs with no semantic association as older adults experience more difficulty with creating a new association in order to encode the TBR word pair for later retrieval. From the redintegration perspective, it was believed that young and older adults would use the same redintegration process to facilitate recall of the TBR items, particularly in the difficult task conditions. However, as the words in the associate pairs are associated with each other, older adults to a greater extent than young adults would presumably rely heavily on the semantic association as an additional retrieval cue to assist with reconstructing the degraded short-term phonological memory traces for later recall. It was therefore reasonable to believe that while young and older adults benefit from the semantic association that exists within a word pair, when the memory task becomes difficult, older adults would be more reliant on these semantic associations to assist with short-term recall.



## **Aims**

The primary aim of this study was to continue investigating the redintegration process by uniquely measuring redintegration using associate word pairs. The literature has provided substantial evidence that short-term recall performance improves considerably when there is a semantic relationship inherent among a pair of TBR items (Badham et al., 2012; Neale & Tehan, 2007; Poirier et al., 2011; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b; Tse, 2009). It was believed that the reported benefits of association in verbal STM tasks would extend to redintegrative processing in this study, with its benefits most prominent when short-term recall is assumed to be problematic during the difficult task conditions. Having the words associated with a category would delimit the number of potential recall candidates by effectively guiding the search to locate the correct long-term phonological and semantic representations to aid in reconstructing the short-term phonological memory traces of the TBR items for later output (Badham et al., 2012; Neale & Tehan, 2007; Poirier et al., 2011; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b; Tse, 2009). As no researchers have conducted such an examination between redintegration and associate word pairs by manipulating the difficulty of the experimental task, this represented an important area of inquiry.

This study also aimed to continue examining whether age-related differences exist in redintegration when measured using associate word pairs. The literature states that, although young adults outperform older adults in verbal STM tasks when the TBR items are unrelated, there is a considerable reduction in the magnitude of the difference in recall performance when there is a semantic or associate relationship inherent among the TBR items (Kausler & Lair,

1966; Naveh-Benjamin, 2000; Zaretsky & Halberstam, 1968). It was believed that when redintegration is called upon to facilitate short-term recall, the process would remain invariant to age, but older adults may have a greater propensity to engage in redintegration to combat the interference produced in the experimental task. Furthermore, they would utilise their long-term associate knowledge to a greater extent than young adults to assist with verbal STM performance. As Neale and Tehan (2007) are the only researchers to have examined age differences in redintegration, this study, like Study one, aimed to add to the body of literature.

### **Hypotheses**

It was hypothesised that for correct-in-position recall, item recall, and order accuracy, at the short-term recall level across all task difficulty conditions, young adults would recall a significantly higher proportion of associate and non-associate word pairs compared with older adults. Due to the different levels of interference, despite the associate pairs sharing an association, young adults would outperform older adults because of the varied nature of the cognitive demands across the memory conditions in the experimental task.

It was hypothesised that for correct-in-position recall, item recall, and order accuracy, there would be a significant positive relationship between the associate advantage and task difficulty. In the easier task conditions, the recall difference between associate and non-associate word pairs would not be present. Consistent with the redintegration process, the short-term phonological memory traces for the associate and non-associate word pairs would be relatively intact because they would have sustained little damage from the manipulation of task difficulty during encoding. As a result, the associate and non-associate word pairs would be retrieved directly from verbal STM. In the difficult task conditions, redintegration effects

would emerge, where participants would recall an increasingly higher proportion of associate word pairs than non-associate word pairs. Consistent with the redintegration process, individuals would call upon long-term semantic knowledge to help reconstruct the damaged short-term phonological traces for the TBR word pairs resulting from interference produced by the task difficulty manipulation during encoding. The semantic relationship between the words in the associate word pair would act as an additional retrieval cue to guide the search for long-term information and limit the number of potential recall candidates for later output. Redintegration effects, in this study, would be in the form of the associate advantage, where the size of the recall difference between associate and non-associate word pairs would increase, in favour of associate word pairs.

It was hypothesised that for correct-in-position recall, item recall, and order accuracy, at the most difficult level of the task, the size of the recall difference between associate and non-associate word pairs would be greater for older adults than young adults. In these conditions, where interference in the memory task from the task difficulty manipulation was at its greatest, older adults would be largely reliant on redintegration than young adults to rebuild the damaged short-term phonological memory traces for the TBR word pairs. More importantly, older adults would utilise their long-term semantic knowledge to facilitate the reconstruction for the associate word pairs as they have an inherent relationship and would ease the cognitive demands of retrieving and subsequently recalling these word pairs for later output. This is in comparison with the non-associate word pairs, which do not bear any semblance of an associate relationship.

## Method

### Participants

Forty adult volunteers participated in this study and were different from Study One. Twenty young adults (40% men and 60% women,  $M_{\text{age}} = 21.55$  years, age range 18-32 years) were recruited from undergraduate psychology courses at an Australian university (60%) and the general community (40%). Undergraduate students received partial course credit in exchange for their participation. Participants in the general community did not receive any incentives for their participation. Twenty independent living older adults (20% men and 80% women,  $M_{\text{age}} = 74.50$  years, age range 61-86 years) were recruited from a retirement village in Australia, local community groups, and the general community. Participants in the older adult group did not receive any incentives for their participation. The age ranges for young and older adults were consistent with Neale and Tehan (2007) and similar ageing research (Balota & Duchek, 1988; Craik et al., 1987; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2002). All participants spoke English as their first language. Participants were recruited using the same methods in Study one of this thesis (see p. 124). Interested participants received the same information letter and consent form to complete. Those individuals who provided informed consent participated in the study. This study received full ethics approval by the Human Research Ethics Committee at the Australian Catholic University (approval number V 2009 31). Table 7.1 summaries the remaining demographics for the sample.

Table 7.1  
*Demographic Characteristics across Age*

Characteristic	Young ( <i>n</i> = 20)		Older ( <i>n</i> = 20)		<i>t</i>	<i>df</i>	<i>p</i>	<i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>				
Health on testing day <sup>a</sup>								
Good to excellent	90%		95%					
Not very good	10%		5%					
Vision								
Normal	55%		40%					
Corrected-to-normal	45%		60%					
Hearing								
Normal	100%		90%					
Corrected-to-normal	0%		10%					
Mill Hill <sup>b</sup>	13.10	2.08	15.15	3.08	-2.47	38	.018	0.79
Education (years)	13.55	2.19	11.70	3.44	2.03	32.24	.051	0.65

*Note.* *n* = number of participants.

<sup>a</sup> was self-rated on a five point Likert Scale from 1 (Excellent) to 5 (Poor).

<sup>b</sup> refers to the Mill Hill Vocabulary Scale (Raven, 1989).

## Design

This study used a 2 x 2 x 2 x 2 x 2 mixed factorial experimental design. The four within-subjects independent variables were: (1) word pair (associate, non-associate), (2) recall interval (immediate, delay), (3) study condition (silence, irrelevant speech), and (4) presentation rate (one second, two seconds). The between-subjects independent variable was age (young, older).

Consistent with Study One of this thesis, the primary dependent variables were: (1) correct-in-position recall, (2) item recall, and (3) order accuracy. The secondary dependent variables of interest were the errors the participant made during recall: (1) transpositions and (2) omissions.

## Materials

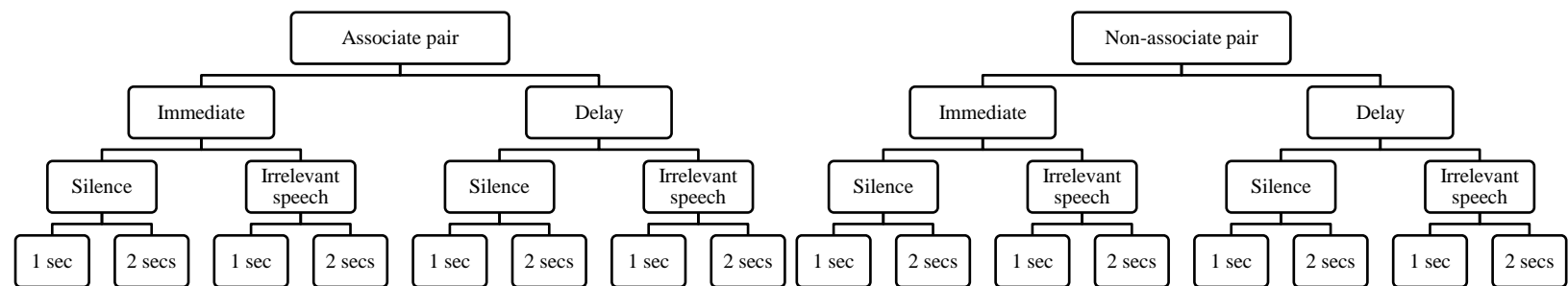
**Background measures.** The biographical questionnaire and the Mill Hill Vocabulary Scale (Raven, 1989) were the same measures used in Study one.

**Word stimuli.** Three hundred and twenty word pairs (160 associate pairs and 160 non-associate pairs) were created to comprise two word pools based on association (associate and non-associate). Each associate word trial consisted of two word pairs, totalling four words. To create each word pair, firstly, 80 words were randomly selected from Appendix A of the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 1998). Similar to the words selected for Study one, words were selected with the following restrictions: words were nouns, between one and two syllables in length, and between three to six letters in length. Selection of the second word in the pair was determined using the following restrictions: a noun between one and two syllables in length, between three and six letters in length, and the strongest associate of the word. The associate strength was determined by examining the value of the forward strength as established by the University of South Florida Free Association Norms (Nelson et al., 1998), where the first associate is identified as the strongest associate. Using the associate pair *pad-paper* as an example, of the associates that have been examined with the word *pad* (i.e., *paper*, *pen*, *pencil*, *write*, *cushion*, *notebook*, *apartment*, *soft*, *mattress*, *period*, *cover*, *house*, and *seat*), *paper* had the highest forward strength to *pad* (see Appendix B-7).

Each non-associate word trial consisted of two non-associate word pairs, totalling four words. The words in each pair did not share any degree of semantic association. The non-associate pairs were developed by randomly selecting an additional 80 words from Appendix

A of the University of South Florida Free Association Norms (Nelson et al., 1998) using the same criteria to select the words for the 40 associate pairs to create another second of 40 associate pairs. To create the non-associate pairs, the first word in the second associate pair was allocated to serial position one. The second word in the first associate pair was allocated to serial position two. The first word in the fourth associate pair was allocated to serial position three. The second word in the third associate pair was allocated to serial position four. For example, using the associate pairs *lash* and *eye*, *grow* and *tall*, *usurp* and *take*, *gown* and *dress*, to create the non-associate pairs, *grow* was allocated to serial position one and *eye* was allocated to serial position two, resulting in *grow, eye*. *Gown* was allocated to serial three and *take* was allocated to serial four, resulting in *gown, take*. Therefore, the non-associate trial comprised of the non-associate pairs *grow, eye, gown, take*. This process was repeated to create the remaining pairs that comprised the non-associate trials (see Appendix B-7).

**Word trials.** Figure 7.1 presents the composition of the word trials the participant viewed across the eight memory conditions. The same computer program was used to generate one unique block of 80 trials containing 40 associate word trials and 40 non-associate word trials that were randomly allocated to one of eight memory conditions for the participant to view during the experiment. Forty of the word trials were presented at a rate of one word every second and the remaining 40 word trials were presented a rate of one word every two seconds (see Appendix B-8 for an example block of word trials at each presentation rate).



*Figure 7.1.* Composition of the task difficulty conditions using recall interval, study condition, and presentation rate across word pair.



**Procedure**

The procedure was identical to Study one of this thesis.

**Scoring**

The scoring for all word trials was identical to Study one of this thesis.

**Results****Data screening**

The approach for screening the data prior to analysis for correct-in-position recall, item recall, order accuracy, transposition errors, and omission errors was consistent with Study one of this thesis (see p. 132).

**Data analysis**

The results from the  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVAs in this study, using only the Mill Hill Score as a covariate for correct-in-position recall, item recall, order accuracy, transposition errors, and omission errors, were consistent with Study one of this thesis. There were no differences in the main effects reported and therefore, the original mixed factorial ANOVAs without the covariates are reported. This applied to correct-in-position recall, item recall, order accuracy, transposition errors, and omission errors (see p. 133). All significant interactions are reported in Appendix C-3.1 and all non-significant interactions are reported in Appendix C-3.2.

**Correct-in-position recall**

**Descriptive statistics.** Table 7.2 presents the mean proportions of correct-in-position recall for young and older adults during recall of words from the associate and non-associate pairs across the eight memory conditions.

Table 7.2

*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Correct-in-Position Recall across Task Difficulty, Word Pair, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Associate			Non-associate			Associate			Non-associate		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.96	.07	[.92, .99]	.91	.08	[.87, .95]	.93	.10	[.88, .97]	.83	.16	[.76, .90]
		1 sec	.96	.07	[.92, .99]	.83	.13	[.76, .89]	.93	.08	[.89, .97]	.83	.17	[.75, .91]
	Speech	2 sec	.98	.06	[.95, 1]	.90	.14	[.84, .96]	.91	.10	[.86, .96]	.81	.16	[.74, .89]
		1 sec	.93	.10	[.88, .98]	.87	.16	[.80, .94]	.88	.12	[.82, .93]	.80	.19	[.71, .89]
Delay	Silence	2 sec	.80	.17	[.72, .88]	.67	.22	[.57, .78]	.74	.20	[.65, .83]	.60	.21	[.49, .70]
		1 sec	.78	.19	[.70, .87]	.64	.18	[.55, .72]	.63	.20	[.54, .72]	.48	.26	[.36, .60]
	Speech	2 sec	.80	.15	[.72, .87]	.66	.22	[.56, .76]	.71	.23	[.61, .82]	.61	.23	[.50, .71]
		1 sec	.78	.18	[.69, .86]	.63	.19	[.53, .72]	.72	.25	[.60, .83]	.50	.24	[.38, .61]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Associate = associate word pairs, Non-associate = non-associate word pairs.

The data from Table 7.2 indicated that as the task increased in difficulty, there was an associate advantage during recall. A higher proportion of words from the associate pairs were recalled in serial position compared with the non-associate pairs and this pattern of recall performance was consistent for all participants. At the age level, young adults recalled a higher proportion of words from the associate and non-associate pairs in serial position compared with older adults.

**Inferential statistics.** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for correct-in-position recall. The within-subjects variables were word pair, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Main effects.** There was a significant main effect for word pair, where participants recalled a significantly higher proportion of words from the associate pairs ( $M = .84$ ,  $SD = .11$ ) in serial position compared with the non-associate pairs ( $M = .72$ ,  $SD = .15$ ),  $F(1, 38) = 128.60$ ,  $MSE = 2.18$ ,  $p < .001$ ,  $\eta_p^2 = .77$ , *observed power* = 1.00. There was a significant main effect for recall interval, where participants recalled a significantly higher proportion of words from the associate and non-associate pairs in serial position during immediate conditions ( $M = .89$ ,  $SD = .09$ ) compared with after a delayed interval ( $M = .67$ ,  $SD = .17$ ),  $F(1, 38) = 139.70$ ,  $MSE = 7.73$ ,  $p < .001$ ,  $\eta_p^2 = .79$ , *observed power* = 1.00. Finally, there was a significant main effect for presentation rate, where participants recalled a significantly higher proportion of words from the associate and non-associate pairs in serial position during the two-second presentation rate ( $M = .80$ ,  $SD = .13$ ) compared with the one-second presentation rate ( $M = .76$ ,  $SD = .13$ ),  $F(1, 38) = 20.99$ ,  $MSE = 0.25$ ,  $p < .001$ ,  $\eta_p^2 = .36$ , *observed power* = .99.

**Item recall**

**Descriptive statistics.** Table 7.3 presents the mean proportions of item recall for young and older adults during recall of words from the associate and non-associate pairs across the eight memory conditions.

Table 7.3  
*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Item Recall across Task Difficulty, Word Pair, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Associate			Non-associate			Associate			Non-associate		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.98	.05	[.95, 1]	.95	.05	[.92, .97]	.95	.08	[.92, .99]	.86	.13	[.80, .92]
		1 sec	.97	.05	[.95, .99]	.88	.11	[.83, .92]	.96	.08	[.92, .99]	.86	.15	[.79, .93]
	Speech	2 sec	.99	.05	[.97, 1]	.93	.10	[.88, .98]	.94	.08	[.90, .98]	.89	.11	[.83, .94]
		1 sec	.96	.09	[.92, 1]	.90	.13	[.84, .96]	.93	.10	[.88, .97]	.89	.09	[.85, .93]
Delay	Silence	2 sec	.88	.11	[.83, .93]	.73	.18	[.65, .82]	.83	.13	[.77, .89]	.69	.19	[.60, .78]
		1 sec	.85	.13	[.79, .91]	.73	.15	[.66, .80]	.73	.17	[.65, .81]	.58	.23	[.47, .69]
	Speech	2 sec	.83	.14	[.77, .90]	.72	.20	[.63, .82]	.78	.19	[.69, .87]	.70	.17	[.62, .78]
		1 sec	.86	.14	[.79, .92]	.69	.19	[.60, .78]	.79	.20	[.69, .88]	.59	.22	[.49, .69]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Associate = associate word pairs, Non-associate = non-associate word pairs.

The data from Table 7.3 suggests an associate advantage also appeared during item recall. Irrespective of serial position, participants recalled a higher proportion of words from the associate pairs compared with the non-associate pairs. Again, this pattern of recall performance was consistent for young and older adults. In addition, young adults, across all memory conditions, recalled a higher proportion of words from the associate and non-associate pairs compared with older adults.

***Inferential statistics.*** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for item recall. The within-subject variables were word pair, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

***Main effects.*** There was a significant main effect for word pair, where participants recalled a significantly higher proportion words from the associate pairs ( $M = .89$ ,  $SD = .08$ ) compared with the non-associate pairs ( $M = .79$ ,  $SD = .12$ ),  $F(1, 38) = 140.51$ ,  $MSE = 1.69$ ,  $p < .001$ ,  $\eta_p^2 = .79$ , *observed power* = 1.00. There was also a significant main effect for recall interval, where participants recalled a significantly higher proportion of words from the associate and non-associate pairs during immediate conditions ( $M = .93$ ,  $SD = .07$ ) than after a delayed interval ( $M = .75$ ,  $SD = .14$ ),  $F(1, 38) = 124.90$ ,  $MSE = 5.04$ ,  $p < .001$ ,  $\eta_p^2 = .77$ , *observed power* = 1.00. Finally, presentation rate yielded a significant main effect, where participants recalled a significantly higher proportion of words from the associate and non-associate pairs during the two-second presentation rate ( $M = .85$ ,  $SD = .10$ ) compared with the one-second presentation rate ( $M = .82$ ,  $SD = .11$ ),  $F(1, 38) = 18.79$ ,  $MSE = 0.15$ ,  $p < .001$ ,  $\eta_p^2 = .33$ , *observed power* = .99.

**Order accuracy**

**Descriptive statistics.** Table 7.4 presents the mean proportions for order accuracy across young and older adults during recall for words from the associate and non-associate pairs in the eight memory conditions.



Table 7.4  
*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Order Accuracy across Task Difficulty, Word Pair, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Associate			Non-associate			Associate			Non-associate		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.98	.03	[.97, 1]	.96	.06	[.93, .99]	.97	.04	[.95, .99]	.97	.04	[.93, 1]
		1 sec	.99	.04	[.97, 1]	.94	.06	[.91, .97]	.98	.04	[.96, 1]	.96	.06	[.93, .99]
	Speech	2 sec	.99	.04	[.97, 1]	.96	.08	[.92, 1]	.97	.06	[.94, .99]	.91	.09	[.87, .95]
		1 sec	.97	.06	[.94, 1]	.96	.06	[.93, .99]	.95	.08	[.91, .98]	.89	.15	[.82, .96]
Delay	Silence	2 sec	.91	.13	[.85, .97]	.91	.12	[.85, .96]	.88	.16	[.81, .95]	.86	.17	[.78, .93]
		1 sec	.91	.11	[.86, .96]	.87	.13	[.81, .93]	.86	.17	[.78, .94]	.78	.19	[.69, .87]
	Speech	2 sec	.95	.08	[.92, .99]	.91	.11	[.86, .96]	.90	.11	[.85, .95]	.84	.17	[.76, .92]
		1 sec	.91	.11	[.85, .96]	.91	.10	[.86, .95]	.90	.16	[.82, .97]	.82	.17	[.74, .90]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Associate = associate word pairs, Non-associate = non-associate word pairs.

As evident from Table 7.4, the probability of recalling a word from the word trial in its serial position, given the participant initially recalled the word, was higher for the associate pairs than for the non-associate pairs. This associate advantage was consistent for young and older adults across the eight memory conditions. Regarding age differences, overall order accuracy was higher for young adults compared with older adults.

***Inferential statistics.*** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for order accuracy. The within-subject variables were word pair, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

***Main effects.*** There was a significant main effect for word pair, where order accuracy was significantly higher for words in the associate pairs ( $M = .94$ ,  $SD = .05$ ) compared with the non-associate pairs ( $M = .90$ ,  $SD = .08$ ),  $F(1, 38) = 17.09$ ,  $MSE = 0.20$ ,  $p < .001$ ,  $\eta_p^2 = .31$ , *observed power* = .98. There was also a significant main effect for recall interval, where order accuracy for words from the associate and non-associate pairs was significantly higher in the immediate conditions ( $M = .96$ ,  $SD = .04$ ) than after a delayed interval ( $M = .88$ ,  $SD = .09$ ),  $F(1, 38) = 53.90$ ,  $MSE = 0.97$ ,  $p < .001$ ,  $\eta_p^2 = .59$ , *observed power* = 1.00. There was a significant main effect for presentation rate, where order accuracy was significantly higher for words from the associate and non-associate pairs during the two-second presentation rate ( $M = .93$ ,  $SD = .06$ ) compared with the one-second presentation rate ( $M = .91$ ,  $SD = .07$ ),  $F(1, 38) = 5.33$ ,  $MSE = 0.05$ ,  $p = .026$ ,  $\eta_p^2 = .12$ , *observed power* = .61. Finally, there was a significant main effect for age, where order accuracy was significantly higher for young adults ( $M = .94$ ,

$SD = .04$ ) compared with older adults ( $M = .90$ ,  $SD = .07$ ),  $F(1, 38) = 4.59$ ,  $MSE = 0.01$ ,  $p = .039$ ,  $\eta_p^2 = .11$ , *observed power* = .55.

### **Transposition errors**

**Descriptive statistics.** Tables 7.5 displays the mean proportions of transposition errors young and older adults produced when recalling words from the associate and non-associate pairs across the eight memory conditions.

Table 7.5  
*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Transposition Errors across Task Difficulty, Word Pair, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Associate			Non-associate			Associate			Non-associate		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.02	.03	[0, .03]	.04	.06	[.01, .06]	.03	.04	[.01, .04]	.02	.04	[0, .04]
		1 sec	.01	.03	[0, .03]	.03	.04	[.01, .05]	.02	.04	[0, .04]	.03	.04	[0, .05]
	Speech	2 sec	.01	.03	[0, .02]	.04	.07	[0, .07]	.03	.05	[0, .05]	.07	.07	[.04, .10]
		1 sec	.03	.05	[.01, .06]	.03	.05	[.01, .05]	.05	.07	[.01, .08]	.07	.12	[.01, .12]
Delay	Silence	2 sec	.03	.04	[.01, .05]	.05	.08	[.01, .09]	.06	.09	[.02, .10]	.08	.09	[.04, .12]
		1 sec	.04	.05	[.01, .06]	.07	.08	[.03, .11]	.06	.09	[.02, .10]	.08	.07	[.05, .11]
	Speech	2 sec	.02	.04	[0, .04]	.02	.03	[.07, .04]	.06	.06	[.02, .09]	.06	.06	[.03, .09]
		1 sec	.04	.06	[.01, .07]	.04	.05	[.01, .06]	.05	.09	[.01, .09]	.05	.06	[.03, .08]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Associate = associate word pairs, Non-associate = non-associate word pairs.

It was evident from Table 7.5 that across the eight memory conditions, participants produced a higher proportion of transposition errors when recalling words from the non-associate pairs compared with the associate pairs. However, in seven of the eight memory conditions, older adults produced a higher proportion of transposition errors when recalling words from the associate and non-associate pairs compared with young adults.

***Inferential statistics.*** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for the transposition errors produced during recall. The within-subjects variables were word pair, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

***Main effects.*** There was a significant main effect for word pair, where participants produced a significantly higher proportion of transposition errors when recalling words from the non-associate pairs ( $M = .05$ ,  $SD = .04$ ) than the associate pairs ( $M = .03$ ,  $SD = .03$ ),  $F(1, 38) = 7.16$ ,  $MSE = 0.03$ ,  $p = .011$ ,  $\eta_p^2 = .16$ , *observed power* = .74. There was a significant main effect for recall interval, where participants produced a significantly higher proportion of transposition errors after a delayed interval ( $M = .05$ ,  $SD = .04$ ) compared with immediate conditions ( $M = .03$ ,  $SD = .03$ ),  $F(1, 38) = 12.73$ ,  $MSE = 0.06$ ,  $p = .001$ ,  $\eta_p^2 = .25$ , *observed power* = .94. Finally, there was a significant main effect for age, where older adults ( $M = .05$ ,  $SD = .03$ ) produced a significantly higher proportion of transposition errors during recall compared with young adults ( $M = .03$ ,  $SD = .02$ ),  $F(1, 38) = 4.32$ ,  $MSE = 0.06$ ,  $p = .045$ ,  $\eta_p^2 = .10$ , *observed power* = .53.

**Omission errors**

**Descriptive statistics.** Table 7.6 presents the mean proportions of words from the associate and non-associate pairs young and older adults omitted during recall across the eight memory conditions.

Table 7.6  
*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Omission Errors across Task Difficulty, Word Pair, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Associate			Non-associate			Associate			Non-associate		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.02	.04	[0, .04]	.04	.07	[.02, .06]	.03	.07	[0, .06]	.10	.11	[.05, .15]
		1 sec	.01	.03	[0, .03]	.08	.10	[.04, .12]	.03	.07	[0, .07]	.08	.11	[.03, .13]
	Speech	2 sec	.01	.03	[0, .02]	.04	.08	[0, .08]	.05	.07	[.02, .08]	.07	.09	[.02, .11]
		1 sec	.02	.03	[0, .04]	.06	.08	[.03, .10]	.03	.06	[.01, .06]	.07	.07	[.03, .10]
Delay	Silence	2 sec	.09	.07	[.05, .12]	.20	.16	[.12, .27]	.12	.12	[.07, .18]	.24	.18	[.16, .33]
		1 sec	.13	.12	[.07, .18]	.17	.14	[.11, .23]	.21	.18	[.13, .28]	.34	.23	[.23, .45]
	Speech	2 sec	.11	.11	[.06, .17]	.20	.17	[.12, .28]	.16	.17	[.08, .24]	.25	.17	[.17, .33]
		1 sec	.09	.11	[.04, .15]	.26	.20	[.16, .35]	.17	.18	[.09, .25]	.32	.21	[.23, .42]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Associate = associate word pairs, Non-associate = non-associate word pairs.

Overall, the means from Table 7.6 appeared to suggest that participants omitted a higher proportion words from the non-associate pairs compared with the associate pairs. In relation to age differences, across all memory conditions, older adults omitted a higher proportion of words from the associate and non-associate pairs during recall compared with young adults.

***Inferential statistics.*** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for the omission errors produced during recall. The within subjects variables were word pair, recall interval, study condition, and presentation rate. Age was the between subjects variable.

***Main effects.*** There was a significant main effect for word pair, where participants omitted a significantly higher proportion of words from the non-associate pairs ( $M = .16$ ,  $SD = .10$ ) compared with the associate pairs ( $M = .08$ ,  $SD = .07$ ),  $F(1, 38) = 79.71$ ,  $MSE = 0.94$ ,  $p < .001$ ,  $\eta_p^2 = .68$ , *observed power* = 1.00. There was a significant main effect for recall interval, where participants omitted a significantly higher proportion of words from the associate and non-associate pairs after a delayed interval ( $M = .19$ ,  $SD = .13$ ) compared with immediate conditions ( $M = .05$ ,  $SD = .05$ ),  $F(1, 38) = 89.01$ ,  $MSE = 3.34$ ,  $p < .001$ ,  $\eta_p^2 = .70$ , *observed power* = 1.00. Finally, there was a significant main effect for presentation rate, where participants omitted a significantly higher proportion of words from the associate and non-associate pairs during the one-second presentation rate ( $M = .13$ ,  $SD = .09$ ) compared with the two-second presentation rate ( $M = .11$ ,  $SD = .08$ ),  $F(1, 38) = 9.80$ ,  $MSE = 0.07$ ,  $p = .003$ ,  $\eta_p^2 = .21$ , *observed power* = .86.

### **Task difficulty and Redintegration**

**Task difficulty.** Consistent with Study one of this thesis, the  $2 \times 2 \times 2$  (recall interval, study condition, and presentation rate) design produced eight estimates of task difficulty. The rank order for the means in the eight levels memory conditions was based on the outcomes of the



study. Table 7.7 presents a summary of the correlations between the associate and non-associate lists for young and older adults across correct-in-position recall, item recall, and order accuracy.

Table 7.7

*Spearman's Rank Order Correlations for Task Difficulty as a Function of Word Pair and Age*

Age	Word pair	Young ( <i>n</i> = 20)		Older ( <i>n</i> = 20)	
		Associate	Non- associate	Associate	Non- associate
Correct-in-Position Scoring					
Young	Associate	1.00			
	Non-associate	.95	1.00		
Older	Associate	.83	.79	1.00	
	Non-associate	.88	.88	.91	1.00
Item Scoring					
Young	Associate	1.00			
	Non-associate	.88	1.00		
Older	Associate	.88	.76	1.00	
	Non-associate	.69	.71	.71	1.00
Order Scoring					
Young	Associate	1.00			
	Non-associate	.81	1.00		
Older	Associate	.86	.74	1.00	
	Non-associate	.86	.76	.91	1.00

Note. *n* = number of participants

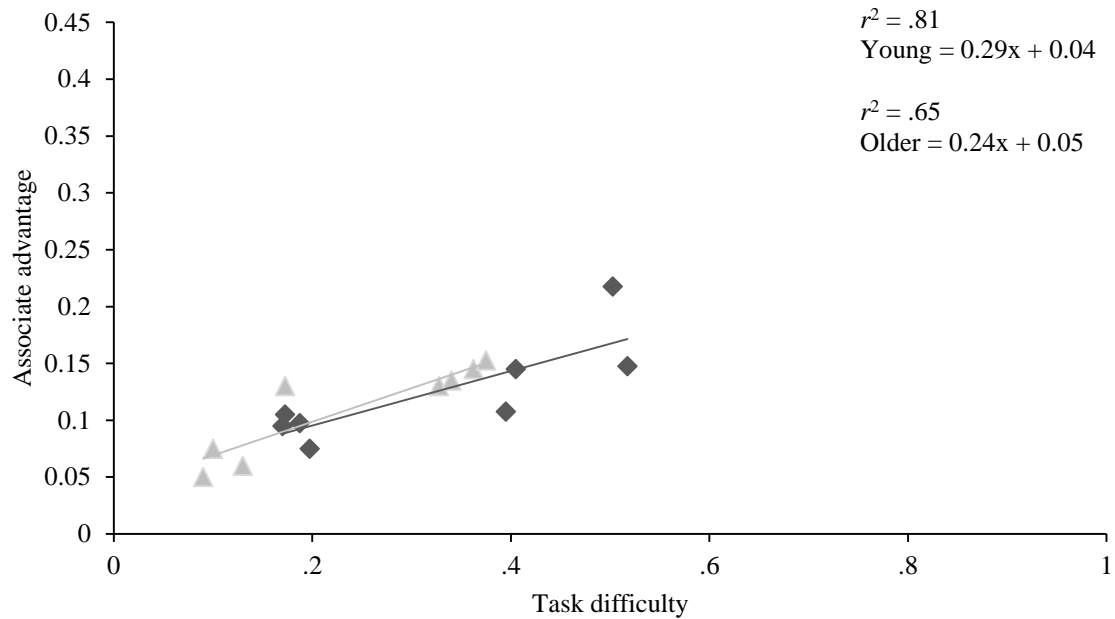
As can be seen in Table 7.7, there were strong positive correlations between the associate and non-associate lists for young and older adults across correct-in-position scoring (older adults,  $r = .91$ ; young adults,  $r = .95$ ), item scoring (older adults,  $r = .71$ ; young adults ( $r = .88$ ) and order accuracy (older adults,  $r = .91$ ; young adults,  $r = .81$ ). These results suggested that task difficulty was independent of associate relationships among the TBR words and was consistent in creating interference during the experimental task.

**Redintegration.** Redintegration effects are represented by the associate advantage as a function of task difficulty. Consistent with Study one of this thesis, the associate advantage (y-axis) is represented by the size of the recall difference between the proportion of words recalled

from the associate and non-associate pairs participants recalled in each of the eight memory conditions. Task difficulty (x-axis) is represented by the proportion of transposition and omission errors participants made when recalling lists of non-associate pairs across the eight memory conditions. Therefore, if a participant scored .8 on a list of non-associate pairs, the remaining .2 is errors made in recall. That is, 20% of performance on the list of non-associate pairs were either transpositions or omissions. Performance on the lists of non-associate pairs was used as a baseline measure because the absence of a semantic relationship between the words in the non-associate pairs would provide the individual with no additional help when using redintegration to reconstruct the damaged short-term phonological memory traces of the TBR words for later output.

In terms of redintegration outcomes, a positive relationship is represented by an increase in the associate advantage as task difficulty increased. That is, as the memory task became more difficult, the size of the recall difference between the words recalled from the associate and non-associate word pairs increased, in favour of associate pairs. A negative relationship is represented by a decrease in the size of the associate advantage as task difficulty increased. This suggests there is no advantage of association and participants recalled a comparable proportion of words from the associate and non-associate pairs. These outcomes were analysed for correct-in-position recall, item recall, and order accuracy at the group mean level, consistent with Study one of this thesis.

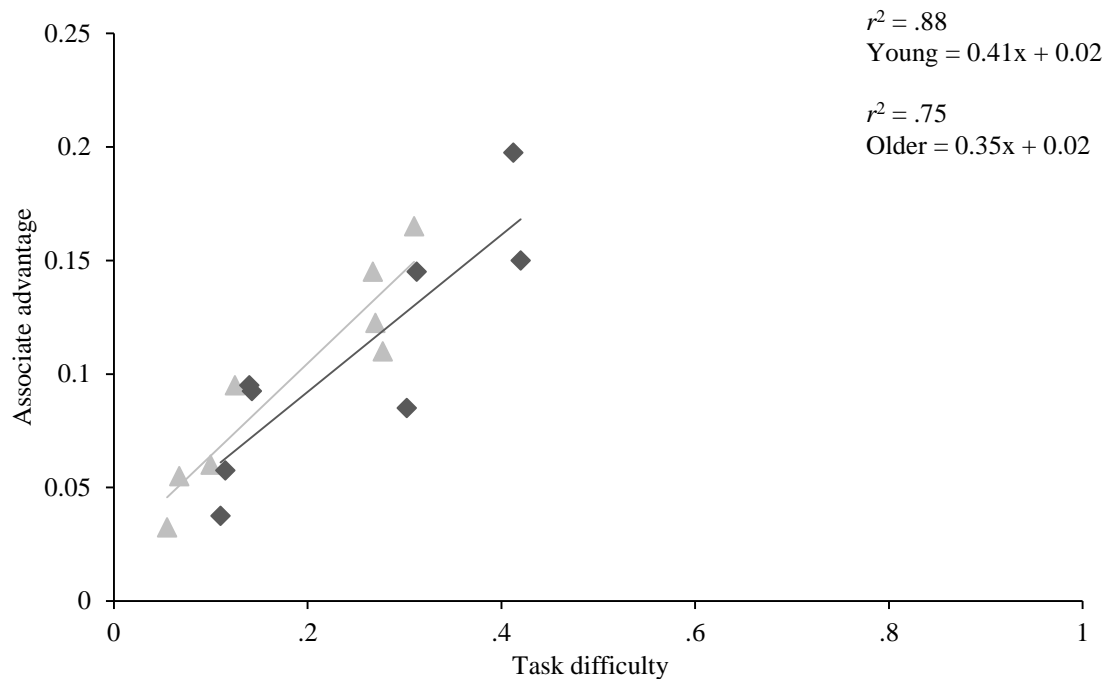
***Correct-in-position recall.*** Figure 7.2 presents the redintegration outcomes for correct-in-position recall comparing young and older adults using the group mean levels of performance across the eight memory conditions.



*Figure 7.2.* Associate advantage as a function of task difficulty for correct-in-position recall for young adults (diamonds) and older adults (triangles)

As can be seen in Figure 7.2, it was evident that the associate advantage increased with task difficulty. This relationship was moderately strong for the older adults ( $r^2 = .65$ ) but stronger for the young adults ( $r^2 = .81$ ), indicating that associations somewhat assisted with recalling the TBR words in their correct serial position. There was no significant difference between the slopes of the older ( $b = 0.24$ ) and young adults ( $b = 0.29$ ),  $t(12) = -0.57$ ,  $p = .579$ . There was also no significant difference between the intercepts of the older ( $c = 0.05$ ) and young adults ( $c = 0.04$ ),  $t(12) = 0.26$ ,  $p = .800$ , indicating redintegrative processing was comparable across age. Redintegration outcomes at the sample level are presented in Appendix C-3.3. Redintegration outcomes at the individual level are presented in Appendices C-3.4 and C-3.5.

**Item recall.** Figure 7.3 presents the redintegration outcomes for item recall comparing young and older adults using the group mean levels of performance across the eight memory conditions.



*Figure 7.3.* Associate advantage as a function of task difficulty for item recall for young adults (diamonds) and older adults (triangles)

From Figure 7.3, ignoring order information, a similar recall trend emerged for young and older adults: As task difficulty increased, the size of the associate advantage increased. It is important to highlight that the strength of the relationship between the associate advantage and task difficulty was strong for the older ( $r^2 = .75$ ) and young adults ( $r^2 = .88$ ), where associations greatly benefited recall of the TBR words. There was no significant difference between the slopes of the older ( $b = 0.35$ ) and young adults ( $b = 0.41$ ),  $t(12) = -0.57$ ,  $p = .578$ . There was also no significant difference between the intercepts of the older ( $c = 0.02$ ) and young adults ( $c = 0.02$ ),  $t(12) = -0.00$ ,  $p = .999$ , indicating redintegrative processing was comparable across age. Redintegration outcomes at the sample level are presented in

Appendix C-3.6. Redintegration outcomes at the individual level are presented in Appendices C-3.7 and C-3.8.

**Order accuracy.** Figure 7.4 presents the redintegration effects for order accuracy comparing young and older adults in their mean levels of performance across the eight memory conditions.

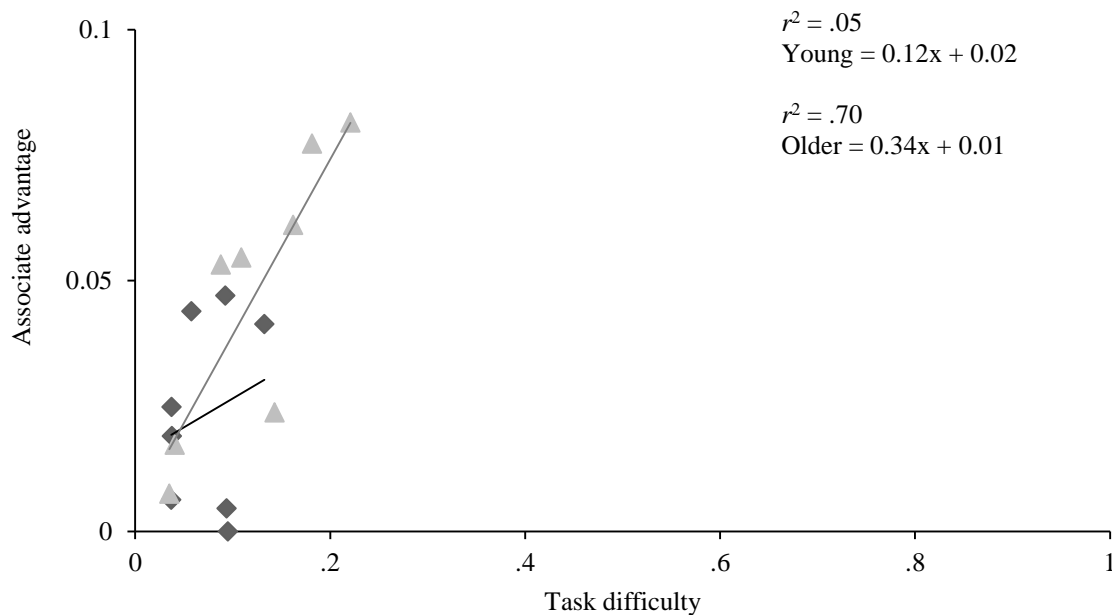


Figure 7.4. Associate advantage as a function of task difficulty for order accuracy for young adults (diamonds) and older adults (triangles)

Considering order information, Figure 7.4 shows that young and older adults demonstrated a positive relationship between the associate advantage and task difficulty. Although this relationship was strong for the older adults ( $r^2 = .70$ ), this same relationship was extremely weak for the young adults ( $r^2 = .05$ ), indicating that associations had a greater impact on increasing the probability for older adults to recall the TBR words in their serial position compared with young adults. There was no significant difference between the slopes of the older ( $b = 0.34$ ) and young adults ( $b = 0.12$ ),  $t(12) = 1.08$ ,  $p = .303$ . There was also no significant difference between the intercepts of the older ( $c = 0.01$ ) and young adults ( $c =$

0.02),  $t(12) = -0.52$ ,  $p = .613$ , indicating redintegrative processing was comparable across age. Redintegration outcomes at the sample level are presented in Appendix C-3.9. Redintegration outcomes at the individual level are presented in Appendices C-3.10 and C-3.11.

## **Discussion**

### **Study overview**

This study aimed to make a unique contribution to the redintegration literature by measuring redintegration using associate word pairs through Schweickert's (1993) Multinomial Processing Tree Model of Redintegration. The memory literature has ascertained the importance of long-term semantic associations improving short-term recall performance in the forms of semantic relatedness (Neale & Tehan, 2007; Poirier et al., 2011; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b), inter-item associative strength (Tse, 2009), and integrative relations (Badham et al., 2012) shared among the pair of TBR items. As explained from the redintegration perspective, the semantic relation inherent among the TBR items served to act as an additional retrieval cue to limit the number of potential recall candidates and enhance reconstruction of the degraded short-term phonological memory traces of the TBR items for later output. It was important to determine whether these semantic advantages in short-term recall extended to redintegration.

This study also aimed to continue examining age differences in redintegration to determine whether measuring redintegration using other variables, such as associate word pairs, would provide new insight into potential age-related differences in redintegration or whether redintegration still remains age invariant. The findings from Neale and Tehan (2007), along with Study one of this thesis, have established that redintegration is age invariant, where

young and older adults engage in the same process to facilitate verbal STM performance. Furthermore, the ageing and associate memory literature purports that young adults outperform older adults in cognitive-based tasks, particularly when the TBR information is weakly related or has no semblance of an associate relationship. However, in tasks where associations are inherent among the TBR items, older adults utilise their long-term knowledge to improve their verbal STM performance and match that of the young adults (Kausler & Lair, 1966; Naveh-Benjamin, 2000; Zaretsky & Halberstam, 1968). It was important to investigate whether these age-related differences in associate memory tasks would extend to redintegrative processing.

### **Associate word pairs and redintegration**

This study has made an important contribution to the redintegration literature by observing an associate advantage during short-term recall when redintegration was measured using associate word pairs. In line with the expectations of this study, the unique combination of recall intervals, study conditions, and presentation rates, created a graded level of task difficulty across the various experimental conditions that increased the reliance on redintegration to facilitate short-term recall for correct-in-position recall, item recall, and order accuracy. Redintegration effects in this study were in the form of the associate advantage, where participants recalled an increasingly higher proportion of words in the associate pairs compared with the non-associate pairs as task difficulty increased. Redintegration, as explained through Schweickert's (1993) Multinomial Processing Tree Model of Redintegration, adequately accounted for the associate advantage observed during short-term recall. Essentially, when individuals could not recall the words in the pairs, individuals used their long-term phonological and semantic knowledge to reconstruct those degraded short-

term phonological memory traces for later output (Neale & Tehan, 2007; Schweickert, 1993; Thorn et al., 2004). Individuals used the associate relationship inherent between the words in the associate pairs as an additional retrieval cue to limit the number of potential recall candidates and locate the correct long-term information that could be integrated with the remaining information that was available in verbal STM to help reconstruct the degraded short-term phonological memory traces. For the non-associate pairs, as the words did not share any degree of semantic association, individuals would have searched the entire contents of their LTM to locate the correct information for each word in order to rebuild the memory trace for each TBR word for subsequent output. Moreover, these benefits of association at the item level also extended to the order level, where having the TBR words associated with each other enhanced the likelihood of recalling those words in their correct serial position, particularly with increasing task difficulty. Together, these findings clearly illustrate that consistent with the redintegration literature, long-term knowledge in the form of semantic associations, further facilitated the redintegration process and improves access to long-term representations that aids verbal STM performance (Neale & Tehan, 2007; Poirier et al., 2011; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b; Tse, 2009).

The associate advantages observed in this study for correct-in-position recall, item recall, and order accuracy confirmed the importance of long-term semantic associations benefiting verbal STM performance. Participants utilised the organised nature of information in LTM by identifying that the words in some of the TBR pairs were associated. Performance appears to suggest that during encoding, a spreading activation occurred in LTM, whereby the semantic representation of one TBR word activated the semantic representations of other words in the same semantic category. This spreading activation (Collins & Loftus, 1975;



MacKay & Burke, 1990) then guided the search for those potential recall candidates to the specific category and subsequently increased the efficiency of the redintegration process. Specifically, individuals were able to retrieve the correct information in order to reconstruct the degraded short-term phonological memory traces of those words along with its serial position and, in turn, enhanced immediate serial recall performance. Poirier and Saint-Aubin (1995) found a categorical relatedness advantage in short-term recall and this advantage became stronger when they introduced interference, in the form of articulatory suppression, into the experimental task. When individuals were required to engage in the articulatory suppression activity, the size of the recall difference between categorically related items and categorically unrelated items became greater than under quiet conditions. Poirier and Saint-Aubin also believed that there was a greater reliance on the semantic category of the TBR items as an additional retrieval cue to combat the interference produced during encoding from the articulatory suppression activity and aid short-term recall. Similarly, Neale and Tehan (2007) along with Saint-Aubin and Poirier (1995; 1999a; 1999b) found a semantic similarity advantage, where the size of the recall difference between the semantically similar and dissimilar TBR items increased when some form of interfering activity was introduced into the experimental task. Individuals perceived the relation between the TBR items and thus relied on semantic similarity as an additional retrieval cue to locate the short-term phonological representations of the TBR items in LTM for later short-term output. With specific reference to Schweickert's (1993) Multinomial Processing Tree Model of Redintegration, Tse (2009) found that having the TBR words related by category or association enhanced the redintegration process. Specifically, the relation shared between the TBR items induced a spreading activation in LTM that guided the search for those potential recall candidates from a specific category or theme through activating their semantic representations in LTM. The

results of this study, together with previous research, have demonstrated that that when short-term recall is problematic, individuals use their previously stored long-term phonological and semantic knowledge to facilitate redintegrative processing and improve memory performance (Neale & Tehan, 2007; Poirier et al., 2011; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b; Schweickert, 1993).

In conclusion, this study has measured redintegration using associate word pairs and has established an associate advantage in verbal STM, where the recall difference between words in the associate and non-associate pairs increased with the difficulty of the experimental task. These findings also continue to support the memory literature that outlines the benefits of long-term knowledge facilitating verbal STM performance (Bousfield, 1953; Bower et al., 1969; Collins & Loftus, 1975; MacKay & Burke, 1990). When short-term recall was problematic, individuals largely relied on their long-term semantic knowledge to aid short-term recall of the TBR items (Poirier et al., 2011; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b; Tse, 2009). When there was some level of association among the TBR words, individuals utilised this association as an additional retrieval cue that induced a spreading activation in LTM. This spreading activation then continued to guide the search for long-term information to increase the likelihood of redintegrating the short-term phonological memory traces for the TBR items for later output (Neale & Tehan, 2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b; Tse, 2009). Most importantly, these findings continued to support the notion of redintegration operating in verbal STM that in the face of interference during a short-term recall task, individuals effectively cue the search for long-term knowledge to identify information that will assist with retrieving and recalling the required information.

### **Age differences, associate word pairs, and redintegration**

This study has also made an important contribution to the redintegration literature by revealing further insight into how young and older adults redintegrate, particularly when the TBR information is associated. The performance of young and older adults in this study yielded three key findings. Firstly, young and older adults recalled a comparable proportion of words in the associate and non-associate pairs for correct-in-position recall and item recall. The only significant age difference in recall performance was for order accuracy, where young adults were significantly more accurate at recalling the TBR words in their correct serial position, given they recalled the TBR word initially, compared with older adults. Secondly, at the redintegration level, regression analyses for correct-in-position recall, item recall, and order accuracy revealed there was no significant difference in the slopes or intercepts for redintegration, indicating that young and older adults called upon the same redintegrative processing to facilitate verbal STM performance. Young and older adults engage in the same process when short-term recall became problematic and used the association inherent among the associate pairs as an additional retrieval cue to enhance redintegration for those words they could not recall. Thirdly, also evidenced in the regression analyses for correct-in-position recall, item recall, and order accuracy, the size of the recall difference between words in the associate and non-associate pairs was greater for older adults compared with young adults. Given the cognitively demanding nature of the experimental task, where interference became greater during the difficult task conditions, these results also suggest that older adults utilised these semantic associations to reduce the amount of cognitive effort required to complete the experimental task by drawing upon their pre-existing knowledge to enhance their memory performance. Thus, adults across the lifespan demonstrate the beneficial effects of long-term

semantic knowledge by capitalising on the semantic associations inherent among the words in the associate pairs to enhance redintegration and facilitate retrieval of the TBR items for subsequent output.

The findings from this study have clearly illustrated that the benefits of semantic knowledge improving age-related memory performance translated to redintegrative processing. Memory performance mirrored Neale and Tehan's (2007) where participants, irrespective of age, utilised item similarity (i.e., semantic, phonological) to facilitate the redintegration process, particularly during the difficult task conditions. However, the comparable recall performance of young and older adults across the various task conditions in this study for short-term recall, specifically correct-in-position recall and item recall, was somewhat surprising, given that the graded interference in the experimental task was assumed to have a greater impact upon encoding and retrieval processes, particularly for the older adults relative to young adults. The average level of performance in each condition across the two methods of scoring were close to ceiling in the easier conditions and remained relatively high even as task difficulty increased. These findings suggest that irrespective of age, there was a strong reliance on long-term semantic associations to facilitate verbal STM performance. When information had some level of semantic association, young and to a greater degree, older adults, capitalised on these associations to encode the TBR items into verbal STM more efficiently and then use the semantic associations as a retrieval mechanism to identify the correct long-term information that would assist with recalling the TBR items for subsequent output. Furthermore, where the TBR items bare no semblance of an associate relationship, there are no cues available to guide encoding and then use as a retrieval mechanism to guide the search for pre-existing information, which was at a greater detriment

to the older adults as opposed to their young counterparts. These findings are consistent with previous research that demonstrates typical age differences in unrelated information, but these age differences in performance are abolished when the TBR information is semantically related as encoding and retrieval conditions are enhanced (Kausler & Lair, 1966; Naveh-Benjamin, 2000; Zaretsky & Halberstam, 1968). In similar experimental paradigms, Kausler and Lair (1966) along with Zaretsky and Halberstam (1968) found no significant age differences in recall performance when young and older adults recalled word pairs with high and medium associative strength. In contrast, young adults recalled a significantly higher proportion of word pairs with low experimental associative strength relative to older adults. Their findings indicated that when information is highly associated or has some level of semantic association, young adults and, to a greater degree, older adults, capitalise on the associations inherent among the TBR items as a retrieval mechanism to identify the correct information in LTM to facilitate short-term recall (Kausler & Lair, 1966; Naveh-Benjamin, 2000; Zaretsky & Halberstam, 1968). Similarly when Naveh-Benjamin (2000) along with Howard et al. (1991) enhanced encoding and retrieval conditions with the provision of environmental cues, the magnitude of age differences during recall were minimal, even abolished because older adults utilised their years of language knowledge to enhance encoding and retrieval to match the performance of their young counterparts. These findings collectively inform the importance of long-term semantic knowledge aiding redintegration and verbal STM performance for adults across the lifespan.

To conclude, the respective performances of young and older adults in this study have indicated that when encoding and retrieval are problematic, individuals engage in the same redintegrative processing to facilitate short-term recall. They draw upon their long-term

semantic knowledge to assist with encoding and subsequently retrieving information to reconstruct the damaged short-term phonological memory traces of the TBR words. Furthermore, they all capitalise on retrieval cues (i.e., associations) to enhance the redintegration process, which facilitates subsequent retrieval of those TBR items for later output (Kausler & Lair, 1966; Naveh-Benjamin, 2000; Neale & Tehan, 2007; Zaretsky & Halberstam, 1968). These informative findings continue to support the notion that irrespective of age, individuals use redintegration to call upon previously stored long-term associations to facilitate verbal STM performance.

### **Recall errors and redintegrative processing**

Consistent with Study one of this thesis, the errors participants produced during the experimental task were of secondary interest to this study. From the redintegration perspective, individuals produce errors during recall because of difficulties with interpreting the short-term phonological memory traces based on the remaining information available in verbal STM and because those memory traces were degraded to the extent that no more useable information remained on which to build a reconstruction attempt (Neale & Tehan, 2007; Schweickert, 1993; Thorn et al., 2004). In this study, participants produced a significantly higher proportion of transposition and omission errors when recalling words in the non-associate pairs compared with associate pairs. Much like Study one of this thesis, the manipulations of task difficulty interfered with encoding that it also interfered with attempts at redintegrating those degraded short-term phonological memory traces for the forgotten TBR items (Neale & Tehan, 2007; Schweickert, 1993; Thorn et al., 2004).

**Transposition and omission errors in redintegration.** Transposition errors occur when participants transpose the order of two TBR items by recalling them in their adjacent

serial positions (Saint-Aubin & Poirier, 2000). Participants in this study would presumably produce a higher proportion of transposition errors for words in the associate pairs compared with non-associate pairs because the semantic relationship inherent among the words in the associate pairs may have contributed to difficulties with interpreting the short-term phonological memory traces of those items. Surprisingly, this did not occur because in a reverse trend on memory performance, participants produced a significantly higher proportion of transposition errors during short-term recall for words in the non-associate pairs compared with associate pairs. For example, rather than recalling *grow, eye, gown, take*, a participant recalled *grow, gown, eye, take*, where *eye* and *gown* were transposed. This is an interesting observation given that the literature suggests that difficulties with interpreting the short-term phonological memory traces of the TBR items occurs for items that are associated with each other. One suggestion for this finding is unlike the associate pairs, there was no logical inherent semantic association that could have potentially assisted with encoding the pair of words in verbal STM. Coupled with the increased interference in the memory task, particularly during the difficult task conditions, there was a greater likelihood of participants transposing the words in the non-associate pair because there was no form of additional retrieval cue, other than the information they would have generated in verbal STM, to reconstruct the degraded short-term phonological memory trace. By comparison for the associate pairs, the semantic association may have guided encoding the words into verbal STM, reducing the likelihood of confusing the short-term phonological memory traces of those items during retrieval and increase the chances of recalling the words in their correct serial order.

Omission errors, on the other hand, occur when participants omit a word during short-term recall as they have difficulties with rebuilding the missing components of the degraded short-term phonological memory trace (Saint-Aubin & Poirier, 2000). Omissions at recall depends on the amount of information remaining verbal STM to locate long-term information and attempt to reintegrate the memory trace (Saint-Aubin & Poirier, 2000). In this study, participants omitted a significantly higher proportion of TBR items from the non-associate pairs compared with the associate pairs. During the difficult task conditions, problems presumably occurred during reintegration where there was no useful information long-term to match with the remaining information available in the short-term phonological memory trace for the TBR item. The absence of a semantic relationship between the words in the non-associate pair may have contributed to difficulties experienced at encoding which means that there was no cue available during retrieval to guide the reconstruction process. This is in comparison with pairs that shared an associate relationship, which can be utilised at encoding to guide the search process, thus contributing to a reduced likelihood of omitting the TBR items in the associate word pair at recall. This associate advantage is consistent with the pattern of performance Saint-Aubin and Poirier (1995; 1999a; 1999b) observed in their examinations of the semantic similarity effect. Item similarity facilitated the reintegration process by narrowing the search for long-term information to rebuild the short-term phonological memory traces for the TBR items, resulting in higher recall and reduced rate of omissions for semantically similar words compared with semantically dissimilar words. Together, these findings suggest that when short-term recall is problematic, individuals are heavily reliant on their long-term semantic knowledge to reconstruct degraded short-term phonological memory traces of the TBR items for later output.



**Extra-list intrusions and redintegration.** Further examination of participant responses revealed that during output, participants also produced semantically related and unrelated extra-list intrusions for the TBR associate pairs and non-associate pairs. Extra-list intrusions refer to when individuals recall a word that was not presented in a list of TBR items (Deese, 1959; Roediger III & McDermott, 1995). For example, when presented with words in the associate pair *foot-toes*, one participant replaced *foot* with the word *feet*. Similarly, for words in the non-associate pair *yolk-see*, a different participant replaced *see* with the word *egg*. Specifically, participants produced a greater number of semantically related intrusions relative to semantically unrelated intrusions. From the redintegration perspective, individuals encoded the semantic association between the items in the TBR associate pair that induced a spreading activation in LTM for information pertaining to the TBR items. However, during retrieval, other non-presented but semantic associates of the TBR items became activated in LTM. When reconstructing the short-term phonological memory trace, participants believed the phonological representation of the non-presented semantic associate of the TBR item to be a correct match with the information available in the short-term phonological memory trace of the TBR item that they erroneously reconstructed the degraded short-term phonological memory trace with the representation of the non-presented semantic associate. This resulted in the participant recalling the non-presented semantic associate instead of the original TBR item. For the non-associate pairs, despite the TBR items not being associated with each other, participants presumably used the same strategy. They encoded the category associated with each TBR item into verbal STM and during retrieval, they produced an extra-list intrusion at recall. These unexpected findings indicate that a false memory effect may have occurred during redintegration, an observation that has not been previously established in the literature.

This observation is consistent with Badham et al. (2012, Experiment 2), that identified a similar pattern of extra-list intrusions in their study. Specifically, participants recalled words that were congruent with the TBR items in the semantically related and integrative word pairs. Badham et al. attributed these errors to the difficulties participants experienced during encoding and retrieval such that participants used the integrative and semantic relations shared between the words in the pair as retrieval cues to support short-term recall. They further inferred that intrusions resulted from participants forming concepts consistent with world knowledge, which may have made it easier to encode and/or retrieve the pairs than the unrelated pairs, but also contributed to the higher proportion of intrusions made in their study. Therefore, the prevalence of extra-list intrusions during short-term recall in this study, be it semantically related or semantically unrelated to the items in the TBR associate and non-associate pairs, indicate there is a strong reliance on long-term semantic knowledge. Such a reliance activated other representations in LTM that were associated with the TBR item which enhanced redintegration of the TBR words, but also led to false memories being produced during redintegration.

To conclude, the transposition, omission, and extra-list intrusion errors in this study provide important evidence that interference during encoding affected retrieval to the extent that it resulted in unsuccessful attempts at redintegrating the damaged short-term phonological memory traces for the TBR pairs (Neale & Tehan, 2007; Schweickert, 1993). However, these difficulties during redintegration were somewhat alleviated when there was a semantic association inherent among the words in the TBR pair. This pattern of errors further substantiates the claim that there is an increased reliance on long-term knowledge to the extent that individuals cued the search for long-term information by relying on semantic associations

to assist with retrieving the correct TBR items for later short-term recall (Neale & Tehan, 2007; Poirier et al., 2011; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b).

## **Conclusion**

To conclude, this empirical investigation continued demonstrating the utility of redintegration through its measurement using associate word pairs. As task difficulty increased, redintegration effects in the form of an associate advantage became evident during short-term recall, where participants recalled a higher proportion of words in the associate pairs relative to words in the non-associate pairs. Importantly, a cueing effect emerged during redintegration, where individuals used these semantic associations as an additional retrieval cue to guide the search for long-term information that enhanced redintegration, with young and older adults engaging in the same redintegrative processing to facilitate short-term recall. Finally, the higher proportion of transposition and omission errors for non-associate pairs relative to associate pairs indicated that the manipulation of task difficulty produced the predicted levels of interference during encoding so that individuals had trouble redintegrating the short-term phonological memory traces of the TBR items. These subsequent difficulties also led to participants producing extra-list intrusions, semantically related and unrelated to the TBR associate and non-associate word pairs during short-term recall. These notable findings strengthen the importance of utilising long-term associate knowledge when short-term recall becomes problematic, but also that such a reliance can lead to producing false memories at output (Badham et al., 2012; Neale & Tehan, 2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b; Tse, 2009). These findings highlight that a spreading activation occurs in LTM that activates the long-term representations for the TBR

items but, as observed in this study, the spreading activation extends to other non-presented semantic associates of the TBR items. The reliance on long-term semantic knowledge is so great that when retrieval is considerably difficult, individuals will erroneously use information they deem an appropriate match with the remaining information in verbal STM that they unintentionally produce false memories at output. Given this new possibility that false memories may emerge during redintegration, Chapter eight continues examining the redintegration process by measuring redintegration using the false memory effect (Deese, 1959; Roediger III & McDermott, 1995).

### **Chapter eight: Third empirical study-False memory and redintegration**

Long-term representations are not always reliable representations of the past and they can reflect events that never occurred (Deese, 1959; Roediger III & McDermott, 1995). Examination of participant responses from Chapter seven demonstrated this concept of false memories, where participants produced semantically related and unrelated extra-list intrusions during recall, which became more prevalent during the difficult task conditions. By definition, extra-list intrusions are items recalled that were not in the original list of TBR items (Roediger III & McDermott, 1995). The presence of semantically related extra-list intrusions during recall further substantiated the intrinsic relationship between verbal STM and LTM, where individuals used the semantic relationship among the TBR items as an additional retrieval cue to facilitate the redintegration process. From the redintegration perspective, these intrusions indicated that the search for long-term information activated other non-presented semantic associates of the TBR items to the extent that individuals erroneously reconstructed the memory trace with the representations of the non-presented associate. Subsequently, the non-presented associate was recalled instead of the originally presented TBR item. Given no studies to this date have measured redintegration using the false memory effect (Roediger III & McDermott, 1995), this relationship represented an important area of inquiry.

#### **The false memory effect and verbal short-term memory**

A false memory refers to either remembering an event that never happened or remembering an event that happened but differently from how the event originally occurred (Bartlett, 1932; Underwood, 1965). Empirical investigations into the false memory effect have established that false memories occur because memory for other related but non-presented information becomes active in LTM such that when memory for the original information is

distorted, individuals inferentially use the non-presented information to reconstruct the original memory (Bartlett, 1932; Underwood, 1965). The false memory effect became formalised in a paradigm in what researchers known as the Deese/Roediger and McDermott (DRM) paradigm (Roediger III & McDermott, 1995). This paradigm articulated the mechanisms underpinning this effect and established that the probability of extra-list intrusions occurring during recall was relative to the associative strength of that intruding item to the other TBR items in the list.

The false memory effect has been firmly established in LTM (Deese, 1959; Roediger III & McDermott, 1995) through free recall and recognition tasks (Roediger III & McDermott, 1995; Underwood, 1965). The shared association among the TBR items in the DRM lists was proposed to induce a spreading-like activation of semantic representations in LTM to retrieve information pertinent to the TBR items and facilitate recall (Roediger III & McDermott, 1995; Underwood, 1965). Yet, because the words in the DRM list were associated with a critical non-presented lure, the spreading activation is also said to have activated the semantic representations of other non-presented associates, including the critical non-presented lure (Roediger III & McDermott, 1995; Underwood, 1965). During recall, individuals unintentionally recalled the critical non-presented lure instead of the originally presented TBR item, thus producing a false memory (Roediger III & McDermott, 1995; Underwood, 1965).

While these observations are true in LTM, few studies have examined the false memory effect in verbal STM. The extant literature appears to suggest that individuals produce false memories in verbal STM because an important interaction occurs between the permanently stored information in LTM and the temporarily stored information held in verbal STM (Atkins & Reuter-Lorenz, 2008; Coane, McBride, Raulerson III, & Jordan, 2007; Tehan, 2010). A

study by Coane, McBride, Rauleson III, and Jordan (2007) demonstrated this interaction in their examination of the false memory effect in verbal STM. They used a short-term recognition memory task and compared reaction times and recall accuracy to four different item probes: an item test probe, a weakly related probe, the critical non-presented lure, and an unrelated item probe. Coane et al. proposed that response times to rejecting the critical non-presented lure probe would be slower in comparison to the other word probes because the critical non-presented lure probe would require additional checking in verbal STM to ensure it was not a TBR item due to its the heightened activation in LTM.

Coane et al. (2007) found that correct rejection of the critical non-presented lure probe was slower relative to the weakly related, unrelated, and item probes. Importantly, there was no significant difference in reaction times for correctly rejecting the weakly related and unrelated probes, suggesting the critical non-presented lures were more likely than other non-studied items to undergo that additional checking, which produced longer reaction times. Recall accuracy was also lower for the critical non-presented lure and item probes than for the weakly related and unrelated probes. Coane et al. then sought to test whether the differences in reaction times were due to differences in the TBR items. Using lists of semantically related and unrelated items, reaction times for correctly rejecting the critical non-presented lure probe in the semantically related lists were slower than for the weakly related probe. In contrast, for the semantically unrelated lists, there was no significant difference between the reaction times for correctly rejecting the critical non-presented lure and unrelated probes, but the false alarm rates to the critical non-presented lure probe were still greater than the false alarm rates to the weakly related or unrelated probes. Coane et al. inferred from their multitude of findings that participants continued experiencing problems with discriminating the critical non-presented

lure probe from other item probes because of the increased levels of activation from previously stored long-term information. As such, because of the competing information, individuals engaged in additional monitoring in verbal STM to recognise the TBR item and correctly reject the probe item. Their findings provided support for the role of long-term semantic information facilitating the storage and retrieval of the TBR information in verbal STM.

Atkins and Reuter-Lorenz (2008) also believed that false memories were best explained through the product of processes shared in verbal STM and LTM. To examine their proposal, Atkins and Reuter-Lorenz completed two groups of experiments. For the recall task, participants viewed 48 different four-item DRM-type lists that were tested after a filled retention interval, during which they were required to complete a mathematics verification task. For the recognition task, after the filled-retention interval, participants were presented with a positive probe, a negative probe, or a lure probe and were instructed to identify the correct probe that appeared in the memory set. Using the frequency of errors as their measure of recall and recognition performance, Atkins and Reuter-Lorenz found that participants were twice as likely to falsely recognise the lure probe compared with the negative probe, but they were more accurate in responding to the positive probe (i.e., a correct “yes” response) compared with the lure probe (i.e., a correct “no” response). Additionally, reaction times for the lure probe were significantly slower than the reaction times for the negative and positive probes. For the free recall task, Atkins and Reuter-Lorenz found participants produced more semantic errors in recall than phonological or other errors, with 66% of the semantic errors consisting of the theme word associated with the items in the original DRM list and 18% of the semantic errors being the semantically associated non-presented lure from the original



DRM-type list. In a second group of experiments, participants completed the same recognition and recall tasks but removed the distractor task to allow participants to engage in subvocal rehearsal. Interestingly, the recognition and recall results mirrored their first group of experiments, with 46% of the semantic errors consisting of the theme word associated with the memory set and 24% of the errors being non-presented items from the original DRM-type lists. From their findings, Atkins and Reuter-Lorenz also suggested that long-term semantic memory was the basic source of associative processes that activated thematically related lures and associates in LTM to access the semantic codes that are shared and common to both short- and long-term remembering. They concluded that their results provided evidence of an interaction between verbal STM and LTM that facilitated the false memory effect in verbal STM.

Tehan (2010) too acknowledged that pre-existing long-term lexical/semantic networks influence the likelihood of successful short-term recall, inhibiting short-term recall, or producing false memories in a verbal STM task. Tehan purported that one's permanent knowledge is comprised of a network of associatively connected items that, although distinct, are connected to a main lexical network. The more connected the TBR items are in LTM, the greater likelihood that individuals would recall the TBR items. Thus, when encoding a list of associatively related TBR items, a spreading activation occurs in LTM that heightens the activation levels of the respective short-term phonological representations compared with a list of unrelated items. However, the spreading activation would also heighten the activation levels of the short-term phonological representations of other non-presented associates of the TBR items, potentially interfering with retrieving the correct information for later output. Importantly, Tehan further noted that interference from the non-presented but activated

associates is likely to be observed when the episodic information for the TBR items is weak or entirely lost. Thus, Tehan expected that the pre-existing information in LTM would facilitate short-term recall in the form of higher recall for lists of associatively related items relative to lists of unrelated items, but also hinder short-term recall performance in the form of producing false memories.

To examine these propositions, Tehan (2010) instructed participants to view 20 six-item trials. For 10 trials, the lists contained six items that had the strongest backward associative relation to a critical non-presented lure, which appeared in descending order of strength to the non-presented lure. The remaining 10 trials contained lists of six randomly selected and unrelated items. Using immediate and delayed recall conditions, Tehan found recall was significantly higher for the associatively related lists compared with the unrelated lists. Importantly, participants recalled a significantly higher proportion of critical non-presented lures during the delayed conditions compared with the immediate conditions. The majority of the non-presented lures that were recalled occurred toward the end of the list, where Tehan presumed that the quality of the episodic information needed to support recall was diminished.

Tehan (2010) interpreted the findings as indicative of an interaction occurring between information held in verbal STM and previously stored semantic knowledge in LTM. The TBR items that were encoded and stored into verbal STM interacted with the pre-existing long-term information. While this interaction aided veridical recall of the TBR items, this interaction, according to Tehan, may have spread to other non-presented associates in LTM, interfering with memory performance in the form of producing a false memory, depending on the amount of episodic that was lost by the output stage. Interestingly, Tehan alluded to the notion that the findings were similar to those studies examining taxonomic similarity effects (Neale & Tehan,

2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b), which did not assume that associative links needed to exist between items to aid short-term recall. Rather, the associations acted as a form of cue to continue narrowing the search for long-term information to a specific section that would aid retrieval of information to recall the TBR items for later output. Ultimately, Tehan believed that the associative links shared among the TBR items induced a spreading activation in LTM, which facilitated veridical and false recall in a verbal STM task. All of these observations aligned with the redintegrative framework that proposes a reciprocal relationship between the information retained in verbal STM, the permanently stored knowledge in LTM, and the retrieval processes used to extract long-term information to facilitate short-term recall.

To conclude, the literature has established the robust false memory effect (Bartlett, 1932; Deese, 1959; Roediger III & McDermott, 1995; Underwood, 1965) in verbal STM (Atkins & Reuter-Lorenz, 2008; Coane et al., 2007; Tehan, 2010). An important interaction exists between information temporarily held in verbal STM and permanently stored in LTM that enhanced recall of the TBR items, but also increased the susceptibility of producing a false memory at output due to a spreading activation in LTM, particularly when the episodic information for the TBR items was weakened. It was reasonable to believe that having the TBR words related to a critical non-presented lure would enhance the redintegration process, as the critical non-presented lure would act as an additional retrieval cue to locate the correct information and enhance item reconstruction. However, this search may also activate the non-presented semantic associates to the TBR items, and the critical non-presented lure. Higher levels of degradation to the short-term phonological memory trace may lead to erroneously reconstructing the trace of the TBR item with the short-term phonological representation for

the critical non-presented lure word instead of the TBR item, leading to false memories using redintegration. Given no study to this date has examined the relationship between the false memory effect and redintegration by manipulating task difficulty, this relationship warranted further investigation.

It was important to note that a majority of the research investigating the false memory effect in verbal STM has been conducted solely with young adults, with few studies comparing their performance with older adults. It was also important to understand the susceptibility to false memories across the age spectrum. Specifically, older adults may process the lists of TBR items differently from young adults, which may shed new light on the mechanisms underlying the false memory effect that, in turn, may influence their ability to redintegrate lists of words related to a critical non-presented lure and lists of unrelated words. As no research to this date has conducted such an exploration between age and false memory using redintegration, this relationship also represented an important area of inquiry.

### **Ageing and the false memory effect in verbal verbal short-term memory**

The memory literature widely accepts cognitive ageing is often associated with differences in memory performance across various tasks, where young adults outperform older adults (Balota et al., 2000; Craik et al., 1987; Craik & McDowd, 1987; Dehon & Bredart, 2004; Luo & Craik, 2008; Norman & Schacter, 1997; Schacter, Koutstaal, Johnson, Gross, & Angell, 1997). Research also suggests cognitive ageing is associated with an increased susceptibility to a wide range of false recollections, where older adults are more susceptible to producing false memories compared with young adults as they experience considerable difficulty with encoding and retrieving information for output (Dehon & Bredart, 2004; Norman & Schacter, 1997; Schacter et al., 1997; Tun, Wingfield, Rosen, & Blanchard, 1998).

Investigations of age differences in false memory tasks have revealed two different patterns of memory performance: Young adults produce higher levels of veridical recall and recognition compared with older adults; however, older adults produce higher levels of false recall and recognition relative to young adults (Dehon & Bredart, 2004; Norman & Schacter, 1997; Schacter et al., 1997; Tun et al., 1998). Researchers have proposed two factors that may explain this age-related increase in false memories: deficits in attentional control (Balota et al., 1999; Schacter et al., 1997; Tun et al., 1998) and difficulties experienced with source monitoring (Roediger III, Balota, & Watson, 2001; Schacter et al., 1997).

**Attentional control.** Attentional control processes are required to discriminate between multiple sources of activated information, but the efficiency of these processes reduces with increasing age (Balota et al., 1999; Schacter et al., 1997; Tun et al., 1998). When attentional control processes are intact, individuals can discriminate between activated sources of information directly from information that is indirectly related but are highly associated to the TBR items. However, if there is damage to attentional control processes, discriminating between the multiple sources of activated information becomes problematic (Balota et al., 1999; Schacter et al., 1997; Tun et al., 1998). A study by Balota et al. (1999) explicated how attentional control may underlie the false memory effect across the age spectrum. They hypothesised that if there was a breakdown in attentional control processes but the semantic structures that boost semantic activation of the critical non-presented lure were intact, this might increase the likelihood of older adults producing false memories at recall compared with young adults.

Balota et al. (1999) tested this proposition by using three groups to track the influence of healthy ageing on false memories: healthy young adults (17-33 years), healthy young-older

adults (60-79 years), and healthy older-older adults (80-96 years), all of which had no cognitive impairment. Using a free recall task with the DRM type-lists and a recognition task containing all the items participants viewed during the task, Balota et al. found a significant 26% difference in veridical recall between the young adults and both the young-older and older-older adults, favouring the young adults. Surprisingly, there was a small but non-significant 5% increase in recall of the critical non-presented lure across the three age groups. Examining the errors produced during recall, irrespective of age group, participants produced semantically related errors to the TBR items, which suggested there was some level of activation of other associate representations in LTM that significantly increased as a function of age. For the recognition task, however, there was a large age increase in the false alarms to the critical non-presented lures. Specifically, the older-older adults falsely recognised a significantly higher proportion of critical non-presented lures compared with the young-older and young adults, respectively.

Balota et al. (1999) interpreted the collective performance of their sample as reflecting deficits in attentional control processes that select among activated pathways due to spreading activation and those processes that select item-specific information due to memory encoding. They suggested there were two sources of information competing for correct output during an episodic memory task. Efficient attentional control systems need to be able to discriminate between the two sources of information by accentuating the item-specific information and inhibiting the activated pathways due to spreading activation in LTM that converged on the critical non-presented lure. Balota et al. believed that older adults heavily relied on the relations across the TBR items rather than attending to each item in the list. Thus, relational

processing may have benefited their veridical recall performance but it also increased their susceptibility to producing false memories in an experimental task.

To compensate for reductions in attentional control processes, researchers have also suggested there is an age-related increase in gist-based processing, which also gives rise to the false memory effect (Reyna & Brainerd, 1991; Tun et al., 1998). By definition, gist-based processing refers to memory processes that rely on the underlying themes of the TBR information rather than relying on item-specific processing (Reyna & Brainerd, 1991; Tun et al., 1998). Tun et al. (1998) established gist-based processing in a false memory task, where they proposed that older adults might be more reliant on gist-based processing because it is less effortful for them than having to make decisions based on the actual TBR items. However, such processing would make them more susceptible to producing false memories compared with young adults because other non-presented information related to the TBR item may become activated through gist-based processing.

To examine that proposition, Tun et al. (1998) had 25 young adults (18-22 years) and 25 older adults (60-85 years) view 10 DRM-type lists and complete a free recall task. Participants then completed a recognition task that encouraged the use of a gist-based strategy to make the young adults perform in a similar manner to the older adults. They viewed 14 items, half of which were older items that had been presented on the study list and the other half were new distractor items, which had not been presented. Participants were asked to respond “yes” if the item was originally presented in the study list or “no” if the item had not been previously presented. Tun et al. found that older adults recalled as many critical non-presented lures as young adults, however, older adults recalled fewer TBR items compared with young adults. Interestingly, there was no significant age difference in correctly recognising the TBR items

and falsely recognising the critical non-presented lure. Tun et al. suggested that young adults perform much like older adults when the recognition task emphasises gist-based processing.

Tun et al. (1998) revisited their findings by altering the remembering conditions to lessen gist-based processing and increase item-specific processing. They incorporated some distractor items into the experimental task (i.e., the critical non-presented lure, a weakly related item, and an unrelated item) to encourage recognition judgements based on item-specific information rather than on the overall gist of the list. False recognition rates of the older adults for the critical non-presented lure were highly comparable to their veridical recognition rates for the TBR items. Furthermore, older adults falsely recognised a significantly higher proportion of items that were weakly associated with the list of TBR items compared with young adults. On the contrary, young adults were less likely to claim the critical non-presented lure was one of the TBR items in the list.

Tun et al. (1998) established that older adults were more reliant on gist-based processing to help conserve reduced attentional resources by relying on a less demanding partial matching strategy to make judgments about competing information. Even though older adults' veridical recall of the TBR items was lower compared to the young adults, they were all just as likely to falsely recall items that were highly associated with the study lists. These findings further increased the plausibility that within the redintegration framework, the probability of producing false memories may increase with age as they may engage in gist-based processing to manage the encoding and retrieval demands of the various task conditions.

**Source monitoring.** Closely aligned with attentional control processes, source monitoring is analogous to a decision process where, of all the activated information, individuals decide whether they experienced an actual event or whether they imagined the



event had occurred (Roediger III et al., 2001; Schacter et al., 1997). In false memory tasks, individuals need to distinguish whether they saw the original TBR item and whether the critical non-presented lure was present in the original list (Roediger III et al., 2001; Schacter et al., 1997). Successful source monitoring is indicative of individuals correctly identifying the critical non-presented lure was not presented in the original list. However, difficulties with source monitoring are indicative of individuals mistakenly identifying the critical non-presented lure as one of the original TBR items (Roediger III et al., 2001; Schacter et al., 1997). A study by Schacter, Koutstaal, Johnson, Gross, and Angell (1997) compared the source monitoring abilities across the age spectrum in a false memory task by using videos and photographs.

For Schacter et al.'s (1997) study, 32 young adults (16-22 years) and 32 older adults (60-75 years) watched a videotape of everyday activities, followed by viewing two intermixed sets of photographs depicting important everyday events. Photographs were drawn from the original video tape (i.e., true photographs) and photographs were drawn from a second videotape that was not presented to them (i.e., false photographs). After viewing the videos, participants completed a verbal recognition test two days after the original test, where they were asked to indicate whether they remembered the items depicted in the photographs as being in the video or not. Schacter et al. found young adults recognised significantly more of the items in the true photographs from the videotape compared with older adults. In a reverse trend on memory performance, older adults were more likely to mistakenly claim they remembered the items from the false photographs in the videotape compared with young adults. When asked to focus only on specific items in the videos in a second experiment, a similar pattern of results emerged. Schacter et al. suggested that on both occasions, young

adults were able to access more detailed source information in memory to help distinguish whether the TBR items were true presentations in memory or false attributions in memory. Older adults, on the other hand, tended to confuse the origin of distinct events that happened because they did not access such detailed information, leading them to make incorrect claims of recollecting those items were present in the video when in fact they were not.

Dehon and Bredart (2004) also examined the possibility of age differences existing in one's capacity for source monitoring in a false memory-based task. They hypothesised that older adults would recall fewer TBR items and more critical non-presented lures during an initial recall test compared with young adults. However, if ageing effects were present in source monitoring, then in the additional task, where they were asked about the presence or absence of the critical non-presented lure during the initial recall test, young and older adults would activate the critical non-presented lure but older adults would be less likely to recall the critical non-presented lure compared with young adults.

In Dehon and Bredart's (2004) first experiment, 30 young adults (20-26 years) and 30 older adults (66-75 years) heard six DRM lists and were asked to complete a free recall task. Participants were then required to say if during the learning or recall phase of the task, an item had come to mind but they had not written it down during the recall task because they were not sure if the experimenter had said it. Participants were given the opportunity to write these items down in a different colour to the items they initially wrote down in the recall task. As expected, Dehon and Bredart found a reliable influence of age on veridical and false recall. Young adults recalled a significantly higher proportion of TBR items compared with the critical non-presented lure word. Conversely, for older adults, the proportions for recalling the TBR items and the critical non-presented lures were comparable. When interest centred on

producing the critical non-presented lures, older adults produced fewer critical non-presented lures compared with the young adults. These findings indicated that young adults were better at monitoring the source of their memories compared with older adults, reducing their susceptibility to producing false memories at output.

Dehon and Bredart (2004) further examined whether older adults could spontaneously engage in source monitoring processes. The key difference in this experiment was participants were given strong warnings before the encoding phase of the task to encourage them to engage in strategic processing and create their own strict decision criteria when viewing the items and recording their responses during the memory task. Here, 56 young adults (18-31 years) and 56 older adults (60-83 years) participated, with half of the participants in each age group told each list was associated with a theme word and all items contained in each list were related to another item not presented in the list. They were advised to deduce which word tied all of the words together and be sure that it was not presented in the word list.

Interestingly, Dehon and Bredart (2004) found that warnings had no effect on the proportion of TBR items older adults recalled. While there was a significant reduction in the proportion of critical non-presented lures young adults produced when they were given a warning, it had no significant effect on older adults. When asked to write down additional words they thought were present, young adults benefited from the warnings as they produced a significantly higher proportion of critical non-presented lures compared with older adults. The fact additional warnings given to participants did not help improve the older adults' memory performance suggests that young adults were more effective in their capacity to consciously and spontaneously monitor the origin of their memories compared with older adults. These deficiencies in source monitoring were indicative of difficulties with accessing distinctive

information in memory, with indistinct encoding making the characteristics of veridical memories and false memories more similar to one another. These observations therefore gave further strength to the argument that older adults' deficit in veridical recall but increased false recall might be attributed to problems with source monitoring. It was therefore reasonable to hypothesise that the probability of producing false memories during redintegration would be greater for older adults, particularly when task conditions are inherently difficult, as deficits at encoding would have a substantial influence upon the TBR items older adults retrieved for later output during the various conditions in the experimental task.

In conclusion, the research has ascertained that while there is an age-related decrease in veridical recall, there is an age-related increase in the susceptibility to producing false memories during an experimental task (Balota et al., 1999; Dehon & Bredart, 2004; Norman & Schacter, 1997; Schacter et al., 1997; Tun et al., 1998). Deficits in attentional control processes (Balota et al., 1999; Tun et al., 1998) and source monitoring abilities (Dehon & Bredart, 2004; Schacter et al., 1997) contributed to the tendency for older adults to produce a greater number of false attributions in verbal STM compared with young adults. It was therefore reasonable to believe that such deficits may largely influence the older adults' capacity to redintegrate and, more importantly, produce false memories during output relative to their young counterparts. It was possible that deficits in attentional control processes and source monitoring may inhibit the older adults' capacity to block the activated pathways converging on the critical non-presented lure that they may believe it is the correct candidate for later recall and interfere with their capacity to redintegrate the originally presented TBR items for later output.

## **Aims**

The primary aim of this study was to measure redintegration using lists of words related to a critical non-presented lure and lists of unrelated words using Schweickert's (1993) Multinomial Processing Tree Model of Redintegration. Long-term semantic knowledge has been found to make a notable contribution to verbal STM performance and its effects extend to the false memory effect (Deese, 1959; Roediger III & McDermott, 1995; Tehan, 2010; Underwood, 1965). The spreading activation that occurs in LTM enhances access to semantic and phonological representations that would assist with recalling the TBR items at output. However, this spreading activation unintentionally activates non-presented semantic competitors, including the critical non-presented lure that may encourage the reconstruction of false memories that participants may ultimately produce during output instead of reconstructing the memory trace with the semantic and phonological information pertaining to the original TBR item. Given researchers have not examined the false memory effect using redintegration, this empirical study sought to investigate this unique relationship.

This study also aimed to continue exploring age differences in redintegration using the false memory effect. Previous research has established that young adults recall a higher proportion of items related to a critical non-presented lure and unrelated items relative to older adults. However, older adults are more susceptible to producing a higher proportion of critical non-presented lures during recall than young adults because of deficits in attentional control processes (Balota et al., 1999; Tun et al., 1998) and source monitoring (Dehon & Bredart, 2004; Schacter et al., 1997). In keeping with the redintegration literature, while young adults are presumed to outperform older adults during veridical recall in the experimental task, due to the increasing nature of interference across the various task conditions, older adults may be

more susceptible to produce false memories during redintegration. Consistent with the previous studies in this thesis, Neale and Tehan (2007) are the only researchers to this date who have examined the relationship between age and redintegration, however, this relationship has not been examined using the false memory effect. The performances of young and older adults in this study would make an important contribution to the redintegration literature.

### **Hypotheses**

It was hypothesised that for correct-in-position recall, item recall, and order accuracy, at the short-term recall across all task difficulty conditions, young adults would recall a significantly higher proportion of related and unrelated words compared with older adults. Due to the increased interference inherent in the experimental task, older adults may find the nature of the task cognitively demanding, impairing their short-term recall performance compared with their young counterparts.

It was hypothesised that for correct-in-position recall, item recall, and order accuracy, there would be a significant positive relationship between the relatedness effect and task difficulty. In the easier task conditions, the recall difference between related and unrelated words would not be present. The short-term phonological memory traces for the related and unrelated items would be relatively intact because their respective memory traces would not have sustained a great level of damage when being encoded into verbal STM. Individuals would therefore be able to retrieve the related and unrelated items directly from verbal STM for subsequent output.

It was also hypothesised that for correct-in-position recall, item recall, and order accuracy, as task difficulty increased, redintegration effects would emerge, where participants

would recall an increasingly higher proportion of related words than unrelated words. In these conditions, the short-term phonological memory traces for the related and unrelated items would be most susceptible to damage from interfering factors that redintegration would be required to facilitate recall. When calling upon their long-term phonological and semantic knowledge, participants would use the relation shared among the related words and the critical non-presented lure as additional retrieval cues to locate the correct long-term representations to retrieve and subsequently reconstruct the degraded traces for the TBR items for later output. Redintegration effects would be in the form of the relatedness advantage, where the size of the recall difference between related and unrelated words would increase, in favour of related words.

It was hypothesised that for correct-in-position recall, item recall, and order accuracy, at the most difficult level of task, the recall difference between related and unrelated words would be larger for older adults than young adults. As task difficulty increased, older adults would be more reliant on redintegration than young adults to facilitate recall because their short-term phonological memory traces established for the TBR items during encoding would be more susceptible to damage. Older adults would therefore be more reliant on their long-term semantic knowledge, the relatedness shared among the TBR items, and the critical non-presented lure to enhance redintegrative processing and subsequent recall.

It was hypothesised that for correct-in-position recall, item recall, and order accuracy, as task difficulty increased, participants would recall an increasingly higher proportion of critical non-presented lures during output. Given the related items were related to the critical non-presented lure, during retrieval, participants may also retrieve the representation of the critical non-presented lure and deem it an appropriate match with the remaining information available

in verbal STM. Thus, individuals may erroneously recall the critical non-presented lure instead of an originally presented TBR item.

It was hypothesised that for correct-in-position recall, item recall, and order accuracy, across all task difficulty conditions, older adults would recall a significantly higher proportion of critical non-presented lures compared with young adults. The respective short-term phonological memory traces may have sustained greater damage from the interference produced by the task difficulty manipulation. In turn, they would reconstruct the degraded short-term phonological memory traces of the original TBR items with the representation of the critical non-presented lure compared with young adults.

## Method

### Participants

Forty adult volunteers participated in Study Three. These participants were different to those adults that participated in Studies One and Two, respectively. Twenty young adults (40% men and 60% women,  $M_{\text{age}} = 23.90$  years, age range 18-39 years) were recruited from undergraduate psychology courses at an Australian University (60%) and the general community (40%). Undergraduate students received for partial course credit in exchange for their participation. No incentives were offered to participants from the general community. Twenty independent living older adults (45% men and 55% women,  $M_{\text{age}} = 65.65$  years, age range 61-74 years) were recruited from local community groups and the general community. Those participants did not receive incentives for their participation. All participants spoke English as their first language. The age ranges for recruiting young and older adults were consistent with Neale and Tehan (2007) and other ageing research (Balota & Duchek, 1988;



Craik et al., 1987; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2002). Methods of participant recruitment were consistent with Study One of this thesis (see p. 125). Interested participants received the same information letter and consent form to complete. All individuals provided informed consent to participate in this study. This study received full ethics approval by the Human Research Ethics Committee at the Australian Catholic University (approval number V 2009 31). Table 8.1 presents a summary of the remaining demographic characteristics for the sample.

Table 8.1  
*Demographic Characteristics across Age*

Characteristic	Young ( <i>n</i> = 20)		Older ( <i>n</i> = 20)		<i>t</i>	<i>df</i>	<i>p</i>	<i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>				
Health on testing day <sup>a</sup>								
Good to excellent	90%		95%					
Not very good	10%		5%					
Vision								
Normal	60%		15%					
Corrected-to-normal	40%		85%					
Hearing								
Normal	100%		90%					
Corrected-to-normal	0%		10%					
Mill Hill <sup>b</sup>	13.05	2.65	15.00	2.45	-2.15	38	.020	0.76
Education (years)	14.20	2.42	13.60	3.83	0.59	32.08	.558	0.18

*Note.* *n* = number of participants.

<sup>a</sup> was self-rated on a five point Likert Scale from 1 (Excellent) to 5 (Poor).

<sup>b</sup> refers to the Mill Hill Vocabulary Scale (Raven, 1989).

## Design

This study used a 2 x 2 x 2 x 2 x 2 mixed factorial experimental design. The four within-subjects independent variables were (1) word relatedness (related, unrelated), (2) recall interval (immediate, delay), (3) study condition (silence, irrelevant speech), and (4) presentation rate (one second, two seconds). The between-subjects independent variable was age (young, older).

As per Study One of this thesis, the primary dependent variables were (1) correct-in-position recall, (2) item recall, and (3) order accuracy. The secondary dependent variables were the errors the participant made during recall: (1) transpositions, (2) omissions, and a new error type (3) critical non-presented lure, which was operationalised as the proportion of instances the participant recalled the critical non-presented lure. The critical non-presented

lure was only measured in the related word trials because the TBR items in the unrelated word trials were not related to a critical non-presented lure.

## Materials

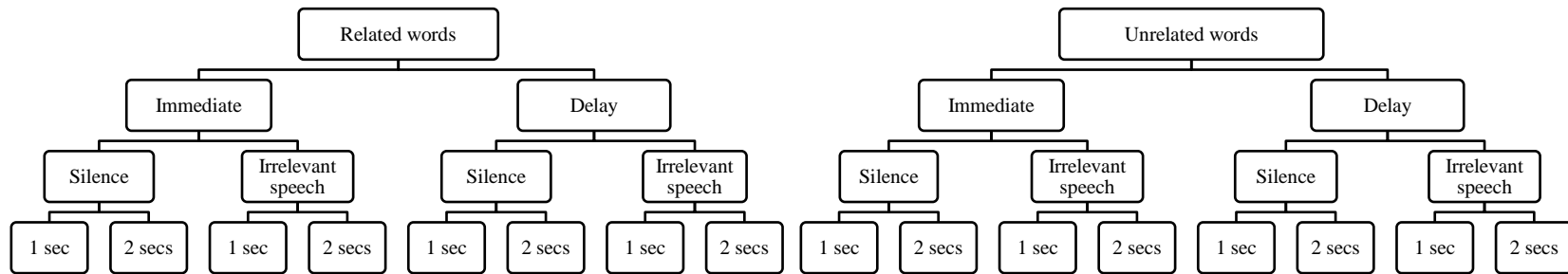
**Background measures.** The biographical questionnaire and the Mill Hill Vocabulary Scale (Raven, 1989) have previously been described in Study One.

**Word stimuli.** Three hundred and twenty word trials (160 related trials and 160 unrelated trials) were created to develop two word pools based on relatedness (related and unrelated). Each related word trial contained four words related to a critical non-presented lure. To create the related word trials, 80 critical non-presented lures with four strong associate word sequences were randomly selected from Appendix C of the University of South Florida Free Association Norms (Nelson et al., 1998). Of these 80 word sequences, 40 were randomly selected for the related word trials. The first associate for each trial had the strongest correlation to the critical non-presented lure ( $r > .70$ ). Associates were arranged in descending order according to associative strength so that the strongest associate was in serial position one, and the weakest associate was in serial position four. For example, for the critical non-presented lure *cake*, the associates were: *icing* (.81), *frosting* (.62), *bake* (.40), and *birthday* (.19) (see Appendix B-9).

The remaining 40 word sequences were used to create the unrelated word trials. Each unrelated word trial contained four words that did not relate to a critical non-presented lure. To create the unrelated word trials, each word was randomly selected from a word sequence and then assigned to each serial position based on their respective associative strength in the word sequence. That is, the strongest associate that was randomly selected from a word sequence was always presented in serial position one, the second strongest associate was always

presented in serial position two, the third strongest associate was always presented in serial position three, and the weakest associate was always presented in serial position four. Using the unrelated word trial *thread*, *account*, *mouse*, *double* as an example, *thread* is the strongest associate for the word sequence with the critical non-presented lure *needle*. *Account* is the second strongest associate for the word sequence with the critical non-presented lure *bank*. *Mouse* is the third strongest associate for the word sequence with the critical non-presented lure *cat*. Finally, *double* is the weakest associate for the word sequence with the critical non-presented lure *two* (see Appendix B-9).

**Word trials.** Figure 8.1 presents the configuration of the word trials presented to the participant. Consistent with Study One of this thesis, the related and unrelated word trials were imported into the Cue Speech program and then randomly allocated to one of eight memory conditions to create one unique block of 80 trials for each participant. Forty of the word trials were presented at a rate of one word per second and the remaining 40 word trials were presented a rate of one word every two seconds (see Appendix B-10 for an example block of word trials).



*Figure 8.1.* Composition of the word trials using recall interval, study condition, and presentation rate across word relatedness.

## **Procedure**

The procedure was identical to Study One.

## **Scoring**

The scoring for all word trials was consistent with Study One. In addition, a total score was calculated for the total number of critical non-presented lures, that is, when the participant recalled the critical non-presented lure in place of an original TBR item. A proportion score was also calculated by dividing the total score by the number of trials in the memory condition (i.e., 20 trials) with the critical non-presented lure score.

## **Results**

### **Data screening**

Data screening for correct-in-position recall, item recall, order accuracy, transposition errors, and omission errors along with data decisions prior to analysis, unless otherwise specified, was consistent with Study one of this thesis (see p. 132).

### **Data analysis**

All data analysis for correct-in-position, item scoring, order accuracy, transposition errors, and omission errors, including using the Mill Hill as a covariate, unless otherwise specified were consistent with Study One of this thesis. There were no differences in the main effects reported and therefore, the original mixed factorial ANOVAs without the covariates are reported. This applied to correct-in-position recall, item recall, order accuracy, transposition errors, critical non-presented lures, and omission errors. (see p. 133). All significant interactions are reported in Appendix C-4.1. All non-significant interactions are reported in Appendix C-4.2.

**Correct-in-position recall**

**Descriptive statistics.** Table 8.2 summarises the mean recall performance of young and older adults for related and unrelated words across the eight memory conditions for correct-in-position recall.

Table 8.2

*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Correct-in-Position Recall across Task Difficulty, Word Relatedness, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Related			Unrelated			Related			Unrelated		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.90	.14	[.83, .96]	.87	.19	[.77, .96]	.82	.21	[.73, .92]	.79	.19	[.70, .88]
		1 sec	.94	.09	[.90, .98]	.83	.20	[.74, .92]	.83	.17	[.75, .91]	.73	.21	[.63, .83]
	Speech	2 sec	.93	.08	[.89, .96]	.83	.20	[.73, .92]	.79	.18	[.71, .87]	.67	.19	[.58, .76]
		1 sec	.84	.18	[.76, .92]	.78	.20	[.68, .87]	.81	.18	[.72, .90]	.68	.24	[.57, .79]
Delay	Silence	2 sec	.81	.14	[.75, .87]	.63	.21	[.54, .73]	.60	.19	[.51, .69]	.53	.27	[.40, .65]
		1 sec	.64	.19	[.55, .73]	.40	.22	[.30, .51]	.55	.24	[.44, .66]	.39	.23	[.28, .50]
	Speech	2 sec	.75	.15	[.67, .82]	.61	.23	[.50, .72]	.60	.20	[.50, .69]	.48	.22	[.38, .58]
		1 sec	.60	.23	[.50, .71]	.53	.21	[.43, .63]	.64	.20	[.55, .73]	.48	.29	[.35, .62]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Related = related words, Unrelated = unrelated words.



From Table 8.2, participants recalled a higher proportion of related words in their serial position compared with unrelated words, demonstrating what appears to be a relatedness advantage in recall. This pattern of memory performance increased with task difficulty. Across all memory conditions, it appears that correct-in-position recall performance for young adults was higher compared with older adults.

**Inferential statistics.** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for correct-in-position recall. The within-subjects variables were word relatedness, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Main effects.** There was a significant main effect for word relatedness, where participants recalled a significantly higher proportion of related words in serial position ( $M = .75$ ,  $SD = .15$ ) compared with unrelated words ( $M = .64$ ,  $SD = .18$ ),  $F(1, 38) = 86.98$ ,  $MSE = 2.05$ ,  $p < .001$ ,  $\eta_p^2 = .70$ , *observed power* = 1.00. There was a significant main effect for recall interval, where participants recalled a significantly higher proportion of words in serial position in immediate conditions ( $M = .81$ ,  $SD = .15$ ) compared with after a delayed interval ( $M = .58$ ,  $SD = .18$ ),  $F(1, 38) = 247.48$ ,  $MSE = 8.95$ ,  $p < .001$ ,  $\eta_p^2 = .87$ , *observed power* = 1.00. Finally, there was a significant main effect for presentation rate, where participants recalled a significantly higher proportion of words in serial position during the two-second presentation rate ( $M = .72$ ,  $SD = .17$ ) compared with the one-second presentation rate ( $M = .67$ ,  $SD = .17$ ),  $F(1, 38) = 28.44$ ,  $MSE = 0.52$ ,  $p < .001$ ,  $\eta_p^2 = .43$ , *observed power* = 1.00.

**Item recall**

**Descriptive statistics.** Table 8.3 presents the mean performance for item recall across the eight memory conditions for young and older adults for related and unrelated words.

Table 8.3

*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Item Recall across Task Difficulty, Word Relatedness, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Related			Unrelated			Related			Unrelated		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.94	.10	[.89, .99]	.89	.17	[.81, .97]	.92	.10	[.87, .96]	.88	.10	[.83, .92]
		1 sec	.96	.06	[.93, .99]	.87	.16	[.79, .94]	.94	.07	[.90, .97]	.81	.16	[.74, .89]
	Speech	2 sec	.95	.06	[.92, .97]	.87	.16	[.80, .91]	.89	.09	[.85, .93]	.78	.15	[.71, .85]
		1 sec	.92	.10	[.87, .97]	.86	.15	[.79, .93]	.92	.09	[.88, .96]	.81	.14	[.75, .88]
Delay	Silence	2 sec	.87	.09	[.83, .91]	.71	.16	[.63, .78]	.77	.15	[.70, .84]	.64	.20	[.55, .74]
		1 sec	.79	.14	[.73, .86]	.52	.20	[.43, .62]	.76	.11	[.70, .81]	.54	.20	[.44, .63]
	Speech	2 sec	.85	.09	[.80, .89]	.69	.20	[.60, .78]	.78	.13	[.72, .84]	.59	.18	[.50, .67]
		1 sec	.76	.15	[.68, .83]	.64	.18	[.55, .72]	.77	.12	[.72, .83]	.60	.22	[.50, .70]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Related = related words, Unrelated = unrelated words.

As evident from Table 8.3, irrespective of serial order at output, participants recalled a higher proportion of related words compared with unrelated words and this pattern of recall was apparent across all memory conditions. In relation to age differences, young and older adults recalled a comparable proportion of related and unrelated words.

**Inferential statistics.** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for item recall. The within-subjects variables were word relatedness, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Main effects.** A significant main effect was found for word relatedness, where participants recalled a significantly higher proportion of related words ( $M = .86$ ,  $SD = .08$ ) than unrelated words ( $M = .73$ ,  $SD = .14$ ),  $F(1, 38) = 125.79$ ,  $MSE = 2.76$ ,  $p < .001$ ,  $\eta_p^2 = .77$ , *observed power* = 1.00. Recall interval yielded a significant main effect, where participants recalled a significantly higher proportion of words in immediate conditions ( $M = .89$ ,  $SD = .09$ ) compared with after a delayed interval ( $M = .70$ ,  $SD = .13$ ),  $F(1, 38) = 233.92$ ,  $MSE = 5.38$ ,  $p < .001$ ,  $\eta_p^2 = .86$ , *observed power* = 1.00. Finally, presentation rate produced a significant main effect, where participants recalled a significantly higher proportion of words during the two-second presentation rate ( $M = .81$ ,  $SD = .11$ ) than the one-second presentation rate ( $M = .78$ ,  $SD = .11$ ),  $F(1, 38) = 15.13$ ,  $MSE = 0.18$ ,  $p < .001$ ,  $\eta_p^2 = .29$ , *observed power* = .97.

### Order accuracy

**Descriptive statistics.** Table 8.4 presents the means for order accuracy during recall for related and unrelated words across the eight memory conditions for young and older adults.

Table 8.4  
*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Order Accuracy across Task Difficulty, Word Relatedness, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Related			Unrelated			Related			Unrelated		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.95	.08	[.91, .99]	.96	.07	[.93, 1]	.89	.17	[.81, .97]	.89	.15	[.82, .97]
		1 sec	.98	.05	[.96, 1]	.95	.10	[.90, .99]	.88	.14	[.82, .95]	.89	.15	[.81, .96]
	Speech	2 sec	.98	.04	[.96, 1]	.94	.11	[.89, .99]	.88	.14	[.81, .94]	.85	.13	[.79, .91]
		1 sec	.90	.13	[.84, .96]	.89	.13	[.83, .95]	.87	.16	[.80, .94]	.82	.19	[.73, .91]
Delay	Silence	2 sec	.92	.10	[.88, .97]	.88	.15	[.81, .94]	.77	.16	[.70, .84]	.79	.21	[.69, .89]
		1 sec	.80	.17	[.72, .88]	.73	.26	[.61, .86]	.70	.24	[.59, .82]	.69	.27	[.57, .82]
	Speech	2 sec	.88	.13	[.82, .94]	.86	.16	[.79, .93]	.75	.17	[.67, .83]	.81	.21	[.71, .90]
		1 sec	.78	.21	[.68, .87]	.82	.16	[.75, .89]	.82	.18	[.73, .90]	.76	.30	[.62, .90]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Related = related words, Unrelated = unrelated words.

As seen in Table 8.4, order accuracy, the probability of recalling a word in its correct serial position, given the participant initially recalled the word, was comparable for related and unrelated words. This pattern of recall performance was consistent for young and older adults. In addition, young adults' order accuracy was higher than older adults' order accuracy in five of the eight memory conditions.

**Inferential statistics.** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for order accuracy. The within-subjects variables were word relatedness, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Main effects.** A significant main effect was found for recall interval, where order accuracy was significantly higher in immediate conditions ( $M = .91$ ,  $SD = .10$ ) than after a delayed interval ( $M = .80$ ,  $SD = .14$ ),  $F(1, 38) = 76.12$ ,  $MSE = 1.93$ ,  $p < .001$ ,  $\eta_p^2 = .67$ , *observed power* = 1.00. Presentation rate produced a significant main effect, where participants recalled a significantly higher proportion of words during the two-second presentation rate ( $M = .87$ ,  $SD = .11$ ) than the one-second presentation rate ( $M = .83$ ,  $SD = .13$ ),  $F(1, 38) = 12.75$ ,  $MSE = 0.32$ ,  $p = .001$ ,  $\eta_p^2 = .25$ , *observed power* = .94. Finally, there was a significant main effect for age, where order accuracy was significantly higher for young adults ( $M = .89$ ,  $SD = .08$ ) compared with older adults ( $M = .82$ ,  $SD = .14$ ),  $F(1, 38) = 4.15$ ,  $MSE = 0.86$ ,  $p = .049$ ,  $\eta_p^2 = .10$ , *observed power* = .51.

### Transposition errors

**Descriptive statistics.** Table 8.5 presents the mean proportion of transposition errors young and older adults produced during recall of the related and unrelated words across the eight memory conditions.

Table 8.5  
*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Transposition Errors across Task Difficulty, Word Relatedness, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Related			Unrelated			Related			Unrelated		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.02	.04	[.00, .04]	.01	.02	[.00, .02]	.03	.05	[.01, .05]	.02	.05	[.00, .04]
		1 sec	.01	.02	[.00, .02]	.02	.04	[.00, .03]	.04	.07	[.00, .07]	.03	.04	[.01, .05]
	Speech	2 sec	.01	.03	[.00, .02]	.02	.05	[.00, .04]	.03	.05	[.01, .05]	.02	.05	[.00, .04]
		1 sec	.03	.05	[.00, .06]	.03	.05	[.00, .05]	.04	.05	[.01, .06]	.05	.08	[.01, .09]
Delay	Silence	2 sec	.02	.04	[.00, .04]	.02	.04	[.00, .04]	.06	.06	[.03, .08]	.04	.06	[.01, .06]
		1 sec	.08	.08	[.04, .12]	.02	.05	[.00, .04]	.05	.05	[.03, .08]	.04	.06	[.01, .08]
	Speech	2 sec	.05	.06	[.02, .08]	.03	.05	[.01, .05]	.07	.07	[.03, .10]	.03	.04	[.00, .05]
		1 sec	.05	.05	[.03, .07]	.01	.02	[.00, .02]	.04	.05	[.01, .06]	.03	.05	[.01, .05]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Related = related words, Unrelated = unrelated words.

It appears that in Table 8.5, participants produced a higher proportion of transposition errors for the unrelated words compared with the related words, particularly during the immediate recall conditions. However, as the memory task became harder (i.e., the delayed recall conditions) this recall trend reversed, where participants produced a higher proportion of transposition errors when recalling the related words compared with the unrelated words. In relation to age differences, for six of the eight memory conditions, older adults produced a higher proportion of transposition errors for related words compared with young adults. For unrelated words, however, across all memory conditions, older adults produced a higher proportion of transposition errors relative to young adults.

**Inferential statistics.** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for the transposition errors produced during recall. The within-subjects variables were word relatedness, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Main effects.** There was a significant main effect for word relatedness, where participants produced a significantly higher proportion of transposition errors for related words ( $M = .04$ ,  $SD = .02$ ) compared with unrelated words ( $M = .02$ ,  $SD = .02$ ),  $F(1, 38) = 8.74$ ,  $MSE = 0.03$ ,  $p = .005$ ,  $\eta_p^2 = .19$ , *observed power* = .82. Recall interval produced a significant main effect, where participants produced a significantly higher proportion of transposition errors after a delayed interval ( $M = .04$ ,  $SD = .02$ ) compared with immediate conditions ( $M = .02$ ,  $SD = .02$ ),  $F(1, 38) = 15.08$ ,  $MSE = 0.04$ ,  $p < .001$ ,  $\eta_p^2 = .28$ , *observed power* = .97. Finally, there was a significant main effect for age, where older adults ( $M = .04$ ,  $SD = .02$ ) produced a significantly higher proportion of transposition errors during recall compared with young adults ( $M = .02$ ,  $SD = .01$ ),  $F(1, 38) = 4.24$ ,  $MSE = 6.02$ ,  $p = .046$ ,  $\eta_p^2 = .10$ , *observed power* = .52.



### Critical non-presented lures

**Descriptive statistics.** Table 8.6 summarises the mean proportion of critical non-presented lures young and older adults recalled across the eight memory conditions for the related word trials. It is important note that memory performance for the unrelated word trials is not reported because the words in the trial were not related to a critical non-presented lure.

Table 8.6

*Means with Confidence Intervals (CIs) and Standard Deviations for the Proportions of Critical Non-presented Lures for Related Trials across Task Difficulty and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)			Older ( <i>n</i> = 20)		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.00	.00	[.00, .00]	.01	.03	[.00, .03]
		1 sec	.00	.00	[.00, .00]	.01	.02	[.00, .01]
	Speech	2 sec	.00	.00	[.00, .00]	.02	.03	[.00, .03]
		1 sec	.01	.02	[.00, .01]	.01	.02	[.00, .02]
Imm	Silence	2 sec	.01	.02	[.00, .02]	.02	.03	[.00, .03]
		1 sec	.01	.02	[.00, .02]	.01	.02	[.00, .02]
	Speech	2 sec	.01	.04	[.00, .03]	.03	.03	[.01, .04]
		1 sec	.02	.03	[.00, .03]	.02	.03	[.01, .03]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second.

Examination of recalling the critical non-presented lure revealed older adults produced a higher proportion of critical non-presented lures compared with young adults. As task difficulty increased, young adults recalled an increasingly higher proportion of critical non-presented lures. However, no such pattern was evident for older adults as they consistently produced the critical non-presented lure at recall. Specifically, older adults recalled a higher proportion of critical non-presented lures during conditions when each

word was presented every two seconds compared with when each word was presented every second.

**Inferential statistics.** A 2 x 2 x 2 x 2 mixed factorial ANOVA was calculated to examine differences in memory performance for the critical non-presented lures produced during recall. The within-subjects variables were recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Main effects.** Recall interval produced a significant main effect, where participants recalled a significantly higher proportion of critical non-presented lures after a delayed interval ( $M = .01$ ,  $SD = .02$ ) compared with immediate conditions ( $M = .01$ ,  $SD = .01$ ),  $F(1, 38) = 13.44$ ,  $MSE = 0.01$ ,  $p = .001$ ,  $\eta_p^2 = .26$ , *observed power* = .95. Finally, study condition produced a significant main effect, where participants recalled a significantly higher proportion of critical non-presented lures during irrelevant speech conditions ( $M = .01$ ,  $SD = .02$ ) compared with silence conditions ( $M = .01$ ,  $SD = .01$ ),  $F(1, 38) = 5.03$ ,  $MSE = 0.00$ ,  $p = .031$ ,  $\eta_p^2 = .12$ , *observed power* = .59.

**Simple correlations.** Simple correlations were calculated using the mean proportion of critical non-presented lures and the mean recall performance for correct-in-position recall averaged across the eight memory conditions to examine whether there was a relationship between redintegrative processing and producing false memories. These simple correlations were calculated separately for young and older adults. For the young adults, there was a significant negative correlation between the mean proportion of critical non-presented lures recalled across the eight memory conditions and the average performance for correct-in-position recall,  $r(8) = -.55$ ,  $p = .013$ . Similarly for the older adults, there was a significant negative correlation between the mean proportion of critical non-presented lures recalled across the eight memory conditions and the average performance for correct-in-position recall,  $r(8) = -.47$ ,  $p = .039$ . These results indicate that

individuals whose memory performance was low for correct-in-position recall were more likely to recall the critical non-presented lure as one of the TBR items during output.

### **Omission errors**

**Descriptive statistics.** Table 8.7 presents the mean proportion of related and unrelated words young and older adults omitted during recall across the eight memory conditions.

Table 8.7  
*Means With Confidence Intervals (CIs) and Standard Deviations for the Proportions of Omission Errors across Task Difficulty, Word Relatedness, and Age*

Recall interval	Study cond	Pres rate	Young ( <i>n</i> = 20)						Older ( <i>n</i> = 20)					
			Related			Unrelated			Related			Unrelated		
			<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Imm	Silence	2 sec	.05	.10	[.00, .09]	.10	.16	[.03, .18]	.06	.10	[.02, .11]	.09	.09	[.05, .13]
		1 sec	.04	.06	[.01, .06]	.11	.14	[.04, .17]	.04	.04	[.02, .06]	.14	.16	[.06, .21]
	Speech	2 sec	.05	.06	[.02, .07]	.11	.15	[.04, .18]	.09	.09	[.05, .13]	.18	.15	[.11, .24]
		1 sec	.07	.09	[.02, .11]	.11	.12	[.05, .16]	.05	.09	[.01, .10]	.14	.12	[.08, .19]
Delay	Silence	2 sec	.10	.09	[.06, .14]	.26	.18	[.17, .34]	.17	.12	[.12, .23]	.30	.18	[.21, .39]
		1 sec	.18	.14	[.12, .24]	.41	.21	[.31, .51]	.19	.11	[.14, .24]	.38	.19	[.29, .47]
	Speech	2 sec	.11	.09	[.06, .15]	.27	.20	[.17, .36]	.16	.12	[.10, .22]	.33	.17	[.25, .41]
		1 sec	.19	.12	[.14, .25]	.31	.20	[.22, .41]	.18	.10	[.13, .23]	.33	.21	[.23, .43]

*Note.* *n* = number of participants, Imm = immediate recall, Delay = delayed recall, Study cond = study condition, Pres rate = presentation rate, 2 sec = 2 seconds, 1 sec = 1 second, Related = related words, Unrelated = unrelated words.

As evident from Table 8.7, participants produced a higher proportion of omission errors for unrelated words compared with related words. At an age level, older adults omitted a higher proportion of related and unrelated words compared with young adults during recall and this was consistent across the eight memory conditions.

**Inferential statistics.** A  $2 \times 2 \times 2 \times 2 \times 2$  mixed factorial ANOVA was calculated to examine differences in memory performance for the omission errors produced during recall. The within-subjects variables were word relatedness, recall interval, study condition, and presentation rate. Age was the between-subjects variable.

**Main effects.** There was a significant main effect for word relatedness, where participants omitted a significantly higher proportion of unrelated words ( $M = .22$ ,  $SD = .13$ ) during recall compared with related words ( $M = .11$ ,  $SD = .07$ ),  $F(1, 38) = 76.32$ ,  $MSE = 2.07$ ,  $p < .001$ ,  $\eta_p^2 = .67$ , *observed power* = 1.00. There was a significant main effect for recall interval, where participants omitted a significantly higher proportion of words after a delayed interval ( $M = .24$ ,  $SD = .12$ ) compared with immediate conditions ( $M = .09$ ,  $SD = .08$ ),  $F(1, 38) = 152.24$ ,  $MSE = 3.82$ ,  $p < .001$ ,  $\eta_p^2 = .80$ , *observed power* = 1.00. Finally, there was a significant main effect for presentation rate, where participants omitted a significantly higher proportion of words during the one-second presentation rate ( $M = .18$ ,  $SD = .10$ ) compared with the two-second presentation rate ( $M = .15$ ,  $SD = .10$ ),  $F(1, 38) = 10.23$ ,  $MSE = 0.09$ ,  $p = .003$ ,  $\eta_p^2 = .22$ , *observed power* = .89.

### **Task difficulty and redintegration**

**Task difficulty.** As with Study one, the  $2 \times 2 \times 2$  (recall interval, study condition, and presentation rate) design produced eight estimates of task difficulty. The rank order for the means in the eight levels of task difficulty was made based on the outcomes of the study. Table 8.8

presents a summary of the rank order correlations between the related and unrelated lists for young and older adults across correct-in-position, item, and order accuracy scoring.

Table 8.8

*Spearman's Rank Order Correlations for Task Difficulty as a Function of Word Relatedness and Age*

Age	Word	Young ( <i>n</i> = 20)		Older ( <i>n</i> = 20)	
		Related	Unrelated	Related	Unrelated
Correct-in-Position Scoring					
Young	Related	1.00			
	Unrelated	.91	1.00		
Older	Related	.79	.88	1.00	
	Unrelated	.84	.97	.93	1.00
Item Scoring					
Young	Related	1.00			
	Unrelated	.88	1.00		
Older	Related	.79	.85	1.00	
	Unrelated	.78	.90	.83	1.00
Order Scoring					
Young	Related	1.00			
	Unrelated	.86	1.00		
Older	Related	.71	.81	1.00	
	Unrelated	.81	.98	.91	1.00

*Note.* *n* = number of participants.

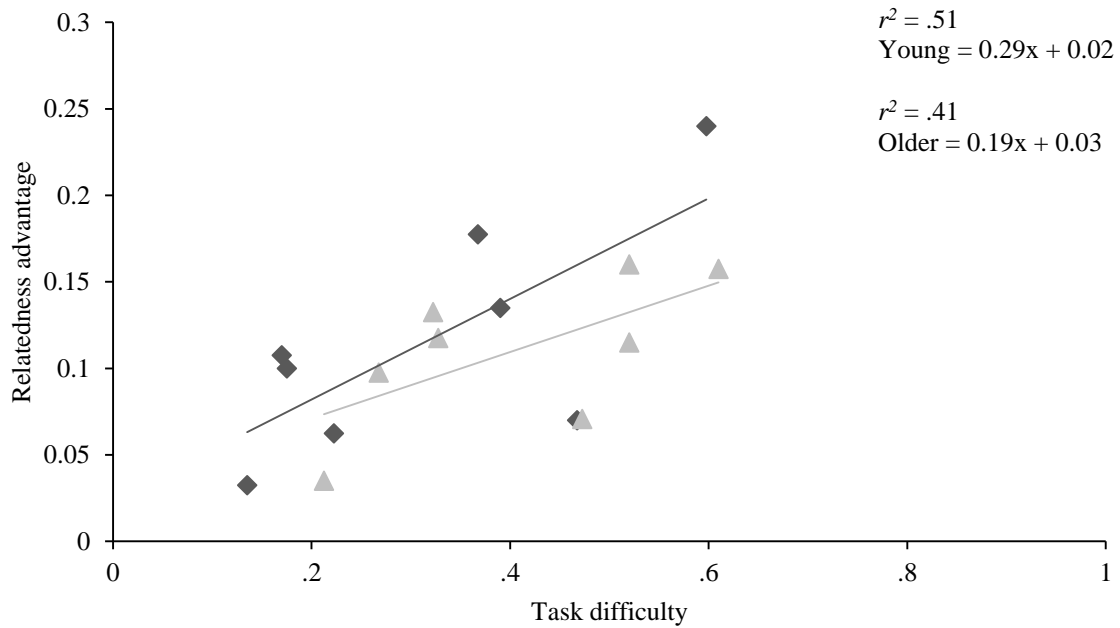
It was evident from Table 8.8 that there were strong positive correlations between related and unrelated lists and for young and older adults across correct-in-position scoring (older adults,  $r = .93$ ; young adults,  $r = .91$ ), item scoring (older adults,  $r = .83$ ; young adults ( $r = .91$ ) and order accuracy (older adults,  $r = .91$ ; young adults,  $r = .86$ ). These results suggest that task difficulty was independent of the false memory effect and consistently produced a graded level of interference during the experimental task for the three methods of scoring.

**Redintegration.** Redintegration effects are displayed using the relatedness advantage as a function of task difficulty. The relatedness advantage (y-axis) is represented by the recall difference between the related and unrelated word. Task difficulty (x-axis) is represented by the

proportion of transposition errors, omission errors, and critical non-presented lures participants produced when recalling the unrelated word lists. To explain, if a participant scored .5 on a list of unrelated words, the remaining .5 are errors made during recall. That is, 50% of performance on the list of unrelated words were either transpositions errors, omissions errors, or critical non-presented lures. Performance on lists of unrelated words was used as a baseline measure because, in a similar vein to Study two of this thesis, the unrelated words provided the participant with no additional help when using redintegration to reconstruct the short-term phonological memory traces of the TBR items to aid short-term recall.

The redintegration outcomes are represented by the size of the relatedness advantage and higher scores for task difficulty. A positive relationship represents an increase in the relatedness advantage as task difficulty increased. That is, as the memory task became more difficult, the size of the recall difference between the related and unrelated words increased, in favour of related words. The relatedness shared amongst the words would act as an additional cue to facilitate the redintegration process and aid retrieval of the words for subsequent output. A negative relationship represents a decrease in the relatedness advantage as task difficulty increased. That is, as the memory task became difficult, the size of the recall difference between related and unrelated words decreased. This would suggest there is no advantage of relatedness and recall for related and unrelated words is comparable. These outcomes were analysed for correct-in-position recall, item recall, and order accuracy, respectively. As per Study one of this thesis, memory performance is presented at the group mean level.

***Correct-in-position recall.*** Figure 8.2 presents the redintegration effects for correct-in-position recall using the group mean levels of performance across the eight conditions for young and older adults, respectively.



*Figure 8.2.* Relatedness advantage as a function of task difficulty for correct-in-position recall across young adults (diamonds) and older adults (triangles)

It is evident from Figure 8.2 that the relatedness advantage increased with task difficulty. This relationship was moderately strong for the older ( $r^2 = .41$ ) and young adults ( $r^2 = .51$ ), indicating that word relatedness somewhat assisted with recalling the TBR words in their serial order. There was no significant difference between the slopes of the older ( $b = 0.19$ ) and young adults ( $b = 0.29$ ),  $t(12) = -0.65$ ,  $p = .528$ . There was also no significant difference between the intercepts of the older ( $c = 0.03$ ) and young adults ( $c = 0.02$ ),  $t(12) = 0.15$ ,  $p = .884$ , indicating redintegrative processing was comparable across age. Redintegration outcomes at the sample level are presented in Appendix C-4.3. Redintegration outcomes at the individual level are presented in Appendices C-4.4 and C-4.5.

**Item recall.** Figure 8.3 presents the redintegration effects using the group mean levels of performance across the eight conditions for young and older adults, respectively.



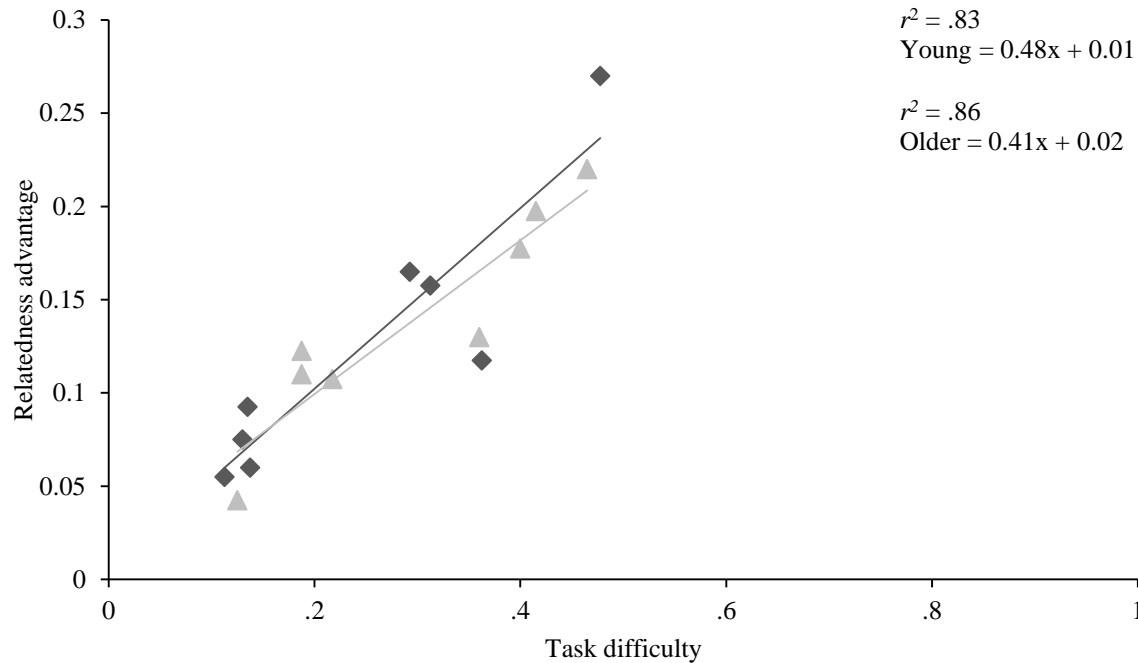
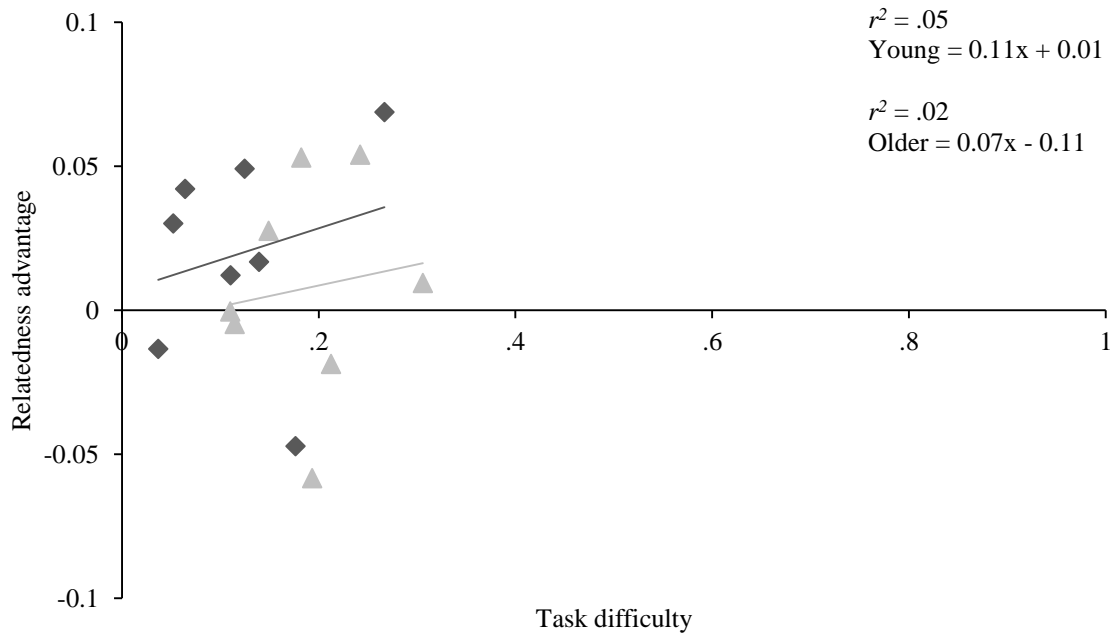


Figure 8.3. Relatedness advantage as a function of task difficulty for item recall across young adults (diamonds) and older adults (triangles)

Focussing solely on item information, Figure 8.3 showed that there was an increase in the size of the relatedness advantage as task difficulty increased. It is important to highlight the strength of the relationship between the relatedness advantage and task difficulty, which was strong for the older ( $r^2 = .86$ ) and young adults ( $r^2 = .83$ ), respectively. These results indicated that word relatedness greatly assisted with producing the TBR words at output. There was no significant difference between the slopes for the older ( $b = 0.41$ ) and young adults ( $b = 0.48$ ),  $t(12) = -0.20$ ,  $p = .532$ . There was no significant difference between the intercepts of the older ( $c = 0.02$ ) and young adults ( $c = 0.01$ ),  $t(12) = 0.35$ ,  $p = .735$ , indicating redintegrative processing was age invariant. Redintegration outcomes at the sample level are presented in Appendix C-4.6. Redintegration outcomes at the individual level are presented in Appendices C-4.7 and C-4.8.

**Order accuracy.** Figure 8.4 presents the redintegration effects using the group mean levels of performance for order accuracy across the eight memory conditions for young and older adults, respectively.



*Figure 8.4.* Relatedness advantage as a function of task difficulty for order accuracy for young adults (diamonds) and older adults (triangles)

The positive relationship between the relatedness advantage and task difficulty for order accuracy, as demonstrated in Figure 8.4, was evident for older and young adults. That is, as task difficulty increased, the relatedness advantage aided recall accuracy of words in their serial position. This relationship was weak for the older ( $r^2 = .02$ ) and young adults ( $r^2 = .05$ ). There was no significant difference between the slopes of the older ( $b = 0.07$ ) and young adults ( $b = 0.11$ ),  $t(12) = -0.12$ ,  $p = .906$ . There was no significant difference between the intercepts of the older ( $c = -0.11$ ) and young adults ( $c = 0.01$ ),  $t(12) = -0.24$ ,  $p = .815$ , again indicating that redintegrative processing was comparable across age. Redintegration outcomes at the sample level are presented in Appendix C-4.9. Redintegration outcomes at the individual level are presented in in Appendices C-4.10 and C-4.11.

## **Discussion**

### **Study overview**

This study continued examining redintegration using Schweickert's (1993) Multinomial Processing Tree Model of Redintegration by measuring redintegration through the false memory effect using a modified version of Roediger and McDermott's (1995) DRM lists. Given the prevalence of semantically related extra-list intrusions that participants produced in Study two of this thesis, it was reasonable to hypothesise that a relatedness advantage and a false memory effect may emerge within a different verbal STM paradigm. The literature has acknowledged that the false memory effect is well established in LTM (Bartlett, 1932; Deese, 1959; Roediger III & McDermott, 1995; Underwood, 1965) and this effect surfaces in verbal STM because of an important interaction that exists between the information temporarily stored in verbal STM and the permanently stored knowledge in LTM (Atkins & Reuter-Lorenz, 2008; Coane et al., 2007; Tehan, 2010). Given this interaction of short-term and long-term knowledge that occurs during the production of false memories is also central to redintegrative processing, and no other study to this date has measured redintegration using the false memory effect, this relationship warranted further investigation.

This study also examined age differences in redintegration as measured through the false memory effect. The literature acknowledges that veridical recall of related and unrelated words is consistently higher for young adults compared with older adults. Yet in a reverse trend on memory performance, recall of the critical non-presented lure is consistently higher for older adults compared with young adults (Balota et al., 1999; Dehon & Bredart, 2004; Tun et al., 1998). These age-related differences surfaced as a result of reductions in attentional control processes and reduced source monitoring abilities from differentiating between the activated

representations in LTM that were directly and indirectly related to the TBR words. It was also reasonable to believe that these deficits may translate to redintegration, particularly as task conditions become difficult, where older adults may become more reliant on redintegration to facilitate short-term recall. Given that Neale and Tehan (2007) and the two previous empirical investigations of this thesis are the only available investigations of ageing and redintegration, and no other study to this date has examined the relationship between ageing and redintegration as measured through the false memory effect, this relationship also warranted further investigation.

### **False memory and redintegration**

This study was the first empirical investigation to measure redintegration using false memory and found a relatedness advantage and the ubiquitous false memory effect using Schweickert's (1993) Multinomial Processing Tree Model of Redintegration. Consistent with the predictions of this study, the manipulation of task difficulty produced redintegration effects in the experimental task. For correct-in-position recall, item recall, and order accuracy, during the easier task conditions, the size of the recall difference between the related and unrelated TBR items was minimal. In these instances, there was little damage sustained to the short-term phonological memory traces of the TBR items from the task difficulty manipulation that individuals did not need to engage in redintegration and reconstruct the short-term phonological memory traces for the TBR items because they could retrieve the traces directly from verbal STM. However, as task difficulty increased, so too did the magnitude of the relatedness advantage. The findings suggest that the amount of interference experienced during encoding was sufficient to compromise the fidelity of the short-term phonological memory traces created for the TBR items. During retrieval, depending on the amount of damage sustained to the short-term phonological memory traces for the TBR items, there was an increased reliance on redintegration to reconstruct those

traces using previously stored long-term semantic information. Moreover, individuals used the relatedness shared amongst the TBR items, along with the critical non-presented lure, as additional retrieval cues to narrow the search for long-term phonological and semantic representations to retrieve the correct information in order to rebuild the traces for later output. As a result, individuals recalled a higher proportion of related words. The redintegration process was vastly different for unrelated TBR items. Participants presumably searched all the contents of LTM for each item since there was no type of cue in the form of a relationship among the items, other than what the individual may have personally generated to retain the TBR items in verbal STM, to guide the search process and reconstruct their respective memory traces. Also of interest, having the TBR words related to one another in addition to a critical non-presented lure also increased the likelihood of recalling the TBR words in their correct serial position. Such a relationship has enhanced encoding the TBR items into verbal STM because the information may have been more meaningful which, in turn, made retrieving both the TBR items along with its correct serial position easier and less cognitively demanding.

Importantly, a false memory effect also emerged during redintegration, a novel finding that has not been previously established within the redintegration literature, where individuals erroneously recalled the critical non-presented lure in place of one of the originally presented TBR items, particularly as task conditions became difficult. It appears that during encoding, participants may have unconsciously identified that the TBR words in the related list were related to each other as well as a non-presented word. As such, individuals have used the relation among the words and the non-presented word (i.e., the critical non-presented lure) as cues to retain the words in verbal STM for later output. At recall, when they could not recall the TBR words, particularly as task conditions increased in difficulty, participants used the relation among the

words along with the critical non-presented lure as additional retrieval cues to further facilitate the redintegration process and locate information that would assist with retrieving the TBR words from verbal STM. During retrieval, participants deemed the long-term phonological and semantic representation of the critical non-presented lure as a match with the available information that remained in the short-term phonological memory trace for the TBR item and as a result, the critical non-presented lure was recalled instead of the originally presented TBR item. For example, in the related word trial *cable, commercial, channel, program*, where the critical non-presented lure was *television*, participants might have encoded *television* as one of the TBR items. At retrieval, depending on the severity of the damage sustained to the short-term phonological memory trace during encoding, participants cued the search for items associated with *television* and they erroneously recalled *television* instead of either *cable, commercial, channel, or program*. These two unique findings continue to illustrate that individuals utilise their long-term semantic knowledge to facilitate verbal STM performance.

The relatedness advantage and false memory effect observed in this study informed the redintegration literature by demonstrating that individuals utilise additional cues in their environment to enhance the search for long-term information that would support memory performance (Neale & Tehan, 2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b). As the results of this study clearly suggest, the increasing level of interference produced by the task difficulty manipulation weakened the episodic information held in verbal STM, making retrieval increasingly problematic. If little information remains in verbal STM, adjudicating between the short-term phonological representations of the TBR items along with the short-term phonological representation of other non-presented semantic associates that have been unintentionally activated in LTM, including the critical non-presented lure, challenging. As

a result, there is an increased likelihood of recalling a higher proportion of related items over unrelated items. However, given the TBR items in this study were related to a critical non-presented lure, this cueing effect also lent itself to producing false memories in this experimental task. Simple correlation analyses also confirmed this assertion, where decreases in correct-in-position recall performance significantly increased the likelihood of recalling the critical non-presented lure and this pattern of memory performance emerged for young and older adults. These observations are similar to Tehan (2010) who suggested that weakened episodic information in verbal STM lends itself to other non-presented but semantic information related to the TBR item entering verbal STM such that false memories may emerge at output. Tehan found recall of the critical non-presented lure was higher during conditions when a filled retention interval was used compared with immediate recall conditions. Atkins and Reuter-Lorenz (2008) also acknowledged that recall of the critical non-presented lure in experimental tasks increased where there was some level of interference in the memory task as information dissipated from verbal STM. When participants were required to complete a mathematics equation prior to recalling the TBR items, participants relied on semantic relatedness to aid short-term recall which, in turn, led to participants also recalling a high proportion of critical non-presented lures and produced semantically related intrusions at recall. Coane et al. (2007) further suggested the semantic relatedness shared among the words increased the familiarity of the TBR items to benefit short-term recall performance, but the semantic relatedness shared among the TBR words also increased their familiarity with the critical non-presented lure in memory. As a result, discriminating between the representations of the critical non-presented lure from the other sources of activated information became troublesome. Thus, the cueing effects observed in this study confirms the assertions in the redintegration literature that individuals can cue the search for long-term information by narrowing their search to specific sections of LTM that contain

phonological and semantic representations only pertaining to the TBR items to enhance verbal STM performance.

At a broader level, these findings continue to confirm the notion that a complex interplay between the previously stored long-term semantic knowledge and the available information in verbal STM to facilitate memory performance (Brown et al., 2000; Melton, 1963; Neath & Nairne, 1995). Consistent with previous research (Atkins & Reuter-Lorenz, 2008; Neale & Tehan, 2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999b; Tse, 2009) and the findings observed in Study two of thesis, where redintegration was measured using associate word pairs, participants used their long-term semantic knowledge to cue the search for information and reconstruct the degraded short-term phonological memory traces of the TBR items for later short-term recall. Importantly, as the items in the related lists shared a relationship among themselves, as well as a relationship with the critical non-presented lure, such cues induced a spreading activation in LTM that activated the representations directly and indirectly related to the TBR item (Collins & Loftus, 1975; MacKay & Burke, 1990). This was in contrast to the items in the unrelated word lists because those items did not share any semantic relationship nor were they related to a critical non-presented lure. Therefore, retrieving those items for later output was challenging, particularly in the difficult task conditions, as individuals would have searched a greater amount of information activated in LTM, decreasing the efficiency of locating information that is pertinent to reconstructing the degraded short-term phonological memory traces of those TBR items they could not recall. The findings from this study are consistent with other related research that has argued the importance of long-term associate knowledge supporting short-term recall performance. Atkins and Reuter-Lorenz's (2008) finding of participants producing double the proportion of semantic errors compared with phonological,



other, and unrelated errors was indicative of an interaction between the knowledge available in verbal STM and the pre-existing knowledge in LTM, where the information in verbal STM activated information in LTM, which was then used to facilitate short-term recall performance. However, these processes can be hindered when the semantically related but non-presented information also become active, making it more difficult to adjudicate between an item's heightened familiarity and its status as a member of the current memory set. Tehan (2010) also contended that long-term semantic networks had a dual effect of facilitating short-term recall but also inducing false recall through a spreading activation that occurred within these long-term associate networks to aid short-term recall. Tehan inferred the significantly higher recall of related items than unrelated items indicated that individuals rely on the associations shared among the TBR items, which induced a spreading activation in LTM. Together, these findings support the view that long-term semantic knowledge benefits short-term recall performance.

In conclusion, a relatedness advantage emerged during redintegration when measured using the false memory effect (Deese, 1959; Roediger III & McDermott, 1995). Individuals utilised the relatedness shared among the TBR items and the critical non-presented lure as additional retrieval cues to assist with reconstructing the damaged short-term phonological memory traces of the TBR items for later recall. Furthermore, participants produced false memories during redintegration, where individuals erroneously recalled the critical non-presented lure in place of an originally presented TBR item. The observations in this study further strengthen the position that when individuals experienced difficulties during encoding, there is a greater reliance on long-term semantic knowledge to facilitate short-term recall (Neale & Tehan, 2007).

### **Age differences, false memory, and redintegration**

The respective performances of young and older adults in this study helped to elucidate the mechanisms underlying redintegrative processing in verbal STM. For correct-in-position recall, item recall, and order accuracy, there was no significant age difference in redintegration, indicating that the processes underlying redintegration appear to be age invariant. Interestingly, young and older adults utilised the associate relationship amongst the TBR words to facilitate short-term recall. However, when short-term recall was problematic, young and older adults were as likely to recall the critical non-presented lure instead of one of the originally presented TBR items. Although the mixed age-related findings in this study did not conform to the false memory literature, they do inform the redintegration literature by demonstrating young and older adults' continued reliance on long-term semantic knowledge to support short-term recall.

Much like the two previous studies of this thesis, young and, to a greater extent, older adults, utilised the same redintegration process and used the relatedness shared amongst the TBR items in addition to the critical non-presented lure as additional retrieval cues to facilitate redintegration. This is an important finding as it lends further support to Neale and Tehan's (2007) study, where they demonstrated that the process of redintegration remained age invariant, with older adults engaging in a greater amount of redintegrative processing to support short-term recall performance compared with young adults. The size of the relatedness advantage was slightly larger for older adults than young adults, suggesting there was a greater reliance on the semantic relatedness among the TBR items to manage the cognitively demanding nature of the experimental task and facilitate short-term recall. However, the relatedness advantage observed for young and older adults when using redintegration did not extend to short-term recall. While young adults recalled a higher proportion of related items than unrelated items compared with

older adults, even as the task conditions increased in difficulty, these recall differences were not large enough to be significant. These findings are inconsistent with the false memory literature, which has consistently found that in false-memory based tasks, veridical recall of the TBR items is significantly higher for young adults than older adults (Balota et al., 1999; Dehon & Bredart, 2004; Norman & Schacter, 1997; Schacter et al., 1997; Tun et al., 1998). One suggestion for the discrepancy between the previous research findings and those of this study is that the experimental paradigm encouraged the unconscious use of long-term knowledge to aid short-term recall and all participants engaged in the same type of processing to improve their verbal STM performance. Similar to Study two of this thesis, older adults utilised the relatedness shared among the TBR items to combat the effects of interference during encoding and may have engaged in some level of relation processing to assist with retrieving the TBR items for later output. As a result, older adults were able to recall a comparable proportion of related and unrelated words to match the verbal STM performance of young adults. The memory literature has previously acknowledged that when there is some semblance of a semantic relationship among the TBR items, older adults' memory performance improves because they draw upon their wealth of long-term knowledge to help improve their short-term recall performance (Poirier et al., 2011; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b; Tse, 2009). These findings therefore indicate that while young and older adults did not perform as expected in the false memory literature, their performance is consistent with the redintegration literature, where older adults greatly relied on their long-term knowledge, utilising the relationships among the TBR items to facilitate short-term recall performance, further supporting redintegrative processing operating in verbal STM.

Also emerging from this study was the increased likelihood for young and older adults to recall the critical non-presented lure in place of one of the original TBR items while engaging in redintegration to aid memory performance. Although older adults produced a higher proportion of critical non-presented lures during output relative to young adults, these differences were not large enough to be significant. The increased tendency for both young and older adults to produce the critical non-presented lure in this study did not align with the source-monitoring framework (Dehon & Bredart, 2004; Schacter et al., 1997). That body of literature indicates that young adults are significantly better at distinguishing external memories they have generated for the TBR items from internal memories they have generated for the TBR items (Dehon & Bredart, 2004; Schacter et al., 1997). However, the findings do align with deficits in attentional control processes (Balota et al., 1999; Tun et al., 1998) and an increased tendency to engage in gist-based processing as opposed to item-based processing when the demands of the experimental task become cognitively demanding (Tun et al., 1998). This framework also asserts that young and older adults had trouble with discriminating between multiple sources of activated information directly and indirectly related to the TBR items. In this study, during the easier task conditions, because there was little interference in the experimental task to affect the discrimination processes, recall of the critical non-presented lure was relatively low, if at all present. However, as task difficulty increased, the discrimination process became difficult, where there was an increased likelihood for young and older adults to produce the critical non-presented lure during output.

Another suggestion for the discrepancy of age-related performance in this study with the false memory literature is that young and older adults were encouraged to engage in a similar type of processing as task conditions became harder. In the difficult task conditions, when the

short-term phonological representations for the TBR items were damaged, redintegration was utilised to rebuild the short-term phonological memory trace with the phonological representation of the critical non-presented lure that was activated via a spreading activation in LTM. This observation is consistent with Tun et al.'s (1998) finding of no significant age differences in recalling or recognising the critical non-presented lure, suggesting that when attentional and cognitive resources are depleted and item-specific information about the TBR items is minimal, all individuals tended to rely on the overall gist of the theme shared by the TBR items to assist with discriminating amongst the competing information in memory and facilitate short-term recall performance. Balota et al. (1999) also found that adults across the three age groups engaged in relational processing to reduce the cognitive demands of the experimental task, which also increased their propensity to produce false memories at output. As a result, there was an increased likelihood of young and older adults recalling the critical non-presented lure. Together, these findings demonstrate that young and older adults are susceptible to producing false memories when engaging in redintegration to aid verbal STM performance.

In conclusion, young and older adults in this study demonstrated that when short-term recall was difficult, they relied on their long-term knowledge to assist with recalling the TBR items at output, even when the experimental task was designed to elicit false recall of a critical non-presented lure. Task difficulty successfully interfered with encoding processes such that their capacity to attend to the appropriate information while inhibiting the intruding information (Balota et al., 1999; Tun et al., 1998) was reduced. It is therefore clear that in the context of the redintegration framework, the false memory effect in verbal STM does not dissipate with age. Rather, young and older adults engage in the same type of processing to benefit their veridical performance and reduce their susceptibility producing false memories in verbal STM.

## **Recall errors and redintegration**

Consistent with the two previous studies of this thesis, the transposition and omission errors produced during the experimental task were of secondary interest to this study. Errors are indicative of problems occurring during encoding that filtered through to redintegrative processing prior to recalling the TBR words for later output (Saint-Aubin & Poirier, 2000). Participants in this study continued to produce transposition and omission errors during recall. Beginning with transposition errors, they are indicative of difficulties with interpreting the short-term phonological memory traces of two TBR items during retrieval (Saint-Aubin & Poirier, 2000). Interestingly, the proportion of transposition errors in this study did not mirror the performance in Study two of this thesis, with participants producing a significantly higher proportion of transposition errors when recalling the related words compared with the unrelated words. Additionally, older adults produced a significantly higher proportion of transposition errors during recall compared with their young counterparts. One suggestion for this observation is that individuals continued to rely on their long-term phonological and semantic representations to assist with recalling the TBR items, with the relatedness among the TBR words further facilitating recall. However, during those experimental conditions when the short-term phonological memory traces sustained a considerable amount of damage, given the similarity of the TBR items in terms of their relationship with each other and the critical non-presented lure, individuals redintegrated the degraded short-term phonological memory trace with the representation of the adjacent TBR item in the list. This finding is similar to observations made in examinations of the phonological similarity effect, where the short-term phonological memory traces sound similar that at retrieval, the two TBR items are subsequently transposed at output (Saint-Aubin & Poirier, 2000). The propensity for older adults to produce a significantly higher

proportion of transposition errors at recall compared with young adults is indicative of their respective short-term phonological memory traces sustaining a greater amount of damage during encoding. As a result, attempts at reintegrating those traces became troublesome as they were combating the interference during the experimental task that it affected their capacity to encode the TBR items into verbal STM.

On the other hand, omission errors are indicative of difficulties reconstructing the features missing from the short-term phonological memory trace of the TBR item (Saint-Aubin & Poirier, 2000). The extent that participants omit the TBR items at recall depends on the amount of information remaining in the short-term phonological memory trace that can assist with searching for long-term information to reconstruct the short-term phonological memory trace (Saint-Aubin & Poirier, 2000). Much like the two previous studies of this thesis, problems occurred during redintegration, particularly during those task conditions where the short-term phonological memory traces of the TBR items sustained enough damage that there was no useful information long-term to match with the remaining information available in the memory trace. Performance in this study mirrored the performance of participants in Study two of this thesis, where participants omitted a significantly higher proportion of TBR items from the unrelated trials compared with the related trials. The absence of a semantic relationship among the TBR items made encoding difficult that attempts at retrieving those items from verbal STM was challenging. This is in comparison with the related words that shared a relationship among each other along with the critical non-presented lure that was utilised at encoding to guide the search process, thus contributing to a reduced likelihood of omitting the TBR items in the related word trials. This pattern of memory performance is consistent with the pattern of performance Saint-Aubin and Poirier (1995; 1999a; 1999b), where item similarity benefited higher recall of those items and a

reduced rate of omissions for semantically similar words compared with semantically dissimilar words. Together, these findings continue to inform the redintegration and memory literature that when short-term recall is problematic, individuals rely on their long-term semantic knowledge to reconstruct degraded short-term phonological memory traces of the TBR items for later output.

## **Conclusion**

In conclusion, this study was the first empirical investigation to measure redintegration using the false memory effect (Deese, 1959; Roediger III & McDermott, 1995), where a relatedness effect emerged during short-term recall. As task difficulty increased, the size of the recall difference between the related and unrelated TBR items increased in favour of the related items (Neale & Tehan, 2007; Schweickert, 1993). Furthermore, having the TBR items related to one another, in addition to a critical non-presented lure word, enhanced the efficiency of the redintegration process by acting as additional retrieval cues to effectively narrow the search by inducing a spreading activation in LTM, locate the correct long-term information, and improve short-term recall. This study was also the first empirical investigation to obtain the ubiquitous false memory effect (Deese, 1959; Roediger III & McDermott, 1995) during redintegration. The increased interference inherent in the memory task compromised the fidelity of the short-term phonological memory traces for the TBR items during encoding that individuals erroneously reconstructed the degraded short-term phonological memory trace with the representation of the critical non-presented lure. With respect to age-related performance, the comparable performance of young and older adults at the short-term recall level and redintegration level indicates all adults engage in the same redintegrative processing to aid short-term recall. The finding that young and older adults were equally as susceptible to recalling the critical non-presented lure when short-term recall was problematic indicated that while the capacity to inhibit non-presented information



that has been activated in LTM is reduced with age, young and to a greater extent, older adults, relied on their long-term semantic knowledge to facilitate short-term recall. Collectively, these findings contribute to the memory literature by identifying the robustness of the redintegration framework where individuals continued to cue the search for long-term knowledge to assist with verbal STM performance.

## Chapter nine: General discussion

### Research overview

This thesis aimed to provide a different view to the dual memory model that proposes human memory comprises two distinct systems: a verbal STM and a LTM (Baddeley & Hitch, 1974; Nairne, 2002). That model suggests newly acquired information from the environment enters a sensory store and this information is then transferred to a verbal STM store, which keeps this information active for approximately 30 seconds before this information is then transferred to the permanent LTM store (Baddeley & Hitch, 1974; Nairne, 2002). Baddeley and Hitch's (1974) WMM has dominated explanations of the dual memory model and clearly explicates the relationship between the various subsystems proposed to be in human memory. The dual memory model also proposes that information forgotten from verbal STM results from the short-term phonological memory traces decaying over time if they are not refreshed through engaging in sub-vocal rehearsal using articulatory processes in the phonological loop (Baddeley, 1992, 2000a, 2000b, 2004; Brown, 1958; Peterson & Peterson, 1959).

Alternatively, the unitary view of human memory proposes there is an intrinsic and symbiotic relationship between verbal STM and LTM (Brown et al., 2000; Melton, 1963; Neath & Nairne, 1995). This framework proposes that human memory exists on a continuum where individuals utilise their long-term knowledge to help facilitate verbal STM performance (Brown et al., 2000; Melton, 1963; Neath & Nairne, 1995). This thesis investigated the unitary view of human memory, with particular attention to the process of redintegration using Schweickert's (1993) Multinomial Processing Tree Model of Redintegration, which posits that individuals use their long-term lexical/semantic knowledge to reconstruct the degraded short-term phonological memory traces of the TBR information in verbal STM for later output. The redintegration model

has received increasing support in the verbal STM literature as it has been able to explain effects that Baddeley and Hitch's (1974) WMM cannot explain. These effects include lexicality (Hulme et al., 1991; Hulme et al., 1995), word frequency (Hulme et al., 1997), semantic similarity (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1995, 1999a, 1999b), and concreteness (Walker & Hulme, 1999). This thesis has established the utility of redintegration by measuring this process using the WLE (Baddeley et al., 1975), associate word pairs, and the false memory effect (Roediger III & McDermott, 1995).

This thesis also aimed to solidify the unitary view of human memory by strengthening the interference-based view on short-term forgetting. Rather than information decaying over time, forgetting occurs when some form of information or activity interferes with encoding the newly acquired information into verbal STM, and this interference can be proactive (Keppel & Underwood, 1962; Melton, 1963; Wickens et al., 1963) or retroactive (Waugh & Norman, 1965). Similar to Neale and Tehan (2007), a new manipulation of task difficulty was created to interfere with encoding the TBR items into verbal STM, compromise the fidelity of those short-term phonological memory traces, and subsequently increase the reliance on redintegration to retrieve the TBR items from verbal STM for later output. Task difficulty comprised the unique combination of recall intervals (Fournet et al., 2003; Neale & Tehan, 2007; Russo & Grammatopoulou, 2003; Tehan et al., 2001; Tolan & Tehan, 1999), study conditions (Colle & Welsh, 1976; Jones & Morris, 1992; Neath, 1999, 2000; Salame & Baddeley, 1990; Tolan & Tehan, 2002), and presentation rates (Bhatarah et al., 2009; Coltheart, 1999; Coltheart & Langdon, 1998; Tan & Ward, 2008), each known to interfere with and impair verbal STM performance. Those variables have not been previously used together to manipulate the level of difficulty in an experimental task and produce redintegration effects at output. Thus, as task

difficulty increased, participants recalled a higher proportion of short words than long words (i.e., the word length advantage), words in the associate pairs than the non-associate pairs (i.e., the associate advantage), and related words than unrelated words (i.e., the relatedness advantage). Participants also produced a false memory effect, a novel finding, where participants recalled an increasingly higher proportion of critical non-presented lures instead of the originally presented TBR items.

Finally, this thesis aimed to continue examining whether age differences exist in redintegration as Neale and Tehan (2007) are the only researchers to this date who have conducted such an investigation. Using their measure of redintegration, their manipulation of task difficulty, and samples of young and older adults, Neale and Tehan observed that as task difficulty increased, participants recalled an increasingly higher proportion of semantically and phonologically similar words compared with their dissimilar counterparts. Young and older adults did not significantly differ in their use of redintegration, which provided strong evidence that young and older adults engage in the same redintegration process to facilitate short-term recall. This thesis therefore extended Neale and Tehan's finding by measuring redintegration and manipulating task difficulty using other variables and compared different samples of young and older adults. Across the three studies in this thesis, at the redintegration level, young and older adults did not significantly differ in their use of redintegration, but older adults were more reliant on redintegration to aid short-term recall compared with young adults. This was evidenced by the larger size of the respective word length, associate, and relatedness advantages for older adults compared with young adults. At the short-term recall level, while age differences were present during recall for short and long words, no significant age differences emerged for recall of words in the associate and non-associate pairs, along with related and unrelated words. These findings

are consistent with the ageing and verbal STM literature and suggest that older adults utilise forms of environmental or contextual support, which improves their memory performance. The differential effects of word length, association, and relatedness combined with the manipulation of task difficulty across young and older adults' short-term recall performance therefore strengthened the notion of redintegration operating in verbal STM.

### **Redintegration**

This thesis has made an important contribution to the verbal STM literature by measuring redintegration using the WLE (Baddeley et al., 1975), associate word pairs, and the false memory effect (Roediger III & McDermott, 1995). The redintegration account stems from the assumption that individuals use their long-term lexical/semantic knowledge to rebuild the degraded short-term phonological memory traces for later recall. The results of this thesis strongly supported Schweickert's assertions: when task conditions became difficult, individuals used redintegration to facilitate recall of the TBR items because the short-term phonological memory traces were degraded due to the interference produced by the manipulation of task difficulty during encoding. Redintegration effects were in the form of the positive relationship between task difficulty and word length advantage (chapter six), the associate advantage (chapter seven), and the relatedness advantage (chapter eight). A false memory effect also emerged during redintegration (chapter eight), which was a novel finding that has not been previously established within the redintegration framework. These findings adequately addressed Neale and Tehan's (2007) assertion that their cueing effect could only be extended to variables where it was plausible that individuals could use a form of cue to aid memory performance.

The redintegration effects in this thesis indicated that a cueing effect emerged; an observation that is receiving increasing support in the redintegration and verbal STM literature.

To effectively search for long-term information, individuals used the remaining information that was available in the degraded short-term phonological memory trace for the TBR item to begin the reconstruction process. Individuals then used the characteristics of the TBR items as additional retrieval cues that induced a spreading activation in LTM, which enhanced the search to increase the likelihood of reconstructing the degraded short-term phonological memory traces. Specifically, individuals used the length of the TBR word, the association inherent among the word in the associate pair, the relatedness shared among the TBR words, and the critical non-presented lure to guide the search to a specific section of LTM and further narrow the potential recall candidates for subsequent output. This thesis was consistent with the assertions Neale and Tehan (2007), Poirier and Saint-Aubin (1995) along with Saint-Aubin and Poirier (1995; 1999a; 1999b) made that advocated for a cueing mechanism embedded within redintegration. Neale and Tehan observed that when task difficulty increased, individuals relied heavily on similarity at semantic and phonological levels to enhance the redintegration process and recall the TBR items. They inferred from their findings that similarity functioned as a cue that pointed to a specific section in LTM, thereby enhancing access to potential recall candidates to reconstruct the degraded short-term phonological memory traces of the TBR items. Poirier, along with Saint-Aubin and Poirier also came to a similar conclusion about the categorical advantage they observed in their respective studies. Knowing the words were from the same semantic category pointed to a specific section of LTM that helped to narrow the exhaustive search that would have taken place in LTM to locate the correct information to assist with redintegrating the degraded short-term phonological memory traces of those TBR items for later recall. Therefore, the results from this thesis coupled with the previous literature suggest that irrespective of whether the cue is lexical, semantic, phonological, associative, or related in form, individuals utilised cues in their

immediate environment to enhance redintegration of the forgotten information for subsequent recall.

At a broader level, the result of this thesis provide support for the unitary model of memory as participants have demonstrated, through their use of redintegration, the intrinsic relationship that exists between verbal STM and LTM. Increasing difficulty in the experimental task interfered with the individual's capacity to create strong short-term phonological memory traces for the TBR information retained in verbal STM. However, it is argued that this information does not completely dissipate from verbal STM, as assumed by the dual memory theorists (Baddeley & Hitch, 1974; Burgess & Hitch, 1999; Nairne, 2002). Rather, individuals utilised the degraded short-term information and redintegrated the necessary traces via information located in LTM to facilitate short-term recall (Schweickert, 1993). These findings suggest that individuals rely on some form of cue to assist with everyday living. When there is appropriate support in the environment, it may assist with reducing the amount of cognitive resources required to encode the newly acquired information and allocate those resources to effectively retrieving this information for later use (Howard et al., 1991; Lowndes et al., 2008; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2002). One such example is using different memory strategies that make use of previously stored long-term information. These strategies organise newly acquired information into a cohesive whole so that retrieval of part of that information usually assist with retrieving the remainder of the information (Hampstead et al., 2012; Verhaeghen, Marcoen, & Goossens, 1992). Mnemonic strategies also make information more elaborate so a greater amount of information can be stored and this additional information is easier to retrieve. Such strategies include the method of loci, acrostics, rhymes, semantic organisation, semantic elaboration, and mental imagery (Hampstead et al., 2012; Verhaeghen et al., 1992). The literature suggests that

healthy older adults benefit from mnemonic strategy use more than from engaging in other types of cognitive training (Verhaeghen et al., 1992) and such findings have been supported by other studies investigating mnemonic strategy use within memory rehabilitation programs (Craik et al., 2007; Kessels & de Hann, 2003; Willis et al., 2006). These findings point to the suggestion that individuals utilise a form of cue, irrespective of whether the cue is internally or externally generated, that can assist with encoding and retrieval processes to improve verbal STM performance. In relation to redintegrative processing, the results from this thesis clearly indicate that individuals utilised the characteristics of the TBR items as additional retrieval cues to enhance the redintegration process and aid short-term recall. By encouraging individuals to identify a form of cue among the TBR information, it may enhance encoding, reduce the processing demands upon the individual, and increase the efficiency with which individuals retrieve the TBR information from verbal STM.

The findings from this thesis have largely been explained through redintegration and the possibility of alternative explanations has largely been ignored to this point. There is growing acceptance in the memory literature that psycholinguistic models (Martin & Gupta, 2004; Martin, Lesch, & Bartha, 1999), as they suggest that long-term representations and systems involved in language processing are more closely related to short-term recall than what the redintegration literature proposes. The redintegration hypothesis restricts the influence of long-term representations to the retrieval stage in a verbal STM task (Neale & Tehan, 2007; Schweickert, 1993; Thorn et al., 2004). However, these psycholinguistic models emphasise that there is a considerable overlap between verbal STM tasks and language processing, as the semantic, lexical, and sublexical networks are widely thought to underlie language representations are actually viewed as supporting verbal STM. These models move away from the classic suggestion



that verbal STM relies on a separate phonological representation of the target items and postulates that presenting linguistic information involves activating the relevant stored long-term knowledge. In turn, the characteristics of these representations can then influence short-term recall performance.

Burgess and Hitch (2006) offer a computational/network model of verbal STM in a revision on their earlier model (Burgess & Hitch, 1999), where items are represented within lexical and phonological interconnected networks. In their earlier model, Burgess and Hitch proposed that the language network, represented by local nodes at the lexical and sublexical level are linked with a dynamic context layer that changes over time and enables encoding information pertaining to serial position by associating each item activated in the lexical network with a distinct state of the context layer. In their revised model, they propose that individuals learn a novel sequence of familiar items that involves strengthening connections between representations of the items and states of an internal context or timing signal through repetition. Repeated lists benefit from long-term knowledge to the degree that the initial items serve as retrieval cues for an existing chunk in LTM. Burgess and Hitch considered that repeated encoding of the same list into short-term memory contributes to the gradual strengthening of a unified representation of that list's sequence in LTM. These unified long-term memory representations would then assist recall of a new list to the degree that the new list is similar to the list represented in LTM. Roodenrys (2009) also proposed that an interactive network model was necessary where various levels of representation, including letter, phonemic, and lexical levels are activated and compete with each other, as observed through the phonological similarity and neighbourhood effects. In the models proposed by Martin et al. (1999) along with Martin and Gupta (2004), they assume that long-term knowledge structures (i.e., phonological, lexical and semantic layers) primarily drive memory

and processing outcomes. Their models contain input buffers that maintain information about serial order and output buffers that are required for response preparation. In essence, the long-term knowledge store for verbal information is connected to the buffers in verbal STM such that activated information from the long-term knowledge store continues to activate information in the buffers and the activated information in the buffers then feeds back to keep the representations activated in the long-term knowledge store. Together, these psycholinguistic models are consistent that the short-term retention of verbal material depends on activating long-term memory representations (i.e., phonological, lexical, and semantic) for words and maintaining their activation in verbal STM. Thus, while the redintegration process is the best explanation for the results across the three empirical studies of this thesis, it is also important to acknowledge the increasing acknowledgement of language models underlying short-term recall in verbal STM tasks.

It can therefore be surmised from the findings of this thesis and the previous literature that verbal STM and LTM should not be considered as separate stores that work to encode, store, and retrieve information for later output. Rather, this intrinsic and symbiotic relationship between verbal STM and LTM demonstrates that human memory is a unified system that works to utilise the previously stored knowledge to assist with managing the demands of everyday living (Brown et al., 2000; Melton, 1963; Neath & Nairne, 1995). Individuals utilise a form of cue, irrespective of its form, to enhance encoding the TBR information into verbal STM and subsequent increase the likelihood of reproducing that same information for later output.

### **Task difficulty**

Another important finding worthy of discussion is that short-term forgetting resulted from interference-based activity that subsequently impaired verbal STM performance. Several findings

corroborate this view. Firstly, in all three studies, the length of the retention interval remained fixed at 12 seconds for all task conditions. Thus, time could not account for the degradation of short-term phonological memory traces. Much like Keppel and Underwood's (1962) study, where they replicated Peterson and Peterson's (1959) study by keeping the retention interval constant at 12 seconds for each individual trial, they found that irrespective of whether participants recalled the TBR items after a three-second or 18-second delay, participants recalled all of the three-consonant trigrams after each time delay. Secondly, the manipulation of task difficulty in this thesis interfered with the participants' capacity to encode the TBR items into verbal STM, compromising the fidelity of those short-term phonological memory traces, and increasing the reliance on redintegration to facilitate short-term recall. Interference was achieved by the unique combination of recall intervals (Fournet et al., 2003; Neale & Tehan, 2007; Russo & Grammatopoulou, 2003; Tehan et al., 2001; Tolan & Tehan, 1999), study conditions (Buchner & Erdfelder, 2005; Colle & Welsh, 1976; Jones & Morris, 1992; Neath, 1999, 2000; Salame & Baddeley, 1990; Tolan & Tehan, 2002), and presentation rates (Bhatarah et al., 2009; Coltheart, 1999; Coltheart & Langdon, 1998; Tan & Ward, 2008). The combination of these variables performed somewhat consistently across the three empirical studies, as evidenced by the rank order correlations. The emergence of redintegration effects for correct-in-position recall, item recall, and order accuracy indicate that this thesis created a valid measure of task difficulty. This finding is consistent with Neale and Tehan (2007) who created their own manipulation of task difficulty which also interfered with encoding the TBR items into verbal STM so redintegration could be called upon to aid memory performance. Finally, the manipulation of task difficulty produced sufficient damage to the short-term phonological memory traces of the TBR items that participants produced a significantly high proportion of transposition and omission errors across the three studies, especially during the difficult task conditions. These errors indicate that the

manipulation of task difficulty interfered with encoding to the extent that participants incorrectly redintegrated the degraded short-term phonological memory trace for the TBR item and in some instances, the short-term phonological memory traces for the TBR item could not be rebuilt. Factors that would ordinarily increase access to long-term representations to facilitate the redintegration process (e.g., lexicality, word frequency, semantic similarity, concreteness, word length, associations, and relatedness) were blocked due to the increased degradation of the short-term phonological memory traces (Saint-Aubin & Poirier, 2000). When Poirier and Saint-Aubin (1995) along with Saint-Aubin and Poirier (1995; 1999a; 1999b) introduced articulatory suppression into their task by asking participants to repeat *mathématiques* during encoding, retrieval, or at both stages of the experimental task, participants produced an increased proportion of transposition and omission errors at recall. Furthermore, in some instances, the degradation of the short-term phonological memory trace was so great that individuals produced false memories at output where they erroneously recalled non-presented semantic associates of the TBR items during output. As evidenced from Studies one and two of this thesis, participants erroneously reconstructed the degraded short-term phonological memory trace of the original TBR item with the representation of a non-presented semantic associate, deeming it to be a match at the stage of recall. Hence, this manipulation of task difficulty interfered with the formation and discriminability of short-term phonological memory traces for the TBR items, subsequently increasing the reliance on redintegration to facilitate verbal STM performance than if each task difficulty variable was presented on its own (Schweickert et al., 1999).

At a broader level, the results of this thesis support the interference perspective on short-term forgetting, where incoming information from the external environment, despite the individual's best efforts to ignore its presence, interferes with their capacity to encode newly

acquired information into verbal STM. To combat such interference, individuals rely on cues from their external environment as well as cues they may have generated internally to assist with acquiring and subsequently retrieving the required information from memory for later recall. This is consistent with previous research that irrespective of whether interference was in the form of switching the TBR items from numbers to letters or letters to numbers (Wickens et al., 1963) or increasing the number of interfering items that preceded the test item (Waugh & Norman, 1965), these manipulations affected the individual's capacity to locate and retain the TBR information in verbal STM. It is therefore clear from the aforementioned research and the results of this thesis that the decay theory is no longer the sole explanation for forgetting in verbal STM and that there is strong support for the interference-based perspective on short-term forgetting. Irrespective of its form, interference encouraged the reliance on long-term knowledge to the extent that individuals call upon redintegration and use additional environmental cues to support verbal STM performance.

### **Ageing**

Perhaps another important contribution of this thesis in support of redintegration operating in verbal STM is that redintegration remains invariant to age. For the three empirical studies, young and older adults engaged in the same redintegration process to reconstruct the degraded short-term phonological memory traces for the TBR items. Older adults were more likely to enhance the search for information in verbal STM by using the characteristic of the TBR item (i.e., word length, association, relatedness) as an additional retrieval cue to help reconstruct those degraded short-term phonological memory traces. Young adults engaged in the same redintegrative processing, however, they were not as reliant on redintegration because the size of the respective word length, associate and relatedness advantages across the three empirical

studies were smaller in comparison to older adults. This observation indicates that the short-term phonological memory traces for the TBR items were relatively intact and sustained little damage in verbal STM that there was not a greater reliance on redintegration to facilitate short-term recall. These are key observations because, aside from Neale and Tehan (2007), no other study to this date has demonstrated this unique relationship between ageing and redintegration. Thus, the findings from this study along with Neale and Tehan continue to support the notion that the process of redintegration is unaffected by age, but the reliance on redintegration varies across the age spectrum.

At the short-term recall level, mixed findings emerged for age-related performance. Young adults recalled a significantly higher proportion of short and long words compared with older adults for correct-in-position and item recall. Yet, recall was comparable for words in the associate and non-associate pairs, related and unrelated words, and recall of the critical non-presented lure. These findings appear to indicate that when there is no form of contextual or environmental support, the TBR information is processed at the lexical level and, as a result, young adults typically outperform older adults. However, in contrast to previous research, when there is some form of contextual or environmental support, these same age-related differences were abolished. One suggestion for this discrepancy is that the experimental paradigm in this thesis was considerably different to the traditional tasks used to assess verbal STM. In contrast to studies that use, for example, strict immediate and delayed recall conditions, in this thesis the experimental paradigm used to assess verbal STM performance had conditions that were designed to manipulate the encoding and retrieval demands from easy to difficult and manipulate the reliance on long-term knowledge to facilitate short-term recall performance. Age differences were expected to be minimal in the easier conditions but become increasingly larger in the

difficult task conditions. However, as the experimental task encouraged the reliance on redintegrative processing, the expected age differences that would ordinarily appear at the short-term recall level were minimised because older adults capitalised on their long-term knowledge, as assumed when engaging in redintegration, to assist with encoding and subsequently retrieving those same items from verbal STM for later output. In turn, older adults were able to match the performance of young adults at the short-term recall level. Previous studies have not manipulated encoding conditions to the extent achieved in this thesis and as such, the expected age differences were not present during output. It is evident from the multitude of findings in this thesis that there is an increasing reliance on long-term knowledge as one ages and when there is some form of contextual support, older adults utilise this support to enhance their verbal STM performance.

The pattern of age-related memory performance in this thesis is consistent with the central tenet of the ageing and verbal STM literature that with increasing age is a corresponding decrease in verbal STM performance because of a decline in cognitive resources (Balota et al., 2000; Grady & Craik, 2000; Luo & Craik, 2008; Salthouse, 1996). In order to compensate for this decline in cognitive resources, there becomes an increasing reliance on some form of environmental or contextual support to improve memory performance (Balota et al., 2000; Grady & Craik, 2000; Luo & Craik, 2008). Older adults experienced considerable difficulty with managing the varying encoding and retrieval demands of the experimental task compared with young adults, as evidenced by their lower mean recall performance as task conditions became difficult. In turn, older adults became more reliant on redintegration and used defining characteristics as additional cues to support verbal STM performance. Howard et al.'s (1991) study established that additional retrieval cues helped to alleviate some of the cognitive demands of the experimental task for the older adults and they could allocate those resources to retrieving

the second word in the word pair and ultimately improve their overall short-term recall performance. Similarly, Lowndes et al. (2008) along with Naveh-Benjamin (2002) found that the supportive environmental conditions provided during encoding and/or retrieval alleviated some of the cognitive demands of the experimental task and improved the likelihood of outputting the TBR items during short-term recall.

Similarly, the findings of this thesis align with the position that there is also an age-related decrease in the memory processes required to inhibit irrelevant information that would interfere with verbal STM performance (Balota et al., 2000; Hasher & Zacks, 1979; Luo & Craik, 2008). The reduced inhibition account advocates for the notion that when inhibitory function is impaired, the contents of verbal STM may be consumed with irrelevant information that detracts from encoding the TBR items, making subsequent retrieval of these TBR items for later output increasingly difficult. Hasher and Zacks (1979; 1988) demonstrated in their research that when encoding conditions are optimal, young and older adults retrieve sufficient information to support verbal STM performance in the form of making inferences. However, when factors are manipulated at the encoding stage (be it in the form of delayed presentation between the prime and recall or the speed at which the prime was presented) to assist with short-term recall, older adults experience considerable difficulty because they become distracted by other irrelevant information that may enter verbal STM, making the experimental task increasingly difficult. As a result, they have to rely on the information available to them in their immediate environment to support short-term recall performance. Together, the performances of young and older adults in this thesis have confirmed that older adults are as capable as young adults to call upon their long-term knowledge to facilitate verbal STM performance. Older adults are more reliant on their long-term knowledge as they experienced greater difficulty with managing the varying encoding



and retrieval demands of the experimental task, making subsequent recall difficult. Their respective performances continue to demonstrate how adults across the lifespan continue to rely on permanently stored knowledge, irrespective of whether it is lexical or semantic in form, to assist with retrieving the required information that would aid short-term recall and ultimately benefit verbal STM performance.

### **Limitations, conclusions, future directions, and practical implications**

**Limitations.** While this thesis continued to substantiate the unitary view of human memory through redintegration, it is important to acknowledge its limitations. One limitation was the absence of measuring response speed when recalling the TBR items. Participants had a fixed amount of time between seeing the row of question marks and presentation of the first TBR item in the next list of words. It would have been useful to measure the speed at which participants articulated their responses to compare times based on lexical characteristics (i.e., word length) and words based on semantic characteristics (i.e., association or relatedness). On average short-term recall was higher for words in the associate pairs and related words relative to short words. It could be hypothesised that the response times would be faster for words that shared a semantic relationship as the memory literature has strongly suggested that information connected in a series of networks may induce a spreading activation that activates the corresponding long-term representations for those words quicker (Collins & Loftus, 1975; MacKay & Burke, 1990). In turn, the redintegration process may be more efficient compared with words that do not share a semantic relationship and words that are selected purely on their lexical characteristics, where a spreading activation does not readily occur. The search and subsequent recall processes may presumably be longer for those items because there is no specific characteristic to enhance recall other than how individuals encoded the TBR items into verbal STM. Given that a cueing effect

has been established within the redintegration process, future research could obtain these measures of response speed, which may provide further insight into the efficiency of the redintegration process and whether it is enhanced by the type of information being encoded and subsequently retrieved from verbal STM for later output.

Another limitation of this thesis was failing to record whether participants used different strategies to encode the TBR items into verbal STM and subsequently retrieve them for later output. As task difficulty increased in the experimental task, participants may have elected to use strategies in order to retain the TBR items in verbal STM and combat the interference produced from the combined effects of recall interval, study condition, and presentation rate. Anecdotal evidence from one participant in Study three reported that some of the words were related to one another while another participant in Study one reported that they made a picture using the different words in order to remember them for later recall. Previous research has already ascertained that with age comes an increasing likelihood to use strategies during encoding and retrieval because of the reduced cognitive capacity to retain information, inhibit irrelevant information, and output the TBR information (Larigauderie, Michaud, & Vicente, 2011). Future research could examine whether young and older adults used strategies to assist with encoding and retrieval as such strategy use may influence the effectiveness of the redintegration process and determine whether the TBR items alone encouraged redintegration or whether individuals used strategies to help enhance the redintegration process.

Finally, this thesis was limited by the number of items contained in each list of TBR items. For the three empirical studies, each list contained four TBR items. Performance for each study across correct-in-position recall, item recall, and order accuracy was close to ceiling in the easier task conditions and slightly decreased as task conditions became harder. While true

redintegration effects emerged in each empirical study of this thesis, having a greater number of items in each list may have accentuated each of the redintegration effects by placing greater demands on the capacity of verbal STM to retain the TBR items while combatting the interference produced from the task difficulty manipulation. Future research could extend the number of TBR items to six items per list and compare the magnitude of these redintegration effects to four-item lists using the measures of redintegration and the manipulation of task difficulty in this thesis.

**Conclusions.** To conclude, this thesis has continued to support the unitary view of human memory by demonstrating the symbiotic and reciprocal relationship between the information available in verbal STM and the permanently stored knowledge in LTM. The novel findings of Neale and Tehan (2007) have been extended by examining redintegration through Schweickert's (1993) Multinomial Processing Tree Model of Redintegration as measured using the WLE (Baddeley et al., 1975), associate word pairs, and the false memory effect (Roediger III & McDermott, 1995). The characteristics of the TBR items effectively cued the search for long-term information that enhanced reconstruction of the degraded short-term phonological memory traces of the TBR items for later output. Moreover, a new manipulation of task difficulty was created using the unique combination of recall intervals (Fournet et al., 2003; Neale & Tehan, 2007; Russo & Grammatopoulou, 2003; Tehan et al., 2001; Tolan & Tehan, 1999), study conditions (Colle & Welsh, 1976; Jones & Morris, 1992; Neath, 1999, 2000; Salame & Baddeley, 1990; Tolan & Tehan, 2002), and presentation rates (Bhatarah et al., 2009; Coltheart, 1999; Coltheart & Langdon, 1998; Tan & Ward, 2008) that increased the reliance on redintegration to facilitate short-term recall. Importantly, this thesis has addressed Neale and Tehan's contention that the cueing effect observed in their research could only be extended to

variables that are cue driven. Here, the cueing effect was demonstrated through word length, associations, and relatedness. Furthermore, this thesis has informed the ageing and verbal STM literature by finding that redintegration is invariant to age, with older adults more reliant on redintegration to facilitate short-term recall performance relative to young adults. In support of the theoretical accounts of ageing in cognitive-based tasks, older adults more so than young adults, experienced difficulty managing the encoding and subsequent retrieval demands of the experimental task such that they largely relied on forms of contextual or environmental support to assist short-term recall performance. Moreover, older adults also had considerable difficulty inhibiting irrelevant information that became activated in LTM during redintegration that they produced a higher proportion of semantically related and unrelated extra-list intrusions at recall. Together, these findings make an important contribution to the memory field by substantiating the notion that the process of redintegration is not affected by age and that individuals across the age spectrum continue to engage in redintegration when short-term recall becomes problematic. Furthermore, individuals in this study have been able to demonstrate the effectiveness of redintegration that they can utilise cues in their immediate environment to search for information that enhances their verbal STM.

**Future directions.** The results from this thesis give rise to the proposition that rather than having a major influence during retrieval to aid short-term recall, the contribution of long-term knowledge to verbal STM performance may also extend to encoding. It was evident in this thesis that long-term knowledge influenced the individual's capacity to encode the TBR items into verbal STM because at recall, participants recalled a higher proportion of short words than long words, words in the associate pairs than non-associate pairs, and related words than unrelated words, along with a higher proportion of critical non-presented lures. Further research is required

to examine this proposition by enhancing encoding conditions through presenting an instruction prior to the TBR items to the participant to determine whether individuals call upon their long-term knowledge from the outset of a verbal STM task to support encoding and ultimately improve short-term recall performance.

Future research could also examine the extent of the cueing effect in verbal STM by manipulating the level of associative strength among the TBR items. In this thesis, the words in the associate pairs were of a high associative strength and the TBR related words were strongly related to a critical non-presented lure. It would be interesting to explore whether this cueing effect would emerge for words that are of a medium or low associative strength as previous research has indicated that when the TBR items are medium or weakly related, short-term recall performance declines (Kausler & Lair, 1966; Naveh-Benjamin et al., 2002; Zaretsky & Halberstam, 1968). Conducting such an investigation may help to continue explicating the mechanisms underpinning the cueing effect that emerges when individuals engage in redintegration to facilitate verbal STM performance.

**Practical implications.** The results of this thesis have practical implications in relation to the development of memory training programmes, particularly for older adults and those individuals diagnosed with a neurological impairment. The three empirical studies have demonstrated that when short-term recall becomes difficult to the extent that they cannot remember the TBR information, young and older adults can effectively locate long-term information and amalgamate it with the available information remaining in verbal STM to assist with later recall. The memory literature has already ascertained that mnemonic strategies improve the likelihood of retrieving information from LTM to assist with short-term recall. Such memory training programmes could encourage the use of memory techniques that may be of assistance in

one's general everyday living (Craik et al., 2007; Hampstead et al., 2012; Verhaeghen et al., 1992; Willis et al., 2006). For example, to remember a list of shopping items, individuals are taught to develop a song that is meaningful to them which includes all of the shopping items they need to purchase. If adults are encouraged to establish an association or meaningful link between the newly acquired information with their permanently stored long-term knowledge, they may have greater success in recalling the required information. The retrieval process might not be as effortful and cognitively demanding upon the individual, as they are guiding the search only for information pertaining to the items in the song as opposed to expending a large amount of cognitive effort to search the entire contents of LTM and locate the information that will help them retrieve the forgotten information. Together, this thesis has made a unique contribution to the memory literature by providing additional evidence of the symbiotic relationship between verbal STM and LTM. Importantly, these findings have provided support for redintegration that suggests long-term information has a key role in short-term recall and utilising long-term knowledge can assist with one's everyday living.

## References

- Anderson, J. A., Silverstein, J. W., Jones, S. A., & Jones, R. S. (1977). Distinctive features, categorical perception, and probability learning: Some applications of a neural model. *Psychological Review*, 84(5), 413-451. doi: 10.1037/0033-295X.84.5.413
- Atkins, A. S., & Reuter-Lorenz, P. A. (2008). False working memories? Semantic distortion in a mere 4 seconds. *Memory and Cognition*, 36(1), 74-81. doi: 10.3758/MC.36.1.74
- Baddeley, A. (1966). Short-term memory for word sequences as a function of acoustic, semantic, and formal similarity. *Quarterly Journal of Experimental Psychology*, 18(4), 362-365. doi: 10.1080/14640746608400055
- Baddeley, A. (1986). *Working memory*. Oxford: Oxford University Press.
- Baddeley, A. (1992). Working memory: Looking back and looking forward. *Nature Reviews: Neuroscience*, 4, 829-839. doi: 10.1038/nrn1201
- Baddeley, A. (2000a). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, 4(11), 417-423. doi: 10.1016/S1364-6613(00)01538-2
- Baddeley, A. (2000b). *Short-term and working memory*. United States of America: Oxford University Press.
- Baddeley, A. (2004). The psychology of memory. In A. D. Baddeley, M. D. Kopelman & B. A. Wilson (Eds.), *The essential handbook of memory disorders for clinicians* (pp. 1-13). England: John Wiley and Sons.
- Baddeley, A., Chincotta, D., Stafford, L., & Turk, D. (2002). Is the word length effect in STM entirely attributable to output delay? Evidence from serial recognition. *The Quarterly Journal of Experimental Psychology*, 55A(2), 353-369. doi: 10.1080/02724980143000523
- Baddeley, A., & Hitch, G. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (pp. 47-89). New York: Academic Press.
- Baddeley, A., Thompson, N., & Buchanan, M. (1975). Word length and the structure of short term memory. *Journal of Verbal Learning and Verbal Behaviour*, 14(6), 575-589. doi: 10.1016/S0022-5371(75)80045-4
- Badham, S. P., Estes, Z., & Maylor, E. A. (2012). Integrative and semantic relations equally alleviate age-related associative memory deficits. *Psychology and Aging*, 27(1), 141-152. doi: 10.1037/a0023924
- Baker, R., & Tehan, G. (2008). *Word-length effects in backward serial recall and the remember/know task*. Paper presented at the 43rd Australian Psychological Society Annual Conference, Hobart, Tasmania.  
[http://eprints.usq.edu.au/5590/1/Baker\\_Tehan\\_APS\\_2008\\_AV.pdf](http://eprints.usq.edu.au/5590/1/Baker_Tehan_APS_2008_AV.pdf)
- Baker, R., Tehan, G., & Tehan, H. (2012). Word length and age influences on forward and backward immediate serial recall. *Memory and Cognition*, 10(4), 40-51. doi: 10.3758/s13421-011-0127-7
- Balota, D. A., Cortese, J. M., Duchek, D. A., Roediger III, H. L., McDermott, K. B., & Yerys, B. E. (1999). Veridical and false memories in healthy older adults and dementia of the alzheimer's type. *Cognitive Neuropsychology*, 16(3/4/5), 361-384. doi: 10.1080/026432999380834
- Balota, D. A., Dolan, P. O., & Ducheck, J. M. (2000). Memory changes in healthy young and older adults. In F. I. M. Craik (Ed.), *Oxford handbook of memory* (pp. 395-410). Oxford, UK: Oxford University Press.

- Balota, D. A., & Duchek, J. M. (1988). Age-related differences in lexical access, spreading activation, and simple pronunciation. *Psychology and Aging, 3*(184-93). doi: 10.1037/0882-7974.3.1.84
- Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology*. Cambridge, England: Cambridge University Press.
- Belleville, S., Peretz, I., & Malenfant, D. (1996). Examination of the working memory components in normal aging and in dementia of the alzheimer type. *Neuropsychologia, 34*(3), 195-207. doi: 10.1016/0028-3932(95)00097-6
- Besner, D., & Davelaar, E. (1982). Basic processes in reading: Two phonological codes. *Canadian Journal of Psychology, 36*(4), 701-711. doi: 10.1037/h0080665
- Bhatarah, P., Ward, G., Smith, J., & Hayes, L. (2009). Examining the relationship between free recall and immediate serial recall: Similar patterns of rehearsal and similar effects of word length, presentation rate, and articulatory suppression. *Memory and Cognition, 37*(5), 689-713. doi: 10.3758/MC.37.5.689
- Bopp, K. L., & Verhaeghen, P. (2007). Age-related differences in control processes in verbal and visuospatial working memory: Storage, transformation, supervision, and coordination. *Journal of Gerontology: Psychological Sciences, 62B*(5), 239-246. Retrieved from [http://affinity.uwaterloo.ca/~cogneuro/publications/Age\\_related\\_differences\\_in\\_control\\_processes.pdf](http://affinity.uwaterloo.ca/~cogneuro/publications/Age_related_differences_in_control_processes.pdf)
- Bortner, M. (1958). Review of the Mill Hill Vocabulary Scale *The sixth mental measurements yearbook* (Vol. 6). Retrieved from EBSCO Mental Measurements Yearbook database
- Bousfield, W. A. (1953). The occurrence of clustering in the recall of randomly arranged associates. *The Journal of General Psychology, 49*(2), 229-240. doi: 10.1080/00221309.1953.9710088
- Bower, G. H., Clark, M. C., Lesgold, A. M., & Winzenz, D. (1969). Hierarchical retrieval schemes in recall of categorised word lists. *Journal of Verbal Learning and Verbal Behaviour, 8*, 323-343. doi: 10.1016/S0022-5371(69)80124-6
- Brown, G., Preece, T., & Hulme, C. (2000). Oscillator-based memory for serial order. *Psychological Review, 107*(1), 127-181. doi: 10.1037/0033-295X.107.1.127
- Brown, J. (1958). Some tests of the decay theory of immediate memory. *Quarterly Journal of Experimental Psychology, 10*(1), 12-21. doi: 10.1080/17470215808416249
- Buchner, A., & Erdfelder, E. (2005). Word frequency of irrelevant speech distractors affects serial recall. *Memory & Cognition, 33*(1), 86-97. doi: 10.3758/BF03195299
- Burgess, N., & Hitch, G. J. (1999). Memory for serial order: A network model of the phonological loop and its timing. *Psychological Review, 106*(3), 551-581. doi: 10.1037/0033-295X.106.3.551
- Burgess, N., & Hitch, G. J. (2006). A revised model of short-term memory and long-term learning of verbal sequences. *Journal of Memory and Language, 55*(4), 627-652. doi: 10.1016/j.jml.2006.08.005
- Caplan, D., Rochon, E., & Waters, G. S. (1992). Articulatory and phonological determinants of word length effects in span tasks. *The Quarterly Journal of Experimental Psychology Section A, 45*(2), 177-192. doi: 10.1080/14640749208401323
- Coane, J. H., McBride, D. M., Raulerson III, B. A., & Jordan, J. S. (2007). False memory in a short-term memory task. *Experimental Psychology, 54*(1), 62-70. doi: 10.1027/1618-3169.54.1.62
- Colle, H. A., & Welsh, A. (1976). Acoustic masking in primary memory. *Journal of Verbal Learning and Verbal Behaviour, 15*(1), 17-31. doi: 10.1016/S0022-5371(76)90003-7



- Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, 82(6), 407-428. doi: 10.1037/0033-295x.82.6.407
- Coltheart, V. (1999). Comparing short-term memory and memory for rapidly presented visual stimuli. *International Journal of Psychology*, 34(5/6), 293-300. doi: 10.1080/002075999399594
- Coltheart, V., & Langdon, R. (1998). Recall of short word lists presented visually at fast rates: Effects of phonological similarity and word length. *Memory and Cognition*, 26(2), 330-342. doi: 10.3758/BF03201144
- Conrad, R. (1964). Acoustic confusions in immediate memory. *British Journal of Psychology*, 55(1), 75-84. doi: 10.1111/j.2044-8295.1964.tb00899.x
- Cowan, N., Wood, N. L., Wood, P. K., Keller, T. A., Nugent, L. D., & Keller, C. V. (1998). Two separate verbal processing rates contributing to short-term memory span. *Journal of Experimental Psychology: General*, 127(2), 141-160. doi: 10.1037/0096-3445.127.2.141
- Craik, F. I. M., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F. I. M. Craik & S. Trechub (Eds.), *Aging and cognitive processes* (pp. 191 - 211). New York: Plenum Press.
- Craik, F. I. M., Byrd, M., & Swanson, J. (1987). Patterns of memory loss in three elderly samples. *Psychology and Aging*, 2(1), 79-86. doi: 10.1037/0882-7974.2.1.79
- Craik, F. I. M., & McDowd, J. (1987). Age differences in recall and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 13(3), 474-479.
- Craik, F. I. M., Wincour, G., Palmer, H., Binns, M. A., Edwards, M., Bridges, K., et al. (2007). Cognitive rehabilitation in the elderly: Effects on memory. *Journal of the International Neuropsychological Society*, 13, 132-142. doi: 10.1017/S1355617707070166
- Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology*, 58(1), 17-22. doi: 10.1037/h0046671
- Dehon, H., & Bredart, S. (2004). False memories: Young and older adults think of semantic associates at the same rate, but young adults are more successful at source monitoring. *Psychology and Aging*, 19(1), 191-197. doi: 10.1037/0882-7494.19.1.191
- Erber, J. (2005). *Aging and older adulthood*. California: Thomson Wadsworth.
- Field, A. P. (2009). *Discovering statistics using spss: And sex and drugs and rock 'n' roll* (3rd ed.). London: Sage
- Fournet, N., Juphard, A., Monnier, C., & Roulin, J.-L. (2003). Phonological similarity in free and serial recall: The effect of increasing retention intervals. *International Journal of Psychology*, 38(6), 384-389. doi: 10.1080/00207590344000204
- Frisch, S. A., Large, N. R., & Pisoni, D. B. (2000). Perception of word likeness: Effects of segment probability and length on the processing of nonwords. *Journal of Memory and Language*, 42, 481-496. doi: 10.1006/jmla.1999.2692
- Gathercole, S. E. (1995). Is nonword repetition a test of phonological memory or long-term knowledge? It all depends on the nonwords. *Memory and Cognition*, 23(1), 83-94. doi: 10.3758/BF03210559
- Gathercole, S. E. (1999). Cognitive approaches to the development of short-term memory. *Trends in Cognitive Sciences*, 3(11), 410-419. doi: 10.1016/S1364-6613(99)01388-1
- Grady, C. L., & Craik, F. I. M. (2000). Changes in memory processing with age. *Current Opinion in Neurobiology*, 10, 224 - 231. doi: 10.1016/S0959-44388(00)00073-8
- Hampstead, B. M., Sathian, K., Phillips, P. A., Amaraneni, A., Delaune, W. R., & Stringer, A. Y. (2012). Mnemonic strategy training improves memory for object location associations in

- both healthy elderly and patients with amnesic mild cognitive impairment: A randomized, single-blind study. *Neuropsychology*, 26(3), 385-399. doi: 10.1037/a0023545
- Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General*, 108(3), 356-388. doi: 10.1037/0096-3445.108.3.356
- Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 193 - 225). San Diego: Academic Press.
- Hendry, L., & Tehan, G. (2005). An item/order tradeoff explanation of word length and generation effects. *Memory*, 13(3/4), 364-371. doi: 10.1080/09658210311000341
- Henry, L. (2012). *The working memory model*. London: SAGE Publications.
- Henson, R. N. A. (1998). Short-term memory for serial order: The start-end model. *Cognitive Psychology*, 36(2), 73-137. doi: 10.3758/BF03198544
- Howard, D. V., Fry, A. F., & Bruce, C. M. (1991). Aging and memory for new associations: Direct versus indirect measures. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 17(4), 779-792. doi: 10.137//0278-7393.17.4.779
- Hulme, C., Maughan, S., & Brown, G. (1991). Memory for familiar and unfamiliar words: Evidence for a long-term memory contribution to short-term memory span. *Journal of Memory and Language*, 30(6), 685 - 701. doi: 10.1016/0749-596X(91)90032-F
- Hulme, C., Roodenrys, S., Brown, G., & Mercer, R. (1995). The role of long-term memory mechanisms in memory span. *British Journal of Psychology*, 86, 527 - 536.
- Hulme, C., Roodenrys, S., Schweickert, R., Brown, G. D. A., Martin, S., & Stuart, G. (1997). Word-frequency effects on short-term memory tasks: Evidence for a redintegration process in immediate serial recall. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 23(5), 1217 - 1232. doi: 10.1037/0278-7393.23.5.1217
- Hulme, C., Surprenant, A. M., Bireta, T. J., Stuart, G., & Neath, I. (2004). Abolishing the word-length effect. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 30, 98 - 106. doi: 10.1037/0278-7393.30.1.98
- Jones, D., Madden, C., & Miles, C. (1992). Privileged access by irrelevant speech to short-term memory: The role of changing state. *The Quarterly Journal of Experimental Psychology Section A*, 44(4), 645 - 669. doi: 10.1080/14640749208401304
- Jones, D., & Morris, N. (1992). Irrelevant speech and serial recall: Implications for theories of attention and working memory. *Scandinavian Journal of Psychology*, 33, 212 - 229. doi: 10.1111/j.1467-9450.1992.tb00911.x
- Kausler, D. H. (1994). *Learning and memory in normal aging*. San Diego: Academic Press.
- Kausler, D. H., & Lair, C. V. (1966). Associative strength and paired-associate learning in elderly subjects. *Journal of Gerontology*, 21(2), 278-280. doi: 10.1093/geronj/21.2.278
- Keppel, G. (1991). *Design and analysis: A researcher's handbook*. California: Prentice Hall.
- Keppel, G., & Underwood, B. J. (1962). Proactive inhibition in short-term retention of single items. *Journal of Verbal Learning and Verbal Behaviour*, 2, 153-161. doi: 10.1016/S0022-5371(62)80023-1
- Kessels, R. P. C., & de Hann, E., H.F. (2003). Mnemonic strategies in older people: A comparison of errorless and effortful learning. *Age and Ageing*, 32(5), 529-533. doi: 10.1093/ageing/afg068
- Kucera, H., & Francis, W. (1967). *Computational analysis of present-day american english*. Providence: Brown University Press.

- Larigauderie, P., Michaud, A., & Vicente, S. (2011). The role of semantic memory in short-term recall: Effect of strategic retrieval ability in an elderly population. *Aging, Neuropsychology, and Cognition*, 18, 147-179. doi: 10.1080/13825585.2010.521813
- Lewandowsky, S., & Murdock, B. B. J. (1989). Memory for serial order. *Psychological Review*, 101(1), 539-543. doi: 10.1037/0033-295X.96.1.25
- Lowndes, G. J., Saling, M. M., Ames, D., Chiu, E., & Gonzalez, L. M. (2008). Recall and recognition measures of paired associate learning in healthy aging. *Aging, Neuropsychology, and Cognition*, 15, 506-522. doi: 10.1080/13825580802099678
- Luo, L., & Craik, F. I. M. (2008). Aging and memory: A cognitive approach. *The Canadian Journal of Psychiatry*, 53(6), 349-353.
- MacKay, D. G., & Burke, D. M. (1990). Chapter Five: Cognition and aging: A theory of new learning and the use of old connections. *Advances in Psychology*, 71, 213-263. doi: 10.1013/S0166-4115(08)60159-4
- Martin, N., & Gupta, P. (2004). Exploring the relationship between word processing and verbal short-term memory: Evidence from associations and dissociations. *Cognitive Neuropsychology*, 21, 213-228. doi: 10.1080/02643290342000447
- Martin, R. C., Lesch, M. F., & Bartha, M. C. (1999). Independence of input and output phonology in word processing and short-term memory. *Journal of Memory and Language*, 41, 3-29. doi: 10.1006/jmla.1999.2637
- Melton, A. W. (1963). Implications of short-term memory for a general theory of memory. *Journal of Verbal Learning and Verbal Behaviour*, 2, 1-21. doi: 10.1016/S0022-5371(63)80063-8
- Millers, L. M., & Roodenrys, S. (2009). The interaction of word frequency and concreteness in immediate serial recall. *Memory and Cognition*, 37(6), 850-865. doi: 10.3758/MC.37.6.850
- Nairne, J. (1990). A feature model of immediate memory. *Memory and Cognition*, 18(3), 251 - 269. doi: 10.3758/BF03213879
- Nairne, J. (2002). Remembering over the short-term: The case against the standard model. *Annual Reviews of Psychology*, 53, 53-81. doi: 10.1146/annurev.psych.53.100901.135131
- Nairne, J., Riegler, G. L., & Serra, M. (1991). Dissociative effects of generation on item and order retention. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 17(4), 702-709. doi: 10.1037/0278-7393.17.4.702
- Naveh-Benjamin, M. (2000). Adult age differences in memory performance: Test of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26(5), 1170-1187. doi: 10.1037//0278-7393.26.5.1170
- Naveh-Benjamin, M., Craik, F. I. M., & Ben-Shaul, L. (2002). Age-related differences in cued recall: Effects of support at encoding and retrieval. *Aging, Neuropsychology, and Cognition*, 9(4), 276-287. doi: 10.1076/anec.9.4.276.8773
- Neale, K., & Tehan, G. (2007). Age and redintegration in immediate memory and their relationship to task difficulty. *Memory and Cognition*, 35(8), 1940 - 1953. doi: 10.3758/BF03192927
- Neath, I. (1999). Modelling the disruptive effects of irrelevant speech on order information. *International Journal of Psychology*, 34(5/6), 410 - 418. doi: 10.1080/002075999399765
- Neath, I. (2000). Modelling the effects of irrelevant speech on memory. *Psychonomic Bulletin & Review*, 7(3), 403 - 423. doi: 10.1080/002075999399765
- Neath, I., & Nairne, J. (1995). Word-length effects in immediate memory: Overwriting trace decay theory. *Psychonomic Bulletin & Review*, 2(4), 429 - 441. doi: 10.3758/BF03210981

- Neath, I., & Suprenant, A. M. (2003). *An introduction to research, data, and theory* (2nd ed.). Belmont, CA: Wadsworth/Thomson Learning.
- Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). The University of South Florida word association, rhyme, and word fragment norms, from <http://www.usf.edu/FreeAssociation/>
- Norman, K. A., & Schacter, D. L. (1997). False recognition in younger and older adults: Exploring the characteristics of illusory memories. *Memory and Cognition*, 25(6), 838-848. doi: 10.3758/BF03211328
- Peters, F., Majerus, S., Olivier, L., van der Linden, M., Salmon, E., & Collette, F. (2007). A multicomponent exploration of verbal short-term storage deficits in normal aging and alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology*, 29(4), 405 - 417. doi: 10.1080/13803390600733064
- Peterson, L. R., & Johnson, S. T. (1971). Some effects of minimising articulation on short-term retention. *Journal of Verbal Learning and Verbal Behaviour*, 10(4), 346-354. doi: 10.1016/S0022-5371(71)80033-6
- Peterson, L. R., & Peterson, M. J. (1959). Short-term retention of individual verbal items. *Journal of Experimental Psychology*, 58(3), 193-198. doi: 10.1037/h0049234
- Poirier, M., Dhir, P., Saint-Aubin, J., Tehan, G., & Hampton, J. (Eds.). (2011). *The influence of semantic memory on verbal short-term memory*.
- Poirier, M., & Saint-Aubin, J. (1995). Memory for related and unrelated words: Further evidence on the influence of semantic factors in immediate serial recall. *The Quarterly Journal of Experimental Psychology Section A*, 48A(2), 384-404. doi: 10.1080/14640749508401396
- Poirier, M., & Saint-Aubin, J. (1996). Immediate serial recall, word frequency, item identity and item position. *Canadian Journal of Experimental Psychology*, 50(4), 408 - 412. doi: 10.1037/1196-1961.50.4.408
- Quinlan, P. T. (1992). The oxford psycholinguistic database, from [http://www.psy.uwa.edu.au/MRCDataBase/uwa\\_mrc.htm](http://www.psy.uwa.edu.au/MRCDataBase/uwa_mrc.htm)
- Rabinowitz, J. C., Craik, F. I. M., & Ackerman, B. P. (1982). A processing resource account of age differences in recall. *Canadian Journal of Psychology*, 36(2), 325-344. doi: 10.1037/h0080643
- Raven, J. (1989). The raven progressive matrices: A review of national norming studies and ethnic socioeconomic variation within the united states. *Journal of Educational Measurement*, 26(1), 1-16. doi: 10.1111/j.1745-3984.1989.tb00314.x
- Reyna, V. F., & Brainerd, C. J. (1991). Fuzzy-trace theory and framing effect in choice: Gist extraction, truncation, and conversion. *Journal of Behavioral Decision Making*, 4, 249-262. doi: 10.1002/bdm.3960040403
- Roche, J., Tolan, G. A., & Tehan, G. (2011). Concreteness effects in short-term memory: A test of the item-order hypothesis. *Canadian Journal of Experimental Psychology*, 65(4), 245-253. doi: 10.1037/a0024693
- Roediger III, H. L., Balota, D. A., & Watson, J. M. (2001). Spreading activation and arousal of false memories. In H. L. Roediger III, J. S. Nairne, I. Neath & A. M. Suprenant (Eds.), *The nature of remembering: Essays in honour of robert g. crowder* (pp. 95-115). Washington, DC: American Psychological Association.
- Roediger III, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21(4), 803-814. doi: 10.1037/0278-7393.21.4.803

- Roodenrys, S. (2009). Explaining phonological neighbourhood effects in short-term memory. In A. Thorn & M. Page (Eds.), *Interactions between short-term and long-term memory in the verbal domain* (pp. 177-197). Hove: Psychology Press.
- Roodenrys, S., & Quinlan, P. T. (2000). The effects of stimulus set size and word frequency on verbal serial recall. *Memory*, 8(2), 71 - 78. doi: 10.1080/096582100387623
- Russo, R., & Grammatopoulou, N. (2003). Word length and articulatory suppression affect short-term and long-term recall tasks. *Memory & Cognition*, 31(5), 728-737. doi: 10.3758/BF03196111
- Sadoski, M., Goetz, E. T., & Fritz, J. B. (1993). Impact of concreteness on comprehensibility, interest, and memory for text: Implications for dual coding theory and text design. *Journal of Educational Psychology*, 85(2), 291 - 304. doi: 10.1037/0022-0663.85.2.291
- Sadoski, M., Goetz, E. T., & Rodriguez, M. (2000). Engaging texts: Effects of concreteness on comprehensibility, interest, and recall in four text types. *Journal of Educational Psychology*, 92(1), 85 - 95. doi: 10.1037//0022-0663.92.1.85
- Saint-Aubin, J., & Poirier, M. (1995). Memory for related and unrelated words: Further evidence on the influence of semantic factors in immediate serial recall. *The Quarterly Journal of Experimental Psychology*, 48A(2), 384 - 404. doi: 10.1080/146407/49508401396
- Saint-Aubin, J., & Poirier, M. (1999a). The influence of long-term memory factors on immediate serial recall: An item and order analysis. *International Journal of Psychology*, 34(5), 347-352. doi: 10.1080/002075999399675
- Saint-Aubin, J., & Poirier, M. (1999b). Semantic similarity and immediate serial recall: Is there a detrimental effect on order information? *The Quarterly Journal of Experimental Psychology Section A*, 52A(2), 367 - 394. doi: 10.1080/713755814
- Saint-Aubin, J., & Poirier, M. (2000). Immediate serial recall of words and nonwords: Tests of the retrieval-based hypothesis. *Psychonomic Bulletin & Review*, 7(2), 332 - 340. doi: 10.3758/BF03212990
- Saint-Aubin, J., & Poirier, M. (2005). Word frequency effects in immediate serial recall: Item familiarity and item co-occurrence have the same effect. *Memory*, 13(3/4), 325 - 332. doi: 10.1080/09658210344000369
- Salame, P., & Baddeley, A. (1990). The effects of irrelevant speech on immediate free recall. *Bulletin of the Psychonomic Society*, 28(6), 540 - 542. Retrieved from doi:10.3758/BF03334073
- Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, 103(3), 403 - 428. doi: 10.1037/0033-295x.103.3.403
- Schacter, D. L., Koutstaal, W., Johnson, M. K., Gross, M. S., & Angell, K. E. (1997). False recollection induced by photographs: A comparison of older and younger adults. *Psychology and Aging*, 12(2), 203-215. doi: 10.1037/0882-7974.12.2.203
- Schweickert, R. (1993). A multinomial processing tree model for degradation and redintegration in immediate recall. *Memory and Cognition*, 21, 168 - 175. doi: 10.3758/BF03202729
- Schweickert, R., Chen, S., & Poirier, M. (1999). Redintegration and the useful lifetime of the verbal memory representation. *International Journal of Psychology*, 34, 447 - 453. doi: 10.1080/002075999399800
- Slessor, G., Phillips, L. H., & Bull, R. (2007). Exploring the specificity of age-related differences in theory of mind tasks. *Psychology and Aging*, 22(3), 639 - 643. doi: 10.1037/0882-7974.22.3.639
- Stuart, G., & Hulme, C. (2000). The effects of word co-occurrence on short-term memory: Associative links in long-term memory affect short-term memory performance. *Journal of*

- Experimental Psychology: Learning, Memory, and Cognition*, 26, 796 - 802. doi: 10.1037/0278-7393.26.3.796
- Suprenant, A. M., & Neath, I. (2009). The nine lives of short-term memory. In A. Thorn & M. P. A. Page (Eds.), *Interactions between short-term memory and long-term memory in the verbal domain* (pp. 16-43). Hove, UK: Psychology Press.
- Tabachnick, B. G., & Fidell, S. S. (2007). *Using multivariate statistics* (5th ed.). Boston: Allyn and Bacon.
- Tan, L., & Ward, G. (2000). A recency-based account of primacy effects in free recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26(6), 1589 - 1625. doi: 10.1037//0278-7393.26.1589
- Tan, L., & Ward, G. (2008). Rehearsal in immediate serial recall. *Psychonomic Bulletin & Review*, 15(3), 535 - 542. doi: 10.3758/PBR.15.3.535
- Tehan, G. (2010). Associative relatedness enhances recall and produces false memories in immediate serial recall. *Canadian Journal of Experimental Psychology*, 64(4), 266-272. doi: 10.1037/10021375
- Tehan, G., Hendry, L., & Kocinski, D. (2001). Word length and phonological similarity effects in simple, complex, and delayed serial recall tasks: Implications for working memory. *Memory*, 9(4), 333 - 348. doi: 10.1080/09658210042000049
- Thorn, A. S. C., Gathercole, S. E., & Frankish, C. R. (2004). Redintegration and the benefits of long-term knowledge in verbal short-term memory: An evaluation of schweickert's (1993) multinomial processing tree model. *Cognitive Psychology*, 50, 133 - 158. doi: 10.1016/j.cogpsych.2004.07.001
- Tolan, G. A., & Tehan, G. (1999). Determinants of short-term forgetting: Decay, retroactive interference, or proactive interference? *International Journal of Psychology*, 34(5/6), 285 - 292. doi: 10.1080/002075999399585
- Tolan, G. A., & Tehan, G. (2002). Testing feature interaction: Between-stream irrelevant speech effects in immediate recall. *Journal of Memory and Language*, 46, 562 - 585. doi: 10.1006/jmla.2001.2820
- Tse, C.-S. (2009). The role of associative strength in the semantic relatedness effect on immediate serial recall. *Memory*, 17(8), 874-891. doi: 10.1080/09658210903376250
- Tulving, E. (1985). Memory and consciousness. *Canadian Psychology/Psychologie Canadienne*, 26(1), 1-12. doi: 10.1037/h0080017
- Tun, P. A., Wingfield, A., Rosen, M. J., & Blanchard, L. (1998). Response latencies for false memories: Gist-based processes in normal aging. *Psychology and Aging*, 13(2), 230-241. doi: 10.1037//0882-7974.13.2.230
- Underwood, B. J. (1965). False recognition produced by implicit verbal responses. *Journal of Experimental Psychology*, 70(1), 122-129. doi: 10.1037/h0022014
- Verhaeghen, P., Marcoen, A., & Goossens, L. (1992). Improving memory performance in the aged through mnemonic training: A meta-analytic study. *Psychology and Aging*, 7(2), 242-251. doi: 10.1037/0882-7974.7.2.242
- Walker, I., & Hulme, C. (1999). Concrete words are easier to recall than abstract words: Evidence for a semantic contribution to short-term serial recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 25(5), 1256-1271. doi: 10.1037/0278-7393.25.5.1256
- Waugh, N. C., & Norman, D. A. (1965). Primary memory. *Psychological Review*, 72, 89-104. doi: 10.1037/h0021797

- Wickens, D. D., Born, D. G., & Allen, C. K. (1963). Proactive inhibition and item similarity in short-term memory. *Journal of Verbal Learning and Verbal Behaviour*, 2(5-6), 440-445. doi: 10.1016/S0022-5371(63)80045-6
- Willis, S. L., Tennstedt, S. L., Marsiske, M., Ball, K., Elias, J., Koepke, K. M., et al. (2006). Long-term effects of cognitive training on everyday functional outcomes in older adults. *Journal of the American Medical Association*, 296(23), 2805-2814. doi: 10.1001/jama.296.23.2805
- Zaretsky, H. H., & Halberstam, J. L. (1968). Age differences in paired-associate learning. *Journal of Gerontology*, 23(2), 165-168. doi: 10.1093/geronj/23.2.165

## Appendices

### Appendix A: Information Letters, Consent Forms, and Human Research Ethics Committee Approval

#### Appendix A – 1: Information letter for young adults



#### SCHOOL OF PSYCHOLOGY

Australian Catholic University Limited  
 ABN 15 050 192 660  
 Melbourne Campus (St Patrick's)  
 115 Victoria Parade, Fitzroy, Vic. 3065  
 Locked Bag 4115 Fitzroy MCD VIC 3065  
 Telephone 03 9953 3126  
 Facsimile 03 9953 3205  
[www.acu.edu.au](http://www.acu.edu.au)

#### INFORMATION LETTER TO PARTICIPANTS

TITLE OF PROJECT: Memory performance for short lists of words

STAFF SUPERVISOR: Associate Professor Anne Tolan

STUDENT RESEARCHER: Miss Amanda Scicluna

COURSE: Master of Psychology (Education and Developmental) / PhD

Dear Participant,

You are invited to take part in a research study that assesses how age and memory problems are related to memory performance, specifically the ability to recall lists of words. As a participant in this experiment you will experience the processes involved in psychological laboratory experimentation, a common method used for studying memory performance. Introductory and advanced courses in psychology require students to have a clear understanding of the processes of laboratory experimentation and memory. Participation in this experiment will further enhance your understanding of concepts learnt within your psychology classes. The proposed research will extend and build upon existing research and knowledge with the view of providing a better understanding of the mechanisms and processes underlying memory performance and more specifically the process of redintegration. This involves the use of long term memory to help facilitate recall in short term memory. This project is part of ongoing research by Associate Professor Tolan (School of Psychology, ACU National) and is being completed as part of the student researcher's Master's/PhD thesis. This project needs participants aged between 18 and 39 years.



Participation in this study involves completing a testing session with the student researcher that would last approximately 40 to 60 minutes. The session would involve completing measures of language and memory. You will also be required to remember short lists of words to be recalled after they are presented in their original order of presentation. Each set of words will appear one at a time on the computer screen. You will be required to respond verbally and the experimenter will record your responses. You will be given sufficient time to respond before the next list of words is presented. Testing will be completed at the Melbourne Campus of Australian Catholic University.

Whilst we hope that this research will help better understand how age and memory problems are related to the processes that are involved in memory performance, we cannot guarantee that you will receive any direct benefits from participating in this study. We do not anticipate any risks with your participation in this research.

If you have any questions about the project, before or after participating, please contact the Staff Supervisor, Associate Professor Anne Tolan on 07 3623 7256 in the School of Psychology, McAuley Campus at the Australian Catholic University, 1100 Nudgee Road, Banyo Qld 4014. Before commencing, you will have the opportunity to ask any questions about the project. You will also have the opportunity to discuss your participation and the project in general after completing the experiment. The student researcher will be more than happy to contact you about the results of the research project, if you so wish.

This study has been approved by the Human Research Ethics Committee at the Australian Catholic University. In the event that you have any complaint or concern about the way you have been treated during the study, or you have a query that the student researcher and staff supervisor have not been able to satisfy, you may write to:

Chair, Human Research Ethics Committee  
C/o Research Services  
Australian Catholic University  
Melbourne Campus

Locked Bag 4115

FITZROY VIC 4101

Tel: 03 9953 3157

Fax: 03 9953 3315

Any complaint will be treated in confidence and will be fully investigated. The participant will be informed of the outcome.

If you are willing to participate, please sign the attached consent forms. You should sign both copies of the consent form and return one copy to the student researcher or staff supervisor and the other copy is for your records. Your participation in the research project will be most appreciated.

Amanda Scicluna  
Student Researcher

Associate Professor Anne Tolan  
Staff Supervisor

## Appendix A – 2: Consent form for young adults

### Appendix A – 2.1: Copy for the participant to keep



Australian Catholic University Limited  
 ABN 15 050 192 660  
 Melbourne Campus (St Patrick's)  
 115 Victoria Parade, Fitzroy, Vic. 3065  
 Locked Bag 4115 Fitzroy MCD VIC 3065  
 Telephone 03 9953 3126  
 Facsimile 03 9953 3205  
[www.acu.edu.au](http://www.acu.edu.au)

### INFORMED CONSENT FORM

#### Copy for the Participant to Keep

TITLE OF PROJECT: Memory performance for short lists of words.

STAFF SUPERVISOR: Associate Professor Anne Tolan

STUDENT RESEARCHER: Miss Amanda Scicluna

COURSE: Master of Psychology (Education and Developmental) / PhD

#### Participant's Consent

I.....(*the participant*) have read and understood the information in the information letter inviting participation in the research, and any questions I have asked have been answered to my satisfaction. I agree to participate in this activity, completing the pencil/paper and self-report tasks and watching a computer display lists of words and then recalling each word in the order they are presented. I realise that I can withdraw my consent at any time and I understand that withdrawal will in no way affect my ACU studies. I am aware that the activity will take between 40 and 60 minutes to complete.

I agree that research data collected for the study may be published or provided to other researchers in a form that does not identify me in any way. I agree to be contacted by telephone if needed to arrange a mutually convenient time to complete the research task. I am over 18 years of age.

Name of participant: .....  
 (block letters)

Signature: ..... Date: .....

Student Researcher: Amanda Scicluna

Signature:.....Date: .....

Staff Supervisor: Associate Professor Anne Tolan

Signature:.....Date: .....

***Appendix A – 2.2: Copy for the participant to submit to the researcher***



Australian Catholic University Limited  
 ABN 15 050 192 660  
 Melbourne Campus (St Patrick's)  
 115 Victoria Parade, Fitzroy, Vic. 3065  
 Locked Bag 4115 Fitzroy MCD VIC 3065  
 Telephone 03 9953 3126  
 Facsimile 03 9953 3205  
[www.acu.edu.au](http://www.acu.edu.au)

**INFORMED CONSENT FORM**

**Copy for the Participant to Submit to the Researcher**

TITLE OF PROJECT: Memory performance for short lists of words.  
 STAFF SUPERVISOR: Associate Professor Anne Tolan  
 STUDENT RESEARCHER: Miss Amanda Scicluna  
 COURSE: Master of Psychology (Education and Developmental) / PhD

**Participant's Consent**

I ..... (*the participant*) have read and understood the information in the information letter inviting participation in the research, and any questions I have asked have been answered to my satisfaction. I agree to participate in this activity, completing the pencil/paper and self-report tasks and watching a computer display lists of words and then recalling each word in the order they are presented. I realise that I can withdraw my consent at any time and I understand that withdrawal will in no way affect my ACU studies. I am aware that the activity will take between 40 and 60 minutes to complete.

I agree that research data collected for the study may be published or provided to other researchers in a form that does not identify me in any way. I agree to be contacted by telephone if needed to arrange a mutually convenient time to complete the research task. I am over 18 years of age.

Name of participant: .....  
 (block letters)

Signature: ..... Date: .....

Student Researcher: Amanda Scicluna

Signature: ..... Date: .....

Staff Supervisor: Associate Professor Anne Tolan

Signature: ..... Date: .....

### Appendix A – 3: Information letter for older adults



#### SCHOOL OF PSYCHOLOGY

Australian Catholic University Limited  
 ABN 15 050 192 660  
 Melbourne Campus (St Patrick's)  
 115 Victoria Parade, Fitzroy, Vic. 3065  
 Locked Bag 4115 Fitzroy MCD VIC 3065  
 Telephone 03 9953 3126  
 Facsimile 03 9953 3205  
[www.acu.edu.au](http://www.acu.edu.au)

#### INFORMATION LETTER TO PARTICIPANTS

TITLE OF PROJECT: Memory performance for short lists of words

STAFF SUPERVISOR: Associate Professor. Anne Tolan

STUDENT RESEARCHER: Miss Amanda Scicluna

COURSE: Master of Psychology (Education and Developmental) / PhD

Dear Participant,

You are invited to take part in a research study that assesses how age and memory problems are related to memory performance, specifically the ability to recall lists of words. As a participant in this experiment you will experience the processes involved in psychological laboratory experimentation, a common method used for studying memory performance. The proposed research will extend and build upon existing research and knowledge with the view of providing a better understanding of the mechanisms and processes underlying memory performance and more specifically the process of redintegration. This involves the use of long term memory to help facilitate recall in short term memory. This project is part of ongoing research by Associate Professor Tolan (School of Psychology, ACU National) and is being completed as part of the student researcher's Master's/PhD thesis. This project needs participants aged between 61 and 89 years of age.

Participation in this study involves completing a testing session with the student researcher that would last approximately 40 to 60 minutes. The session would involve completing measures of language and memory. You will also be required to remember short lists of words to be recalled after they are presented in the original order of presentation. Each set of words will appear one at a time on the computer screen. You will be required to respond verbally and the experimenter will record your responses. You will be given sufficient time to respond before the next list of words is presented. Testing will be completed at a mutually convenient location.

Whilst we hope that this research will help better understand how age and memory problems are related to the processes that are involved in memory performance, we cannot guarantee that you will receive any direct benefits from participating in this study. We do not anticipate any risks with your participation in this research.

If you have any questions about the project, before or after participating, please contact the Staff Supervisor, Associate Professor Anne Tolan on 07 3623 7256 in the School of Psychology, McAuley Campus at the Australian Catholic University, 1100 Nudgee Road, Banyo Qld 4014. Before commencing, you will have the opportunity to ask any questions about the project. You will also have the opportunity to discuss your participation and the project in general after completing the experiment. The student researcher will be more than happy to contact you about the results of the research project, if you so wish.

This study has been approved by the Human Research Ethics Committee at the Australian Catholic University. In the event that you have any complaint or concern about the way you have been treated during the study, or you have a query that the student researcher and staff supervisor have not been able to satisfy, you may write to:

Chair, Human Research Ethics Committee  
C/o Research Services  
Australian Catholic University  
Melbourne Campus

Locked Bag 4115

FITZROY VIC 4101

Tel: 03 9953 3157

Fax: 03 9953 3315

Any complaint will be treated in confidence and will be fully investigated. The participant will be informed of the outcome.

If you are willing to participate, please sign the attached consent forms. You should sign both copies of the consent form and return one copy to the student researcher or staff supervisor and the other copy is for your records. Your participation in the research project will be most appreciated.

Amanda Scicluna  
Student Researcher

Associate Professor Anne Tolan  
Staff Supervisor

## Appendix A – 4: Consent form for older adults

### Appendix A – 4.1: Copy for the participant to keep



Australian Catholic University Limited  
 ABN 15 050 192 660  
 Melbourne Campus (St Patrick's)  
 115 Victoria Parade, Fitzroy, Vic. 3065  
 Locked Bag 4115 Fitzroy MCD VIC 3065  
 Telephone 03 9953 3126  
 Facsimile 03 9953 3205  
[www.acu.edu.au](http://www.acu.edu.au)

## INFORMED CONSENT FORM

### Copy for the Participant to Keep

TITLE OF PROJECT: Memory performance for short lists of words.

STAFF SUPERVISOR: Associate Professor. Anne Tolan

STUDENT RESEARCHER: Miss Amanda Scicluna

COURSE: Master of Psychology (Education and Developmental) / PhD

### Participant's Consent

I ..... (*the participant*) have read and understood the information in the information letter inviting participation in the research, and any questions I have asked have been answered to my satisfaction. I agree to participate in this activity, completing the pencil/paper and self-report tasks and watching a computer display lists of words and then recalling each word in the order they are presented. I realise that I can withdraw my consent at any time and am aware that the activity will take between 40 and 60 minutes to complete.

I agree that research data collected for the study may be published or provided to other researchers in a form that does not identify me in any way. I agree to be contacted by telephone if needed to arrange a mutually convenient time to complete the research task. I am over 18 years of age.

Name of participant: .....  
 (block letters)

Signature: ..... Date: .....

Student Researcher: Amanda Scicluna

Signature: ..... Date: .....

Staff Supervisor: Associate Professor Anne Tolan

Signature: ..... Date: .....

**Appendix A – 4.2: Copy for the participant to submit to the researcher**



Australian Catholic University Limited  
 ABN 15 050 192 660  
 Melbourne Campus (St Patrick's)  
 115 Victoria Parade, Fitzroy, Vic. 3065  
 Locked Bag 4115 Fitzroy MCD VIC 3065  
 Telephone 03 9953 3126  
 Facsimile 03 9953 3205  
[www.acu.edu.au](http://www.acu.edu.au)

**INFORMED CONSENT FORM**

**Copy for the Participant to Submit to the Researcher**

TITLE OF PROJECT: Memory performance for short lists of words.

STAFF SUPERVISOR: Associate Professor Anne Tolan

STUDENT RESEARCHER: Miss Amanda Scicluna

COURSE: Master of Psychology (Education and Developmental) / PhD

**Participant's Consent**

I.....(*the participant*) have read and understood the information in the information letter inviting participation in the research, and any questions I have asked have been answered to my satisfaction. I agree to participate in this activity, completing the pencil/paper and self-report tasks and watching a computer display lists of words and then recalling each word in the order they are presented. I realise that I can withdraw my consent at any time and am aware that the activity will take between 40 and 60 minutes to complete.

I agree that research data collected for the study may be published or provided to other researchers in a form that does not identify me in any way. I agree to be contacted by telephone if needed to arrange a mutually convenient time to complete the research task. I am over 18 years of age.

Name of participant: .....  
 (block letters)

Signature: ..... Date: .....

Student Researcher: Amanda Scicluna

Signature:.....Date: .....

Staff Supervisor: Associate Professor Anne Tolan

Signature:.....Date: .....

## Appendix A – 5: Human Research Ethics Committee Approval Form (V2009 31)

Australian Catholic University  
Brisbane Sydney Canberra Ballarat Melbourne



### Human Research Ethics Committee

#### Committee Approval Form

**Principal Investigator/Supervisor:** Dr Anne Tolan

**Co-Investigators:** A/P Peter Rendell

**Student Researcher:** Amanda Scicluna

**Ethics approval has been granted for the following project:**

Age and cognitive differences in short term memory and the process of Redintegration.

**for the period:** 15.05.2009 to 31.12.2012

**Human Research Ethics Committee (HREC) Register Number:** V2009 31

The following standard conditions as stipulated in the *National Statement on Ethical Conduct in Research Involving Humans* (2007) apply:

- (i) that Principal Investigators / Supervisors provide, on the form supplied by the Human Research Ethics Committee, annual reports on matters such as:
  - security of records
  - compliance with approved consent procedures and documentation
  - compliance with special conditions, and
- (ii) that researchers report to the HREC immediately any matter that might affect the ethical acceptability of the protocol, such as:
  - proposed changes to the protocol
  - unforeseen circumstances or events
  - adverse effects on participants

The HREC will conduct an audit each year of all projects deemed to be of more than low risk. There will also be random audits of a sample of projects considered to be of negligible risk and low risk on all campuses each year.

Within one month of the conclusion of the project, researchers are required to complete a *Final Report Form* and submit it to the local Research Services Officer.

If the project continues for more than one year, researchers are required to complete an *Annual Progress Report Form* and submit it to the local Research Services Officer within one month of the anniversary date of the ethics approval.

Signed: ..... Date: .....  
(Research Services Officer,)



## Appendix B: Materials

### Appendix B – 1: Poster for young adult participant recruitment



#### SCHOOL OF PSYCHOLOGY

Australian Catholic University Limited  
 ABN 15 050 192 660  
 Melbourne Campus (St Patrick's)  
 115 Victoria Parade, Fitzroy, Vic. 3065  
 Locked Bag 4115 Fitzroy MCD VIC 3065  
 Telephone 03 9953 3126  
 Facsimile 03 9953 3205  
[www.acu.edu.au](http://www.acu.edu.au)

To remember or not remember,  
 that is the question?!?

- ACU Students are invited to help us with our ongoing research on aging and memory.
  - We need adults between **18 and 39** years of age to remember short lists of words that appear on a computer screen.
  - This will involve attending one session of about **sixty minutes** at ACU with a **10 minute break** half way during the session.

**Wednesday 12<sup>th</sup> May and Friday 14<sup>th</sup> May**  
**9am – 5pm**



- **To arrange a time, email me at: [ta0041639@myacu.edu.au](mailto:ta0041639@myacu.edu.au)**
- Your participation will be greatly appreciated.

Amanda Scicluna  
 Student Researcher

Associate Professor Anne Tolan  
 Assistant Head of School of Psychology

## Appendix B – 2: Poster for older adult participant recruitment

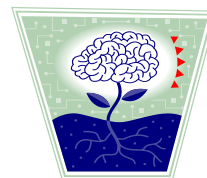


### SCHOOL OF PSYCHOLOGY

Australian Catholic University Limited  
 ABN 15 050 192 660  
 Melbourne Campus (St Patrick's)  
 115 Victoria Parade, Fitzroy, Vic. 3065  
 Locked Bag 4115 Fitzroy MCD VIC 3065  
 Telephone 03 9953 3126  
 Facsimile 03 9953 3205  
[www.acu.edu.au](http://www.acu.edu.au)

## To remember or not remember, that is the question?!?

- Lexington Garden residents are invited to help us with our ongoing research on aging and memory.
  - We need adults over 60 years of age to remember short lists of words that appear on a computer screen.
  - As well, there will be some background questionnaires to be completed.
  - This will involve attending one session of about **sixty minutes** either in a meeting room or at your place of residence with a 10 minute break half way during the session.
  - A morning tea will be held at the conclusion of the research project for all participating residents.



- **To arrange a time, please write your name and contact details on the signing sheet.**
- Following on success of several other projects conducted at Lexington Gardens, your participation will help more students complete their research projects. We thank you for your continued participation.

Amanda Scicluna  
 Student Researcher

Associate Professor Anne Tolan  
 Assistant Head of School of Psychology

### Appendix B – 3: Biographical questionnaire

#### Biographical Questionnaire

Name: .....

Man ☐ Woman ☐

Age: .....

Marital Status: ☐ Single ☐ Married ☐ Divorced ☐ De-facto ☐ Widow

Secondary school: year level completed: .....

Post-secondary education: number of years completed: .....

(Equivalent years of full-time study)

Is English your first language? ☐ Yes ☐ No

Using the following as a guide please answer the three questions below

1. Excellent (no problems)
2. Very Good (no major problems)
3. Good (occasional bad days)
4. Not Very Good (a number of problems)
5. Poor (persistent serious problems)

1. How would you describe state of health over the last month or so?

☐ Excellent ☐ Very Good ☐ Good ☐ Not Very Good ☐ Poor

2. How would you describe your state of health today?

☐ Excellent ☐ Very Good ☐ Good ☐ Not Very Good ☐ Poor

3. How would you describe how you have been sleeping over the last few weeks?

☐ Excellent ☐ Very Good ☐ Good ☐ Not Very Good ☐ Poor

Have you been given any diagnosis related to memory problems? If yes, briefly describe:

---



---

Have you been given any diagnosis related to your vision? If yes, please briefly describe:

---



---

Have you been given any diagnosis related to your hearing? If yes, please briefly describe:

---



---

### Appendix B – 4: Mill Hill Vocabulary Scale (Raven, 1989)

VOCABULARY TEST			
Name or Initials	Date	Age	Sex
In each group of six words below underline the word which means the same thing as the word in capital letters above the group, as it has been done with the first example:			
<b>1. CONNECT</b>		<b>12. SURMOUNT</b>	
accident	<u>join</u>	mountain	descend
lace	bean	overcome	concede
flint	field	appease	snub
<b>2. PROVIDE</b>		<b>13. BOMBASTIC</b>	
harmonize	commit	democratic	pompous
hurt	supply	bickering	cautious
annoy	divide	destructive	anxious
<b>3. STUBBORN</b>		<b>14. ENVISAGE</b>	
obstinate	steady	contemplate	activate
hopeful	hollow	surround	estrangle
orderly	slack	enfeeble	regress
<b>4. SCHOONER</b>		<b>15. PERPETRATE</b>	
building	man	appropriate	commit
ship	singer	propitiate	deface
plant	scholar	control	pierce
<b>5. LIBERTY</b>		<b>16. LIBERTINE</b>	
worry	freedom	missionary	rescuer
rich	serviette	profligate	canard
forest	cheerful	regicide	farrago
<b>6. COURTEOUS</b>		<b>17. QUERULOUS</b>	
dreadful	proud	astrigent	fearful
truthful	short	petulant	curious
curtsey	polite	inquiring	spurious
<b>7. RESEMBLANCE</b>		<b>18. FECUND</b>	
attendance	fondness	esculent	optative
assemble	repose	profound	prolific
likeness	memory	sublime	salic
<b>8. THRIVE</b>		<b>19. ABNEGATE</b>	
flourish	try	contradict	decry
thrash	reap	renounce	execute
think	blame	belie	assemble
<b>9. PRECISE</b>		<b>20. TRADUCE</b>	
natural	stupid	challenge	attenuate
faulty	grand	suspend	establish
small	exact	misrepresent	conclude
<b>10. ELEVATE</b>		<b>21. TEMERITY</b>	
revolve	move	impermanence	rashness
raise	work	nervousness	stability
waver	disperse	punctuality	submissiveness
<b>11. LAVISH</b>			
unaccountable	selfish		
romantic	lawful		
extravagant	praise		

**Appendix B – 5: Experimental stimuli for chapter six (Word length)**

<b>Short words</b>				<b>Long words</b>			
mail	star	pen	hair	lecturer	salad	menu	gallery
dress	pit	pot	trail	cottage	mirror	nickel	thunder
plane	veil	moss	cliff	missile	uniform	locker	camera
sting	mast	dock	wall	secretary	library	copper	vehicle
rust	bow	spade	pearl	penny	bedroom	ribbon	medicine
club	gift	soap	cent	cannon	ferry	rattle	butcher
ring	lace	case	shell	painter	island	bucket	planet
guy	tar	wolf	silk	furniture	sunset	whiskey	professor
box	bat	coast	road	berry	athlete	capsule	palace
roof	drill	dot	queen	partner	cotton	corridor	office
beast	stain	tank	hill	axle	rubber	sugar	gravel
aunt	graph	lens	tin	ambulance	forehead	kerosene	telegraph
knee	coach	sword	note	iodine	canoe	submarine	manor
stove	rim	wheat	judge	shovel	package	vinegar	husband
fan	arm	flame	vein	decoration	alcohol	doctor	valley
mate	steam	jet	aisle	lightning	saloon	hurricane	abdomen
jail	curb	gown	card	hospital	channel	football	brother
fleet	mink	lime	brush	dollar	liquor	landscape	blanket
bush	bill	beer	map	body	balloon	bacteria	letter
palm	cart	cape	inn	market	bubble	breakfast	honey
sink	seat	lane	crown	profile	pineapple	jersey	cereal
court	seal	dawn	cone	ceiling	picture	chicken	cardinal
hut	hall	nurse	grass	highway	garment	mansion	forest
saw	tweed	slope	food	photograph	uncle	racket	emperor
cross	arch	band	gas	cellar	aerial	animal	family
calf	yard	rod	spark	bottle	window	parade	rifle
red	kiss	storm	lock	organ	instructor	shoulder	laundry
desk	pan	slave	haze	china	meadow	rabbi	giant
paste	heel	juice	bomb	medal	grandfather	indian	basket
seam	isle	tie	test	pillow	honeymoon	teacher	supper
chin	tide	drain	cage	cafe	tablespoon	costume	bosom
fish	park	mat	gate	dinner	mechanic	lieutenant	father
pork	ditch	toast	nest	muzzle	cigar	telephone	magazine
deck	dame	pine	globe	children	chapel	minister	fireplace
tear	pin	world	couch	sunshine	microscope	widow	cattle
clock	bowl	bar	fog	cancer	belly	apartment	elephant
hook	witch	sign	cloth	hardware	weapon	procession	candle
lake	root	dome	coal	jacket	pencil	corner	capitol
shop	lip	sea	bolt	prison	lantern	piano	basin
purse	wax	wind	pole	ocean	vessel	walnut	money

## Appendix B – 6: Example word trial from chapter six (Word length)

### Appendix B – 6.1: One second presentation rate

LGISDEL	irrel18	READY	dollar	liquor	landscape	blanket	83	47	
SHISDEL	irrel10	READY	palm	cart	cape	inn	72	47	
SHISDEL	irrel7	READY	jail	curb	gown	card	16	65	
LGISIMM	irrel11	READY	axle	rubber	sugar	gravel	?????		
LGSILDEL	0	READY	furniture	sunset	whiskey	professor	76	79	?????
SHISIMM	irrel3	READY	knee	coach	sword	note	?????		
SHSILIMM	0	READY	rust	bow	spade	pearl	?????		
LGSILIMM	0	READY	secretary	library	copper	vehicle	?????		
SHSILDEL	0	READY	ring	lace	case	shell	100	93	?????
LGSILIMM	0	READY	missile	uniform	locker	camera	?????		
SHSILIMM	0	READY	sting	mast	dock	wall	?????		
SHISIMM	irrel5	READY	fan	arm	flame	vein	?????		
LGSILDEL	0	READY	cannon	ferry	rattle	butcher	58		34
SHISIMM	irrel1	READY	beast	stain	tank	hill	?????		
SHSILIMM	0	READY	plane	veil	moss	cliff	?????		
SHSILIMM	0	READY	dress	pit	pot	trail	?????		
LGISIMM	irrel14	READY	shovel	package	vinegar	husband	?????		
LGSILDEL	0	READY	partner	cotton	corridor	office	84	44	?????
LGISIMM	irrel13	READY	iodine	canoe	submarine	manor	?????		
LGSILIMM	0	READY	lecturer	salad	menu	gallery	?????		
SHSILIMM	0	READY	mail	star	pen	hair	?????		
LGISDEL	irrel16	READY	lightning	saloon	abdomen	73	78	?????	
SHISIMM	irrel2	READY	aunt	graph	lens	tin	?????		
SHISIMM	irrel4	READY	stove	rim	wheat	judge	?????		
SHISDEL	irrel9	READY	bush	bill	beer	map	58	55	?????
SHSILDEL	0	READY	guy	tar	wolf	silk	63	99	?????
SHISDEL	irrel8	READY	fleet	mink	lime	brush	37	92	?????
LGSILDEL	0	READY	berry	athlete	capsule	palace	26	35	?????
LGSILIMM	0	READY	cottage	mirror	nickel	thunder	?????		
LGSILDEL	0	READY	painter	island	bucket	planet	83	63	?????
LGSILIMM	0	READY	penny	bedroom	ribbon	medicine	?????		
SHISDEL	irrel6	READY	mate	steam	jet	aisle	52	56	?????
LGISIMM	irrel15	READY	decoration	alcohol	doctor	valley	?????		
SHSILDEL	0	READY	club	gift	soap	cent	75	41	?????
LGISDEL	irrel17	READY	hospital	channel	football	brother	33	18	?????
SHSILDEL	0	READY	roof	drill	dot	queen	63	83	?????
LGISDEL	irrel19	READY	body	balloon	bacteria	letter	93	49	?????
SHSILDEL	0	READY	box	bat	coast	road	52	98	?????
LGISDEL	irrel20	READY	market	bubble	breakfast	honey	80	14	?????
LGISIMM	irrel12	READY	ambulance	forehead	kerosene	telegraph	?????		

*Appendix B – 6.2: Two second presentation rate*

LGISIMM	irrel15	READY	sunshine	microscope	widow	cattle	?????	
SHSILIMM	0	READY	sink	seat	lane	crown	?????	
LGISIMM	irrel13	READY	muzzle	cigar	telephone	magazine	?????	
LGSILIMM	0	READY	photograph	uncle	racket	emperor	?????	
LGSILIMM	0	READY	profile	pineapple	jersey	cereal	?????	
SHISDEL	irrel9	READY	shop	lip	sea	bolt	97_84	?????
SHISIMM	irrel5	READY	tear	pin	world	couch	?????	
LGISIMM	irrel12	READY	dinner	mechanic	lieutenant	father	?????	
LGISDEL	irrel19	READY	prison	lantern	piano	basin	91_55	?????
SHSILIMM	0	READY	cross	arch	band	gas	?????	
LGSILDEL	0	READY	pillow	honeymoon	teacher	supper	21_63	?????
SHSILIMM	0	READY	court	seal	dawn	cone	?????	
LGSILDEL	0	READY	china	meadow	rabbi	giant	63_78	?????
SHISDEL	irrel10	READY	purse	wax	wind	pole	48_29	?????
LGSILDEL	0	READY	medal	grandfather	indian	basket	39_42	?????
SHSILDEL	0	READY	seam	isle	tie	test	75_10	?????
SHISDEL	irrel6	READY	clock	bowl	bar	fog	57_15	?????
SHISIMM	irrel2	READY	fish	park	mat	gate	?????	
LGISDEL	irrel16	READY	cancer	belly	apartment	elephant	62_48	?????
LGISDEL	irrel18	READY	jacket	pencil	corner	capitol	77_43	?????
LGISIMM	irrel14	READY	children	chapel	minister	fireplace	?????	
SHSILDEL	0	READY	red	kiss	storm	lock	97_70	?????
LGISIMM	irrel11	READY	cafe	tablespoon	costume	bosom	?????	
SHISDEL	irrel8	READY	lake	root	dome	coal	87_82	?????
SHSILDEL	0	READY	paste	heel	juice	bomb	27_27	?????
SHSILIMM	0	READY	hut	hall	nurse	grass	?????	
LGSILIMM	0	READY	highway	garment	mansion	forest	?????	
SHISDEL	irrel7	READY	hook	witch	sign	cloth	24_88	?????
LGISDEL	irrel17	READY	hardware	weapon	procession	candle	24_93	?????
SHSILDEL	0	READY	desk	pan	slave	haze	76_40	?????
LGSILDEL	0	READY	organ	instructor	shoulder	laundry	83_80	?????
LGSILIMM	0	READY	cellar	aerial	animal	family	?????	
SHISIMM	irrel1	READY	chin	tide	drain	cage	?????	
SHISIMM	irrel3	READY	pork	ditch	toast	nest	?????	
LGSILDEL	0	READY	bottle	window	parade	rifle	82_76	?????
SHSILDEL	0	READY	calf	yard	rod	spark	99_26	?????
LGISDEL	irrel20	READY	ocean	vessel	walnut	money	24_67	?????
LGSILIMM	0	READY	ceiling	picture	chicken	cardinal	?????	
SHSILIMM	0	READY	saw	tweed	slope	food	?????	
SHISIMM	irrel4	READY	deck	dame	pine	globe	?????	

## Appendix B – 7: Experimental stimuli for chapter seven (Word pairs)

### Associate word pairs

### Non-Associate word pairs

reap	sow	bow	arrow	lash	fire	usurp	court
aim	fire	all	none	grow	eye	gown	take
tear	rip	indian	red	golf	tall	pass	dress
rat	mouse	tart	sour	warm	ball	palm	fail
duck	pond	none	zero	oak	cold	mink	hand
quit	stop	mill	wind	giant	tree	rail	coat
flat	tire	cell	jail	lamp	big	man	train
city	town	junk	yard	elm	light	jump	woman
verb	noun	law	order	jug	tree	duty	rope
kite	fly	deck	boat	yuck	water	meat	job
nasty	mean	year	month	mark	gross	pan	steak
hear	listen	dusk	dawn	map	check	flea	pot
take	give	peak	top	ivy	road	gull	dog
dish	plate	yard	grass	flap	poison	jack	bird
mad	angry	herd	cow	extra	wing	war	jill
cave	dark	blue	sky	exam	more	east	peace
vein	blood	kick	ball	salt	test	rage	west
talk	speak	help	me	ache	pepper	gas	anger
goat	milk	beg	plead	ice	pain	view	car
tail	dog	vast	large	camp	cold	judge	look
dad	mom	game	play	bowl	animal	bug	horse
raft	float	used	old	die	dish	inch	insect
beer	drink	mall	shop	hymn	live	mat	foot
fur	coat	pay	money	vine	song	deaf	door
bacon	eggs	begin	end	fail	grape	grab	hear
eagle	bird	rank	army	chew	pass	hide	take
loud	soft	coal	black	eye	gum	cart	seek
opera	sing	gone	left	yolk	see	blaze	wagon
lemon	lime	jet	plane	mass	egg	heart	fire
ham	pig	month	year	cloud	church	jog	beat
bun	bread	beef	cow	new	sky	loft	run
lung	leather	hip	bone	era	old	jail	bed
kid	child	walk	run	exit	time	van	prison
area	place	lay	down	oxygen	enter	hoe	car
insect	bug	nest	bird	hair	air	earn	garden
yell	scream	want	need	late	ape	medal	money
feet	toes	mare	horse	aid	early	dry	gold
legs	arms	pad	paper	neck	help	bag	wet
do	don't	cork	wine	rent	head	owe	lunch
deer	doe	get	take	ox	money	colt	money



# Appendix B – 8: Example word trial from chapter seven (Word pairs)

## Appendix B – 8.1: One second presentation rate

URISIMM	irrel13	READY	ivy	road	gull	dog	?????			
URISIMM	irrel11	READY	mark	gross	pan	steak	?????			
ASISIMM	irrel4	READY	dish	plate	yard	grass	?????			
ASISIMM	irrel2	READY	hear	listen	dusk	dawn	?????			
ASISDEL	irrel6	READY	cave	dark	blue	sky	57	80	?????	
URSILIMM	0	READY	golf	tall	pass	dress	?????			
URISDEL	irrel20	READY	camp	cold	judge	look	29	36	?????	
ASISDEL	irrel7	READY	vein	blood	kick	ball	39	63	?????	
URSILIMM	0	READY	grow	eye	gown	take	?????			
URSILDEL	0	READY	giant	tree	rail	coat	64	38	?????	
ASSILIMM	0	READY	tear	rip	indian	red	?????			
ASSILDEL	0	READY	verb	noun	law	order	81	27	?????	
ASSILDEL	0	READY	city	town	junk	yard	55	29	?????	
ASISDEL	irrel9	READY	goat	milk	beg	plead	81	27	?????	
ASISIMM	irrel3	READY	take	give	peak	top	?????			
ASISIMM	irrel5	READY	mad	angry	herd	cow	?????			
URSILDEL	0	READY	lamp	big	man	train	69	66	?????	
ASSILDEL	0	READY	quit	stop	mill	wind	57	80	?????	
ASISIMM	irrel1	READY	nasty	mean	year	month	?????			
URSILIMM	0	READY	warm	ball	palm	fail	?????			
ASISDEL	irrel10	READY	tail	dog	vast	large	45	72	?????	
URSILIMM	0	READY	lash	fire	usurp	court	?????			
ASSILIMM	0	READY	reap	sow	bow	arrow	?????			
ASSILIMM	0	READY	duck	pond	none	zero	?????			
ASSILIMM	0	READY	rat	mouse	tart	sour	?????			
ASSILIMM	0	READY	aim	fire	all	none	?????			
URISDEL	irrel19	READY	ice	pain	view	car	80	26	?????	
URSILDEL	0	READY	yuck	water	meat	job	85	30	?????	
URISDEL	irrel17	READY	salt	test	rage	west	50	68	?????	
URISIMM	irrel15	READY	extra	wing	war	jill	?????			
URISDEL	irrel18	READY	ache	pepper	gas	anger	16	59	?????	
URSILDEL	0	READY	jug	tree	duty	rope	43	36	?????	
ASISDEL	irrel8	READY	talk	speak	help	me	55	29	?????	
URSILDEL	0	READY	elm	light	jump	woman	68	66	?????	
URSILIMM	0	READY	oak	cold	mink	hand	?????			
URISDEL	irrel16	READY	exam	more	east	peace	35	62	?????	
ASSILDEL	0	READY	kite	fly	deck	boat	45	72	?????	
URISIMM	irrel12	READY	map	check	flea	pot	?????			
URISIMM	irrel14	READY	flap	poison	jack	bird	?????			
ASSILDEL	0	READY	flat	tire	cell	jail	39	63	?????	

*Appendix B – 8.2: Two second presentation rate*

URISDEL	irrel17	READY	aid	early	dry	gold	24_93	?????
URISIMM	irrel14	READY	oxygen	enter	hoe	car	?????	
URSILIMM	0	READY	bowl	animal	bug	horse	?????	
URSILIMM	0	READY	vin	song	deaf	door	?????	
URISDEL	irrel16	READY	late	ape	medal	money	62_48	?????
ASSILDEL	0	READY	ham	pig	month	year	75_10	?????
ASISDEL	irrel9	READY	do	don't	cork	wine	97_84	?????
URSILDEL	0	READY	cloud	church	jog	beat	21_63	?????
URSILDEL	0	READY	chew	pass	hide	take	82_76	?????
ASSILIMM	0	READY	raft	float	used	old	?????	
URSILDEL	0	READY	yolk	see	blaze	wagon	63_78	?????
URSILDEL	0	READY	mass	egg	heart	fire	39_42	?????
URISDEL	irrel19	READY	rent	head	owe	lunch	91_55	?????
URSILDEL	0	READY	eye	gum	cart	seek	83_80	?????
URISIMM	irrel15	READY	hair	air	earn	garden	?????	
ASSILIMM	0	READY	fur	coat	pay	money	?????	
URISDEL	irrel18	READY	neck	help	bag	wet	77_43	?????
ASISDEL	irrel8	READY	legs	arms	pad	paper	87_82	?????
ASISIMM	irrel2	READY	lung	leather	hip	bone	?????	
ASSILDEL	0	READY	lemon	lime	jet	plane	27_27	?????
ASSILIMM	0	READY	dad	mom	game	play	?????	
ASISDEL	irrel7	READY	feet	toes	mare	horse	24_88	?????
URSILIMM	0	READY	hymn	live	mat	foot	?????	
URISIMM	irrel11	READY	new	sky	loft	run	?????	
URISIMM	irrel12	READY	era	old	jail	bed	?????	
ASISIMM	irrel1	READY	bun	bread	beef	cow	?????	
ASISDEL	irrel10	READY	deer	doe	get	take	48_29	?????
URSILIMM	0	READY	die	dish	inch	insect	?????	
ASISIMM	irrel3	READY	kid	child	walk	run	?????	
URISDEL	irrel20	READY	ox	money	colt	money	24_67	?????
ASISDEL	irrel6	READY	yell	scream	want	need	57_15	?????
URSILIMM	0	READY	fail	grape	grab	hear	?????	
ASSILIMM	0	READY	bacon	eggs	begin	end	?????	
ASSILDEL	0	READY	loud	soft	coal	black	97_70	?????
ASSILDEL	0	READY	opera	sing	gone	left	76_40	?????
ASISIMM	irrel5	READY	insect	bug	nest	bird	?????	
ASSILIMM	0	READY	beer	drink	mall	shop	?????	
ASSILDEL	0	READY	eagle	bird	rank	army	99_26	?????
URISIMM	irrel13	READY	exit	time	van	prison	?????	
ASISIMM	irrel4	READY	area	place	lay	down	?????	

## Appendix B – 9: Experimental stimuli for chapter eight (False memory)

### Appendix B – 9.1: Related words with the critical lure

Critical lure	Related words			
<i>answer</i>	question	reply	response	solution
<i>take</i>	give	steal	grab	get
<i>bee</i>	hive	bumble	sting	buzz
<i>sleep</i>	bed	tired	rest	pillow
<i>tired</i>	exhausted	fatigue	bored	drowsy
<i>pen</i>	ink	pencil	paper	write
<i>drug</i>	addiction	prescription	marijuana	cocaine
<i>cake</i>	icing	frosting	bake	birthday
<i>nut</i>	cashew	pecan	almond	squirrel
<i>destroy</i>	demolish	ruin	annihilate	create
<i>picture</i>	frame	portrait	photo	camera
<i>boat</i>	row	sail	yacht	ship
<i>doctor</i>	physician	nurse	surgeon	patient
<i>train</i>	caboose	railroad	station	track
<i>stop</i>	halt	go	sign	start
<i>test</i>	quiz	exam	experiment	score
<i>chair</i>	table	seat	stool	couch
<i>indian</i>	tribe	teepee	chief	nature
<i>bank</i>	teller	account	vault	loan
<i>job</i>	occupation	employment	career	task
<i>bear</i>	grizzly	cub	claw	honey
<i>math</i>	arithmetic	calculus	equation	algebra
<i>candle</i>	wick	wax	lit	flame
<i>movie</i>	cinema	film	theatre	popcorn
<i>orange</i>	tangerine	juice	citrus	fruit
<i>hate</i>	despise	dislike	love	like
<i>want</i>	desire	need	yearn	crave
<i>door</i>	knob	hinge	mat	key
<i>can</i>	opener	tin	aluminum	trash
<i>blood</i>	plasma	donor	vein	vampire
<i>small</i>	tiny	big	large	little
<i>law</i>	court	justice	rule	legal
<i>window</i>	pane	sill	curtain	ledge
<i>tree</i>	oak	stump	leaf	pine
<i>rain</i>	umbrella	storm	cloud	hail
<i>leg</i>	arm	thigh	knee	foot
<i>gun</i>	pistol	trigger	bullet	weapon
<i>same</i>	different	alike	similar	equal
<i>king</i>	queen	crown	royalty	monarch
<i>drunk</i>	sober	intoxicated	inebriated	wasted

*Appendix B – 9.2: Unrelated words*

ghoul	pair	diaper	pasture
one	infant	bull	minute
crib	calf	hour	purr
moo	watch	mouse	comedy
clock	dog	humour	coin
kitten	comedian	spend	laugh
hilarious	bank	tears	tyre
cash	sob	drive	cage
weep	transportation	farm	arrest
auto	beast	badge	jump
zoo	officer	track	program
cop	walk	channel	diet
jog	commercial	slim	struggle
cable	skinny	argue	robin
thin	argument	parrot	hear
quarrel	nest	eye	hop
canary	sight	carrot	house
look	hare	animal	spook
bunny	cat	phantom	double
puppy	goblin	couple	child
trout	pain	chance	scramble
harm	effort	dozen	dark
attempt	bacon	switch	age
omelette	lamp	young	rattle
bulb	ancient	reptile	grime
new	serpent	mud	mouth
slither	filth	dentist	smile
soil	braces	funny	nausea
gums	joke	flu	field
giggle	illness	flake	colt
ill	husk	gallop	vase
cob	pony	daisy	lose
saddle	petals	discover	steal
tulip	search	burglar	neighbour
seek	robber	companion	cry
crook	buddy	depressed	sew
pal	happy	pin	coast
unhappy	haystack	surf	bass
thread	shore	fin	ouch
sand	cod	injury	again

## Appendix B – 10: Example word trial from chapter eight (False memory)

### Appendix B – 10.1: One second presentation rate

ASISDEL	irrel6	READY	bulb	lamp	switch	dark	57	80	?????
ASSILDEL	0	READY	different	alike	similar	equal	81	27	?????
URSILDEL	0	READY	halt	haystack	sting	foot	68	66	?????
URISDEL	irrel16	READY	grizzly	husk	surf	again	35	62	?????
ASISIMM	irrel1	READY	tangerine	juice	citrus	fruit	?????		
URSILIMM	0	READY	occupation	sight	rest	solution	?????		
ASSILIMM	0	READY	pane	sill	curtain	ledge	?????		
URSILIMM	0	READY	look	tired	response	child	?????		
URSILIMM	0	READY	crib	trigger	flu	start	?????		
URISDEL	irrel17	READY	cob	shore	chance	ship	50	68	?????
ASISIMM	irrel2	READY	table	seat	stool	couch	?????		
URSILDEL	0	READY	thread	bumble	knee	squirrel	43	36	?????
URSILIMM	0	READY	question	infant	bullet	nausea	?????		
ASSILIMM	0	READY	oak	stump	leaf	pine	?????		
URISIMM	irrel12	READY	cashew	nest	yearn	patient	?????		
ASISDEL	irrel7	READY	arithmetic	calculus	equation	algebra	39	63	?????
ASISIMM	irrel3	READY	unhappy	happy	depressed	cry	?????		
URSILIMM	0	READY	bed	reply	diaper	weapon	?????		
URISDEL	irrel19	READY	attempt	sail	career	hear	80	26	?????
ASISDEL	irrel9	READY	puppy	cat	animal	house	81	27	?????
URSILDEL	0	READY	hive	thigh	almond	robin	85	30	?????
ASSILIMM	0	READY	tiny	big	large	little	?????		
URISIMM	irrel14	READY	desire	nurse	claw	field	?????		
URSILDEL	0	READY	pistol	illness	sign	sew	64	38	?????
ASSILIMM	0	READY	ink	pencil	paper	write	?????		
ASSILDEL	0	READY	plasma	donor	vein	vampire	57	80	?????
URISIMM	irrel13	READY	canary	need	surgeon	honey	?????		
ASISDEL	irrel8	READY	wick	wax	lit	flame	55	29	?????
ASSILIMM	0	READY	quarrel	argument	argue	struggle	?????		
URISIMM	irrel11	READY	arm	pecan	parrot	crave	?????		
URISDEL	irrel18	READY	sand	effort	yacht	task	16	59	?????
ASSILDEL	0	READY	cinema	film	theatre	popcorn	45	72	?????
ASSILDEL	0	READY	cable	commercial	channel	program	39	63	?????
ASISIMM	irrel5	READY	auto	transportation	drive	tyre	?????		
ASSILDEL	0	READY	addiction	prescription	marijuana	cocaine	55	29	?????
URSILDEL	0	READY	ill	go	pin	buzz	69	66	?????
ASISDEL	irrel10	READY	seek	search	discover	lose	45	72	?????
URISIMM	irrel15	READY	physician	cub	flake	coast	?????		
URISDEL	irrel20	READY	row	employment	eye	pillow	29	36	?????
ASISIMM	irrel4	READY	quiz	exam	experiment	score	?????		

*Appendix B – 10.2: Two second presentation rate*

ASISIMM	irrel2	READY	court	justice	rule	legal	?????	
ASISIMM	irrel4	READY	slither	serpent	reptile	rattle	?????	
ASISIMM	irrel3	READY	moo	calf	bull	pasture	?????	
ASISDEL	irrel9	READY	sober	intoxicated	inebriated	wasted	97_84	?????
ASISDEL	irrel6	READY	weep	sob	tears	laugh	57_15	?????
ASISIMM	irrel5	READY	gums	braces	dentist	mouth	?????	
URSILDEL	0	READY	tribe	ancient	mat	hop	21_63	?????
URISDEL	irrel20	READY	icing	fatigue	humour	colt	24_67	?????
URISIMM	irrel13	READY	bunny	crown	aluminum	camera	?????	
URSILIMM	0	READY	soil	robber	annihilate	jump	?????	
ASSILDEL	0	READY	omelette	bacon	dozen	scramble	76_40	?????
URSILDEL	0	READY	jog	officer	chief	age	63_78	?????
URSILDEL	0	READY	crook	ruin	track	arrest	82_76	?????
ASISDEL	irrel7	READY	one	pair	couple	double	24_88	?????
ASSILDEL	0	READY	ghoul	goblin	phantom	spook	75_10	?????
URISDEL	irrel19	READY	caboose	frosting	bored	comedy	91_55	?????
ASISDEL	irrel8	READY	pal	buddy	companion	neighbour	87_82	?????
URSILIMM	0	READY	hilarious	pony	cloud	grime	?????	
URISIMM	irrel11	READY	new	hinge	carrot	monarch	?????	
ASSILIMM	0	READY	teller	account	vault	loan	?????	
URISDEL	irrel18	READY	kitten	railroad	bake	drowsy	77_43	?????
ASSILDEL	0	READY	give	steal	grab	get	27_27	?????
ASSILIMM	0	READY	harm	pain	injury	ouch	?????	
URSILDEL	0	READY	demolish	walk	badge	nature	83_80	?????
ASSILIMM	0	READY	giggle	joke	funny	smile	?????	
URSILIMM	0	READY	umbrella	filth	burglar	create	?????	
URISDEL	irrel16	READY	frame	bank	mouse	track	62_48	?????
URISDEL	irrel17	READY	cash	dog	station	birthday	24_93	?????
ASSILIMM	0	READY	tulip	petals	daisy	vase	?????	
URSILIMM	0	READY	saddle	storm	mud	steal	?????	
URISIMM	irrel15	READY	opener	portrait	spend	purr	?????	
ASSILDEL	0	READY	trout	cod	fin	bass	97_70	?????
URSILIMM	0	READY	exhausted	comedian	gallop	hail	?????	
URISIMM	irrel14	READY	queen	tin	photo	coin	?????	
URISIMM	irrel12	READY	knob	hare	royalty	trash	?????	
ASISIMM	irrel1	READY	clock	watch	hour	minute	?????	
URSILDEL	0	READY	cop	teepee	young	key	39_42	?????
ASISDEL	irrel10	READY	zoo	beast	farm	cage	48_29	?????
ASSILIMM	0	READY	thin	skinny	slim	diet	?????	
ASSILDEL	0	READY	despise	dislike	love	like	99_26	?????

## Appendix C: Results

### Appendix C – 1: Scoring guide

#### Scoring Guide

##### Items recalled

Items are scored correct if they have been recalled correctly from the trial, irrespective of their serial position (this includes items that have been recalled in their correct serial position and items that have been recalled correctly).

##### Transpositions

Items have been recalled correctly but in their adjacent serial position (For example, *water* was recalled in serial position 2 instead of serial position 1. This does not include items recalled in the correct serial position).

##### Omissions

Items that were not recalled from the trial (participant said '*pass*' or '*something*' instead of the item).

##### Correct items recalled

Items are scored correct if they have been recalled correctly and in their correct serial position

##### Order Accuracy

***Total correct items recalled / total items recalled***

##### Proportions

The respective total (items recalled, transpositions, omissions, intrusions, correct recalled) divided by 20. Twenty is derived from the total number of items in the condition.

## Appendix C – 2: Additional analyses for chapter six (Word length)

### Appendix C – 2.1: Significant interactions

#### *Correct-in-position recall*

**Significant 2-way interaction.** A significant 2-way interaction was found between recall interval and presentation rate,  $F(1, 38) = 4.80$ ,  $MSE = 0.11$ ,  $p = .035$ ,  $\eta_p^2 = .11$ , *observed power* = .57. In the immediate conditions, participants recalled a significantly higher proportion of words in serial position when words were presented during the one-second rate ( $M = .83$ ,  $SD = .12$ ) compared with the two-second rate ( $M = .79$ ,  $SD = .13$ ),  $F(1, 38) = 6.00$ ,  $p = .019$ ,  $\eta_p^2 = .14$ , *observed power* = .67. However, there was no significant difference in the proportion of words participants recalled in serial position after a delayed interval when words were presented during the two-second ( $M = .53$ ,  $SD = .17$ ) and one-second rates ( $M = .51$ ,  $SD = .17$ ),  $F(1, 38) = 0.68$ ,  $p = .416$ ,  $\eta_p^2 = .02$ , *observed power* = .13.

During the two-second presentation rate, participants recalled a significantly higher proportion of words in serial position in immediate conditions ( $M = .79$ ,  $SD = .13$ ) compared with after a delayed interval ( $M = .53$ ,  $SD = .17$ ),  $F(1, 38) = 153.19$ ,  $p < .001$ ,  $\eta_p^2 = .80$ , *observed power* = 1.00. During the one-second presentation rate, participants recalled a significantly higher proportion of words in serial position in immediate conditions ( $M = .83$ ,  $SD = .12$ ) compared with after a delayed interval ( $M = .51$ ,  $SD = .17$ ),  $F(1, 38) = 311.16$ ,  $p < .001$ ,  $\eta_p^2 = .89$ , *observed power* = 1.00.

**Significant 3-way interactions.** A significant 3-way interaction was found between word length, recall interval, and study condition,  $F(1, 38) = 5.84$ ,  $MSE = 0.06$ ,  $p = .021$ ,  $\eta_p^2 = .13$ , *observed power* = .65. There was no significant difference in the proportion of short words participants immediately recalled in serial position under silence ( $M = .86$ ,  $SD = .12$ ) and



irrelevant speech ( $M = .88$ ,  $SD = .11$ ),  $F(1, 38) = 0.63$ ,  $p = .433$ ,  $\eta_p^2 = .02$ , *observed power* = .12. Additionally, there was no significant difference in the proportion of short words participants recalled in serial position after a delayed interval under silence ( $M = .58$ ,  $SD = .18$ ) and irrelevant speech ( $M = .58$ ,  $SD = .18$ ),  $F(1, 38) = 0.01$ ,  $p = .943$ ,  $\eta_p^2 = .00$ , *observed power* = .05. Participants recalled a significantly higher proportion of long words, presented in immediate conditions, in serial position under the silence conditions ( $M = .77$ ,  $SD = .15$ ) than the irrelevant speech conditions ( $M = .73$ ,  $SD = .16$ ),  $F(1, 38) = 7.31$ ,  $p = .010$ ,  $\eta_p^2 = .16$ , *observed power* = .75. There was no significant difference, however, in the proportion of long words participants recalled in serial position after a delayed interval under silence ( $M = .45$ ,  $SD = .19$ ) and irrelevant speech ( $M = .47$ ,  $SD = .17$ ),  $F(1, 38) = 0.45$ ,  $p = .505$ ,  $\eta_p^2 = .01$ , *observed power* = .10.

For immediate conditions, under silence, participants recalled a significantly higher proportion of short words ( $M = .86$ ,  $SD = .12$ ) in serial position compared with long words ( $M = .77$ ,  $SD = .15$ ),  $F(1, 38) = 22.34$ ,  $p < .001$ ,  $\eta_p^2 = .37$ , *observed power* = 1.00. For immediate conditions, under irrelevant speech, participants also recalled a significantly higher proportion of short words ( $M = .88$ ,  $SD = .11$ ) in serial position compared with long words ( $M = .73$ ,  $SD = .16$ ),  $F(1, 38) = 90.77$ ,  $p < .001$ ,  $\eta_p^2 = .71$ , *observed power* = 1.00. For delayed conditions, under silence, participants recalled a significantly higher proportion of short words ( $M = .58$ ,  $SD = .18$ ) in serial position compared with long words ( $M = .45$ ,  $SD = .19$ ),  $F(1, 38) = 47.70$ ,  $p < .001$ ,  $\eta_p^2 = .56$ , *observed power* = 1.00. For delayed recall, under irrelevant speech, participants also recalled a significantly higher proportion of short words ( $M = .58$ ,  $SD = .18$ ) in serial position compared with long words ( $M = .47$ ,  $SD = .17$ ),  $F(1, 38) = 29.86$ ,  $p < .001$ ,  $\eta_p^2 = .44$ , *observed power* = 1.00.

Participants recalled a significantly higher proportion of short words in serial position, under silence, during immediate conditions ( $M = .86$ ,  $SD = .12$ ) compared with after a delayed interval ( $M = .58$ ,  $SD = .18$ ),  $F(1, 38) = 134.94$ ,  $p < .001$ ,  $\eta_p^2 = .78$ , *observed power* = 1.00. Participants also recalled a significantly higher proportion of short words in serial position, under irrelevant speech, during immediate conditions ( $M = .88$ ,  $SD = .11$ ) compared with after a delayed interval ( $M = .58$ ,  $SD = .18$ ),  $F(1, 38) = 147.90$ ,  $p < .001$ ,  $\eta_p^2 = .80$ , *observed power* = 1.00. There was a significantly higher proportion of long words recalled in serial position, under silence, during immediate conditions ( $M = .77$ ,  $SD = .15$ ) compared with after a delayed interval ( $M = .45$ ,  $SD = .19$ ),  $F(1, 38) = 262.28$ ,  $p < .001$ ,  $\eta_p^2 = .87$ , *observed power* = 1.00. Similarly, there was a significantly higher proportion of long words recalled in serial position, under irrelevant speech, during immediate conditions ( $M = .73$ ,  $SD = .16$ ) compared with after a delayed interval ( $M = .47$ ,  $SD = .17$ ),  $F(1, 38) = 129.53$ ,  $p < .001$ ,  $\eta_p^2 = .77$ , *observed power* = 1.00.

The 3-way interaction between word length, recall interval, and age was also significant,  $F(1, 38) = 6.60$ ,  $MSE = 0.09$ ,  $p = .014$ ,  $\eta_p^2 = .15$ , *observed power* = .71. There was no significant difference in the proportion of short words immediately recalled in serial position between young ( $M = .90$ ,  $SD = .10$ ) and older adults ( $M = .85$ ,  $SD = .10$ ),  $F(1, 38) = 2.45$ ,  $p = .126$ ,  $\eta_p^2 = .06$ , *observed power* = .33. Although, young adults ( $M = .64$ ,  $SD = .18$ ) recalled a significantly higher proportion of short words in serial position after a delayed interval compared with older adults ( $M = .52$ ,  $SD = .15$ ),  $F(1, 38) = 5.17$ ,  $p = .029$ ,  $\eta_p^2 = .12$ , *observed power* = .60. Similarly, for long words, young adults ( $M = .81$ ,  $SD = .13$ ) recalled a significantly higher proportion of words in serial position compared with older adults ( $M = .68$ ,  $SD = .13$ ),  $F(1, 38) = 9.44$ ,  $p = .004$ ,  $\eta_p^2 = .20$ , *observed power* = .85. Additionally, after a

delayed interval, young adults ( $M = .51$ ,  $SD = .16$ ) recalled a significantly higher proportion of long words in serial position compared with older adults ( $M = .41$ ,  $SD = .15$ ),  $F(1, 38) = 4.51$ ,  $p = .040$ ,  $\eta_p^2 = .11$ , *observed power* = .54.

For immediate conditions, young adults recalled a significantly higher proportion of short words ( $M = .90$ ,  $SD = .10$ ) in serial position compared with long words ( $M = .81$ ,  $SD = .13$ ),  $F(1, 38) = 16.86$ ,  $p < .001$ ,  $\eta_p^2 = .31$ , *observed power* = .98. For delayed conditions, young adults recalled a significantly higher proportion of short words ( $M = .64$ ,  $SD = .18$ ) in serial position compared with long words ( $M = .51$ ,  $SD = .16$ ),  $F(1, 38) = 55.26$ ,  $p < .001$ ,  $\eta_p^2 = .59$ , *observed power* = 1.00. In immediate conditions, older adults recalled a significantly higher proportion of short words ( $M = .85$ ,  $SD = .10$ ) in serial position compared with long words ( $M = .68$ ,  $SD = .13$ ),  $F(1, 38) = 66.93$ ,  $p < .001$ ,  $\eta_p^2 = .64$ , *observed power* = 1.00. For delayed conditions, older adults also recalled a significantly higher proportion of short words ( $M = .52$ ,  $SD = .15$ ) in serial position compared with long words ( $M = .41$ ,  $SD = .15$ ),  $F(1, 38) = 45.14$ ,  $p < .001$ ,  $\eta_p^2 = .54$ , *observed power* = 1.00.

Young adults recalled a significantly higher proportion of short words in serial position during immediate conditions ( $M = .90$ ,  $SD = .10$ ) compared with after a delayed interval ( $M = .64$ ,  $SD = .15$ ),  $F(1, 38) = 78.42$ ,  $p < .001$ ,  $\eta_p^2 = .67$ , *observed power* = 1.00. Young adults recalled a significantly higher proportion of long words in serial position during immediate conditions ( $M = .81$ ,  $SD = .13$ ) compared with after a delayed interval ( $M = .51$ ,  $SD = .16$ ),  $F(1, 38) = 191.94$ ,  $p < .001$ ,  $\eta_p^2 = .84$ , *observed power* = 1.00. Older adults recalled a significantly higher proportion of short words in serial position during immediate conditions ( $M = .85$ ,  $SD = .10$ ) compared with after a delayed interval ( $M = .52$ ,  $SD = .15$ ),  $F(1, 38) = 125.52$ ,  $p < .001$ ,  $\eta_p^2 = .77$ , *observed power* = 1.00. Older adults recalled a significantly higher

proportion of short words in serial position during immediate conditions ( $M = .68$ ,  $SD = .13$ ) compared with after a delayed interval ( $M = .41$ ,  $SD = .15$ ),  $F(1, 38) = 161.04$ ,  $p < .001$ ,  $\eta_p^2 = .81$ , *observed power* = 1.00.

**Significant 4-way interaction.** A significant 4-way interaction emerged between word length, recall interval, presentation rate, and age,  $F(1, 38) = 4.64$ ,  $MSE = 0.10$ ,  $p = .038$ ,  $\eta_p^2 = .11$ , *observed power* = .56. There was no significant difference in the proportion of short words recalled in serial position during immediate conditions, under the two-second presentation rate, between young ( $M = .88$ ,  $SD = .12$ ) and older adults ( $M = .84$ ,  $SD = .12$ ),  $F(1, 38) = 1.22$ ,  $p = .276$ ,  $\eta_p^2 = .03$ , *observed power* = .19. There was no significant difference in the proportion of short words recalled in serial position in immediate conditions, under the one-second presentation rate, between young ( $M = .91$ ,  $SD = .10$ ) and older adults ( $M = .85$ ,  $SD = .10$ ),  $F(1, 38) = 2.99$ ,  $p = .092$ ,  $\eta_p^2 = .07$ , *observed power* = .39. For short words in delayed conditions, under the two-second presentation rate, young adults ( $M = .66$ ,  $SD = .19$ ) recalled a significantly higher proportion of words in serial position compared with older adults ( $M = .51$ ,  $SD = .18$ ),  $F(1, 38) = 6.57$ ,  $MSE = 0.23$ ,  $p = .014$ ,  $\eta_p^2 = .15$ , *observed power* = .70. Yet, there was no significant difference in the proportion of short words recalled in serial position in delayed conditions, under the one-second presentation rate, between young ( $M = .62$ ,  $SD = .19$ ) and older adults ( $M = .54$ ,  $SD = .18$ ),  $F(1, 38) = 1.99$ ,  $p = .167$ ,  $\eta_p^2 = .05$ , *observed power* = .28. For long words in immediate conditions, under the two-second presentation rate, young adults ( $M = .81$ ,  $SD = .14$ ) recalled a significantly higher proportion of words in serial position than older adults ( $M = .64$ ,  $SD = .16$ ),  $F(1, 38) = 12.99$ ,  $p = .001$ ,  $\eta_p^2 = .26$ , *observed power* = .94. For long words in immediate conditions, under the one-second presentation rate, young ( $M = .82$ ,  $SD = .15$ ) and older adults ( $M = .73$ ,  $SD = .15$ ) did

not significantly differ in the proportion of words recalled in serial position,  $F(1, 38) = 3.11$ ,  $p = .086$ ,  $\eta_p^2 = .08$ , *observed power* = .41. For long words in delayed conditions, under the two-second presentation rate, there was no significant difference in the proportion of words recalled in serial position between young ( $M = .52$ ,  $SD = .17$ ) and older adults ( $M = .43$ ,  $SD = .17$ ),  $F(1, 38) = 2.69$ ,  $p = .109$ ,  $\eta_p^2 = .07$ , *observed power* = .36. For long words in delayed conditions, under the one-second presentation rate, young adults ( $M = .50$ ,  $SD = .17$ ) recalled a significantly higher proportion of words in serial position compared with older adults ( $M = .38$ ,  $SD = .17$ ),  $F(1, 38) = 4.74$ ,  $p = .036$ ,  $\eta_p^2 = .11$ , *observed power* = .56.

Young adults, in immediate conditions during the two-second presentation rate, recalled a significantly higher proportion of short words ( $M = .88$ ,  $SD = .12$ ) in serial position than long words ( $M = .81$ ,  $SD = .14$ ),  $F(1, 38) = 6.79$ ,  $p = .017$ ,  $\eta_p^2 = .14$ , *observed power* = .69. Young adults, in immediate conditions during the one-second presentation rate, recalled a significantly higher proportion of short words ( $M = .91$ ,  $SD = .10$ ) in serial position compared with long words ( $M = .82$ ,  $SD = .15$ ),  $F(1, 38) = 12.60$ ,  $p = .001$ ,  $\eta_p^2 = .25$ , *observed power* = .93. Young adults, in delayed conditions during the two-second presentation rate, recalled a significantly higher proportion of short words ( $M = .66$ ,  $SD = .19$ ) in serial position compared with long words ( $M = .52$ ,  $SD = .17$ ),  $F(1, 38) = 19.42$ ,  $p < .001$ ,  $\eta_p^2 = .34$ , *observed power* = .99. Young adults, in delayed conditions during the one-second presentation rate, also recalled a significantly higher proportion of short words ( $M = .62$ ,  $SD = .19$ ) in serial position compared with long words ( $M = .50$ ,  $SD = .17$ ),  $F(1, 38) = 17.70$ ,  $p < .001$ ,  $\eta_p^2 = .32$ , *observed power* = .98. Older adults, in immediate conditions during the two-second presentation rate, recalled a significantly higher proportion of short words ( $M = .84$ ,  $SD = .12$ ) in serial position compared with long words ( $M = .64$ ,  $SD = .16$ ),  $F(1, 38) = 50.94$ ,  $p < .001$ ,  $\eta_p^2 = .57$ , *observed*

*power* = 1.00. Older adults, in immediate conditions during the one-second presentation rate, recalled a significantly higher proportion of short words ( $M = .85$ ,  $SD = .10$ ) in serial position compared with long words ( $M = .73$ ,  $SD = .15$ ),  $F(1, 38) = 21.79$ ,  $p < .001$ ,  $\eta_p^2 = .36$ , *observed power* = 1.00. Older adults, in delayed conditions during the two-second presentation rate, recalled a significantly higher proportion of short words ( $M = .51$ ,  $SD = .18$ ) in serial position compared with long words ( $M = .43$ ,  $SD = .17$ ),  $F(1, 38) = 6.26$ ,  $p = .017$ ,  $\eta_p^2 = .14$ , *observed power* = .68. Older adults, in delayed conditions during the one-second presentation rate, recalled a significantly higher proportion of short words ( $M = .54$ ,  $SD = .18$ ) in serial position compared with long words ( $M = .38$ ,  $SD = .17$ ),  $F(1, 38) = 29.39$ ,  $p < .001$ ,  $\eta_p^2 = .44$ , *observed power* = 1.00.

Young adults recalled a significantly higher proportion of short words in serial position, under the two-second presentation rate, during immediate conditions ( $M = .88$ ,  $SD = .12$ ) compared with after a delayed interval ( $M = .66$ ,  $SD = .19$ ),  $F(1, 38) = 35.09$ ,  $p < .001$ ,  $\eta_p^2 = .48$ , *observed power* = 1.00. Young adults recalled a significantly higher proportion of short words in serial position, under the one-second presentation rate, during immediate conditions ( $M = .91$ ,  $SD = .10$ ) compared with after a delayed interval ( $M = .62$ ,  $SD = .19$ ),  $F(1, 38) = 68.29$ ,  $p < .001$ ,  $\eta_p^2 = .64$ , *observed power* = 1.00. Young adults recalled a significantly higher proportion of long words in serial position, under the two-second presentation rate, during immediate conditions ( $M = .81$ ,  $SD = .14$ ) compared with after a delayed interval ( $M = .52$ ,  $SD = .17$ ),  $F(1, 38) = 59.23$ ,  $p < .001$ ,  $\eta_p^2 = .61$ , *observed power* = 1.00. Young adults recalled a significantly higher proportion of long words in serial position, under the one-second presentation rate, during immediate conditions ( $M = .82$ ,  $SD = .15$ ) compared with after a delayed interval ( $M = .50$ ,  $SD = .17$ ),  $F(1, 38) = 131.64$ ,  $p < .001$ ,  $\eta_p^2 = .78$ , *observed power* =

1.00. Older adults recalled a significantly higher proportion of short words in serial position, under the two-second presentation rate, during immediate conditions ( $M = .84$ ,  $SD = .12$ ) compared with after a delayed interval ( $M = .51$ ,  $SD = .18$ ),  $F(1, 38) = 76.94$ ,  $p < .001$ ,  $\eta_p^2 = .67$ , *observed power* = 1.00. Older adults recalled a significantly higher proportion of short words in serial position, under the one-second presentation rate, during immediate conditions ( $M = .85$ ,  $SD = .10$ ) compared with after a delayed interval ( $M = .54$ ,  $SD = .18$ ),  $F(1, 38) = 81.98$ ,  $p < .001$ ,  $\eta_p^2 = .68$ , *observed power* = 1.00. Older adults recalled a significantly higher proportion of long words in serial position, under the two-second presentation rate, during immediate conditions ( $M = .64$ ,  $SD = .16$ ) compared with after a delayed interval ( $M = .43$ ,  $SD = .17$ ),  $F(1, 38) = 29.81$ ,  $p < .001$ ,  $\eta_p^2 = .44$ , *observed power* = 1.00. Older adults recalled a significantly higher proportion of long words in serial position, under the one-second presentation rate, during immediate conditions ( $M = .73$ ,  $SD = .15$ ) compared with after a delayed interval ( $M = .38$ ,  $SD = .17$ ),  $F(1, 38) = 161.12$ ,  $p < .001$ ,  $\eta_p^2 = .81$ , *observed power* = 1.00.

For young adults, there was no significant difference in the proportion of short words recalled in serial position during immediate conditions when presented at the two-second ( $M = .88$ ,  $SD = .12$ ) and one-second rates ( $M = .91$ ,  $SD = .10$ ),  $F(1, 38) = 1.35$ ,  $p = .252$ ,  $\eta_p^2 = .03$ , *observed power* = .21. Similarly, there was no significant difference in the proportion of short words recalled in serial position during delayed conditions when presented at the two-second ( $M = .66$ ,  $SD = .19$ ) and one-second rates ( $M = .62$ ,  $SD = .19$ ),  $F(1, 38) = 0.76$ ,  $p = .390$ ,  $\eta_p^2 = .02$ , *observed power* = .14. For young adults, there was no significant difference in the proportion of long words recalled in serial position during immediate conditions when presented at the two-second ( $M = .81$ ,  $SD = .14$ ) and one-second rates ( $M = .82$ ,  $SD = .15$ ),

$F(1, 38) = 0.05, p = .820, \eta_p^2 = .00, \text{observed power} = .06$ . Again, there was no significant difference in the proportion of long words recalled in serial position during delayed conditions when presented at the two-second ( $M = .52, SD = .17$ ) and one-second rates ( $M = .50, SD = .17$ ),  $F(1, 38) = 0.27, p = .608, \eta_p^2 = .01, \text{observed power} = .08$ . For older adults, there was no significant difference in the proportion of short words recalled in serial position during immediate conditions when presented at the two-second ( $M = .84, SD = .12$ ) and one-second rates ( $M = .85, SD = .10$ ),  $F(1, 38) = 0.31, p = .583, \eta_p^2 = .01, \text{observed power} = .08$ . There was also no significant difference in the proportion of short words recalled in serial position during delayed conditions when presented at the two-second ( $M = .51, SD = .18$ ) and one-second rates ( $M = .54, SD = .18$ ),  $F(1, 38) = 0.65, p = .425, \eta_p^2 = .02, \text{observed power} = .12$ . However, older adults recalled a significantly higher proportion of long words in serial position, during immediate conditions, when presented at the one-second rate ( $M = .73, SD = .15$ ) compared with the two-second rate ( $M = .64, SD = .16$ ),  $F(1, 38) = 9.14, p = .004, \eta_p^2 = .19, \text{observed power} = .84$ . However, there was no significant difference in the proportion of long words recalled in serial position, during delayed conditions, when presented at the two-second ( $M = .43, SD = .17$ ) and one-second rates ( $M = .38, SD = .17$ ),  $F(1, 38) = 1.77, p = .192, \eta_p^2 = .04, \text{observed power} = .25$ .

### ***Item recall***

***Significant 2-way interactions.*** A significant 2-way interaction was found between word length and recall interval,  $F(1, 38) = 6.94, MSE = 0.05, p = .012, \eta_p^2 = .15, \text{observed power} = .73$ . Participants recalled a significantly higher proportion of short words in immediate conditions ( $M = .91, SD = .08$ ) compared with after a delayed interval ( $M = .69, SD = .13$ ),  $F(1, 38) = 167.98, p < .001, \eta_p^2 = .82, \text{observed power} = 1.00$ . Participants also recalled a



significantly higher proportion of long words in immediate conditions ( $M = .84$ ,  $SD = .10$ ) compared with after a delayed interval ( $M = .59$ ,  $SD = .13$ ),  $F(1, 38) = 336.32$ ,  $p < .001$ ,  $\eta_p^2 = .90$ , *observed power* = 1.00.

For the immediate conditions, participants recalled a significantly higher proportion of short words ( $M = .91$ ,  $SD = .08$ ) than long words ( $M = .84$ ,  $SD = .10$ ),  $F(1, 38) = 70.13$ ,  $p < .001$ ,  $\eta_p^2 = .65$ , *observed power* = 1.00. For the delayed conditions, participants recalled a significantly higher proportion of short words ( $M = .69$ ,  $SD = .13$ ) than long words ( $M = .59$ ,  $SD = .13$ ),  $F(1, 38) = 89.08$ ,  $p < .001$ ,  $\eta_p^2 = .70$ , *observed power* = 1.00.

A significant 2-way interaction was also found between recall interval and presentation rate,  $F(1, 38) = 6.98$ ,  $MSE = 0.09$ ,  $p = .012$ ,  $\eta_p^2 = .16$ , *observed power* = .73. There was no significant difference in the proportion of words that were immediately recalled during the two-second ( $M = .86$ ,  $SD = .10$ ) and one-second presentation rates ( $M = .88$ ,  $SD = .09$ ),  $F(1, 38) = 2.34$ ,  $p = .134$ ,  $\eta_p^2 = .06$ , *observed power* = .32. Similarly, there was no significant difference in the proportion of words recalled after a delayed interval during the two-second ( $M = .66$ ,  $SD = .12$ ) and one-second presentation rates ( $M = .63$ ,  $SD = .11$ ),  $F(1, 38) = 3.50$ ,  $p = .069$ ,  $\eta_p^2 = .08$ , *observed power* = .45.

During the two-second presentation rate, participants recalled a significantly higher proportion of words under immediate conditions ( $M = .86$ ,  $SD = .10$ ) compared with after a delayed interval ( $M = .66$ ,  $SD = .12$ ),  $F(1, 38) = 155.88$ ,  $p < .001$ ,  $\eta_p^2 = .80$ , *observed power* = 1.00. During the one-second presentation rate, participants recalled a significantly higher proportion of words under immediate recall conditions ( $M = .88$ ,  $SD = .09$ ) compared with after a delayed interval ( $M = .63$ ,  $SD = .11$ ),  $F(1, 38) = 253.90$ ,  $p < .001$ ,  $\eta_p^2 = .87$ , *observed power* = 1.00.

**Significant 3-way interactions.** A significant 3-way interaction was found between word length, recall interval, and study condition,  $F(1, 38) = 6.46$ ,  $MSE = 0.05$ ,  $p = .015$ ,  $\eta_p^2 = .15$ , *observed power* = .70. There was no significant difference in the proportion of short words participants immediately recalled under silence ( $M = .91$ ,  $SD = .09$ ) and irrelevant speech ( $M = .90$ ,  $SD = .09$ ),  $F(1, 38) = 0.10$ ,  $p = .758$ ,  $\eta_p^2 = .00$ , *observed power* = .06. There was no significant difference in the proportion of short words participants recalled after a delayed interval under silence ( $M = .71$ ,  $SD = .14$ ) and irrelevant speech ( $M = .68$ ,  $SD = .14$ ),  $F(1, 38) = 1.99$ ,  $p = .167$ ,  $\eta_p^2 = .05$ , *observed power* = .28. However, participants recalled a significantly higher proportion of long words, under immediate conditions, during the silence conditions ( $M = .85$ ,  $SD = .10$ ) compared with the irrelevant speech conditions ( $M = .82$ ,  $SD = .11$ ),  $F(1, 38) = 4.50$ ,  $p = .040$ ,  $\eta_p^2 = .11$ , *observed power* = .54. There was no significant difference in the proportion of long words participants recalled after a delayed interval under silence ( $M = .58$ ,  $SD = .15$ ) and irrelevant speech ( $M = .60$ ,  $SD = .14$ ),  $F(1, 38) = 0.89$ ,  $p = .352$ ,  $\eta_p^2 = .02$ , *observed power* = .15.

For immediate conditions, under silence, participants recalled a significantly higher proportion of short words ( $M = .91$ ,  $SD = .09$ ) than long words ( $M = .85$ ,  $SD = .10$ ),  $F(1, 38) = 23.61$ ,  $p < .001$ ,  $\eta_p^2 = .38$ , *observed power* = 1.00. For immediate conditions, under irrelevant speech, participants recalled a significantly higher proportion of short words ( $M = .90$ ,  $SD = .09$ ) than long words ( $M = .82$ ,  $SD = .11$ ),  $F(1, 38) = 42.55$ ,  $p < .001$ ,  $\eta_p^2 = .53$ , *observed power* = 1.00. For delayed conditions, under silence, participants recalled a significantly higher proportion of short words ( $M = .71$ ,  $SD = .14$ ) than long words ( $M = .58$ ,  $SD = .15$ ),  $F(1, 38) = 48.17$ ,  $p < .001$ ,  $\eta_p^2 = .56$ , *observed power* = 1.00. For delayed conditions, under irrelevant speech, participants recalled a significantly higher proportion of short words ( $M =$

.68,  $SD = .14$ ) than long words ( $M = .60$ ,  $SD = .14$ ),  $F(1, 38) = 21.80$ ,  $p < .001$ ,  $\eta_p^2 = .36$ , *observed power* = 1.00.

Participants recalled a significantly higher proportion of short words, under silence, in immediate conditions ( $M = .91$ ,  $SD = .09$ ) compared with after a delayed interval ( $M = .71$ ,  $SD = .14$ ),  $F(1, 38) = 107.66$ ,  $p < .001$ ,  $\eta_p^2 = .74$ , *observed power* = 1.00. Participants also recalled a significantly higher proportion of short words, under irrelevant speech, in immediate conditions ( $M = .90$ ,  $SD = .09$ ) compared with after a delayed interval ( $M = .68$ ,  $SD = .14$ ),  $F(1, 38) = 120.24$ ,  $p < .001$ ,  $\eta_p^2 = .76$ , *observed power* = 1.00. Participants recalled a significantly higher proportion of long words, under silence, in immediate conditions ( $M = .85$ ,  $SD = .10$ ) compared with after a delayed interval ( $M = .58$ ,  $SD = .15$ ),  $F(1, 38) = 256.06$ ,  $p < .001$ ,  $\eta_p^2 = .87$ , *observed power* = 1.00. Participants also recalled a significantly higher proportion of long words, under irrelevant speech, in immediate conditions ( $M = .82$ ,  $SD = .11$ ) compared with after a delayed interval ( $M = .60$ ,  $SD = .14$ ),  $F(1, 38) = 151.52$ ,  $p < .001$ ,  $\eta_p^2 = .80$ , *observed power* = 1.00.

### ***Order accuracy***

***Significant 3-way interactions.*** A significant 3-way interaction was found between word length, recall interval, and age,  $F(1, 38) = 4.32$ ,  $MSE = 0.05$ ,  $p = .045$ ,  $\eta_p^2 = .10$ , *observed power* = .53. For short words immediately recalled, there was no significant difference in order accuracy between young ( $M = .97$ ,  $SD = .04$ ) and older adults ( $M = .95$ ,  $SD = .04$ ),  $F(1, 38) = 1.89$ ,  $p = .178$ ,  $\eta_p^2 = .05$ , *observed power* = .27. However, when short words were recalled after a delayed interval, order accuracy was significantly higher for young adults ( $M = .85$ ,  $SD = .10$ ) compared with older adults ( $M = .78$ ,  $SD = .10$ ),  $F(1, 38) = 5.09$ ,  $p = .030$ ,  $\eta_p^2 = .12$ , *observed power* = .60. For long words immediately recalled, order accuracy for young

adults ( $M = .93$ ,  $SD = .07$ ) was significantly higher compared with older adults ( $M = .85$ ,  $SD = .11$ ),  $F(1, 38) = 8.22$ ,  $MSE = 0.07$ ,  $p = .007$ ,  $\eta_p^2 = .18$ , *observed power* = .80. Yet when long words were recalled after a delayed interval, there was no significant difference in order accuracy between young ( $M = .79$ ,  $SD = .12$ ) and older adults ( $M = .72$ ,  $SD = .18$ ),  $F(1, 38) = 2.25$ ,  $p = .142$ ,  $\eta_p^2 = .06$ , *observed power* = .31.

Young adults' order accuracy, under immediate conditions, was significantly higher for short words ( $M = .97$ ,  $SD = .04$ ) compared with long words ( $M = .93$ ,  $SD = .07$ ),  $F(1, 38) = 4.34$ ,  $p = .044$ ,  $\eta_p^2 = .10$ , *observed power* = .53. Young adults' order accuracy, after a delayed interval, was significantly higher for short words ( $M = .85$ ,  $SD = .10$ ) compared with long words ( $M = .79$ ,  $SD = .12$ ),  $F(1, 38) = 8.24$ ,  $p = .007$ ,  $\eta_p^2 = .18$ , *observed power* = .80. Older adults' order accuracy, under immediate conditions, was significantly higher for short words ( $M = .95$ ,  $SD = .04$ ) compared with long words ( $M = .85$ ,  $SD = .11$ ),  $F(1, 38) = 32.93$ ,  $p < .001$ ,  $\eta_p^2 = .46$ , *observed power* = 1.00. Older adults' order accuracy, after a delayed interval, was significantly higher for short words ( $M = .78$ ,  $SD = .10$ ) compared with long words ( $M = .72$ ,  $SD = .18$ ),  $F(1, 38) = 8.05$ ,  $p = .007$ ,  $\eta_p^2 = .18$ , *observed power* = .79.

Young adults' order accuracy for short words was significantly higher in immediate conditions ( $M = .97$ ,  $SD = .04$ ) compared with after a delayed interval ( $M = .85$ ,  $SD = .10$ ),  $F(1, 38) = 34.91$ ,  $p < .001$ ,  $\eta_p^2 = .48$ , *observed power* = 1.00. Young adults' order accuracy for long words was significantly higher in immediate conditions ( $M = .93$ ,  $SD = .07$ ) compared with after a delayed interval ( $M = .79$ ,  $SD = .12$ ),  $F(1, 38) = 35.09$ ,  $p < .001$ ,  $\eta_p^2 = .48$ , *observed power* = 1.00. Older adults' order accuracy for long words was significantly higher in immediate conditions ( $M = .95$ ,  $SD = .04$ ) compared with after a delayed interval ( $M = .78$ ,  $SD = .10$ ),  $F(1, 38) = 76.61$ ,  $p < .001$ ,  $\eta_p^2 = .67$ , *observed power* = 1.00. Older adults' order

accuracy for long words was significantly higher in immediate conditions ( $M = .85$ ,  $SD = .10$ ) compared with after a delayed interval ( $M = .72$ ,  $SD = .18$ ),  $F(1, 38) = 31.67$ ,  $p < .001$ ,  $\eta_p^2 = .46$ , *observed power* = 1.00.

A significant 3-way interaction also emerged between word length, study condition, and presentation rate,  $F(1, 38) = 6.80$ ,  $MSE = 0.06$ ,  $p = .013$ ,  $\eta_p^2 = .15$ , *observed power* = .72. When short words were presented under the silence conditions, there was no significant difference in order accuracy during the two-second ( $M = .87$ ,  $SD = .10$ ) and one-second presentation rates ( $M = .88$ ,  $SD = .10$ ),  $F(1, 38) = 0.36$ ,  $p = .552$ ,  $\eta_p^2 = .01$ , *observed power* = .09. However, when short words were presented under the irrelevant speech conditions, order accuracy was significantly higher during the one-second presentation rate ( $M = .92$ ,  $SD = .07$ ) than the two-second presentation rate ( $M = .88$ ,  $SD = .09$ ),  $F(1, 38) = 6.94$ ,  $p = .012$ ,  $\eta_p^2 = .15$ , *observed power* = .73. When long words were presented under the silence conditions, there was no significant difference in order accuracy during the two-second ( $M = .81$ ,  $SD = .17$ ) and one-second presentation rates ( $M = .84$ ,  $SD = .15$ ),  $F(1, 38) = 3.56$ ,  $MSE = 0.09$ ,  $p = .067$ ,  $\eta_p^2 = .09$ , *observed power* = .45. Similarly, when long words were presented under the irrelevant speech conditions, there was no significant difference in order accuracy during the two-second ( $M = .81$ ,  $SD = .14$ ) and one-second presentation rates ( $M = .82$ ,  $SD = .12$ ),  $F(1, 38) = 0.16$ ,  $p = .689$ ,  $\eta_p^2 = .00$ , *observed power* = .07.

In silence conditions during the two-second presentation rate, order accuracy was significantly higher for short words ( $M = .88$ ,  $SD = .10$ ) compared with long words ( $M = .81$ ,  $SD = .17$ ),  $F(1, 38) = 13.94$ ,  $p = .001$ ,  $\eta_p^2 = .27$ , *observed power* = .95. In silence conditions during the one-second presentation rate, there was no significant difference in order accuracy for short ( $M = .87$ ,  $SD = .10$ ) and long words ( $M = .84$ ,  $SD = .15$ ),  $F(1, 38) = 1.58$ ,  $p = .217$ ,

$\eta_p^2 = .04$ , *observed power* = .23. In irrelevant speech conditions during the two-second presentation rate, order accuracy was significantly higher for short words ( $M = .88$ ,  $SD = .09$ ) compared with long words ( $M = .81$ ,  $SD = .14$ ),  $F(1, 38) = 10.86$ ,  $p = .002$ ,  $\eta_p^2 = .22$ , *observed power* = .90. In irrelevant speech conditions during the one-second presentation rate, order accuracy was significantly higher for short words ( $M = .92$ ,  $SD = .07$ ) compared with long words ( $M = .82$ ,  $SD = .12$ ),  $F(1, 38) = 37.66$ ,  $p < .001$ ,  $\eta_p^2 = .50$ , *observed power* = 1.00.

For short words presented at the two-second rate, there was no significant difference in order accuracy under silence ( $M = .88$ ,  $SD = .10$ ) and irrelevant speech ( $M = .88$ ,  $SD = .09$ ),  $F(1, 38) = 0.04$ ,  $p = .835$ ,  $\eta_p^2 = .00$ , *observed power* = .06. For short words presented at the one-second rate, order accuracy was significantly higher in the irrelevant speech conditions ( $M = .92$ ,  $SD = .07$ ) compared with the silence conditions ( $M = .87$ ,  $SD = .10$ ),  $F(1, 38) = 10.44$ ,  $p = .003$ ,  $\eta_p^2 = .22$ , *observed power* = .88. For long words presented at the two-second rate, there was no significant difference in order accuracy under silence ( $M = .81$ ,  $SD = .17$ ) and irrelevant speech ( $M = .81$ ,  $SD = .14$ ),  $F(1, 38) = 0.00$ ,  $p = .953$ ,  $\eta_p^2 = .00$ , *observed power* = .05. For long words presented at the one-second rate, there was no significant difference in order accuracy under silence ( $M = .84$ ,  $SD = .15$ ) and irrelevant speech ( $M = .82$ ,  $SD = .12$ ),  $F(1, 38) = 1.50$ ,  $p = .228$ ,  $\eta_p^2 = .04$ , *observed power* = .22.

### ***Transposition errors***

***Significant 2-way interaction.*** A significant 2-way interaction was found between word length and recall interval,  $F(1, 38) = 4.19$ ,  $MSE = 0.02$ ,  $p = .048$ ,  $\eta_p^2 = .10$ , *observed power* = .51. Participants produced a significantly higher proportion of transposition errors for short words when recall was required after a delayed interval ( $M = .08$ ,  $SD = .05$ ) compared with immediate recall ( $M = .04$ ,  $SD = .04$ ),  $F(1, 38) = 21.05$ ,  $p < .001$ ,  $\eta_p^2 = .36$ , *observed power* =

.99. However, there was no significant difference in the proportion of transposition errors made for long words during immediate recall ( $M = .07$ ,  $SD = .06$ ) and recall after a delayed interval ( $M = .09$ ,  $SD = .04$ ),  $F(1, 38) = 2.25$ ,  $p = .142$ ,  $\eta_p^2 = .06$ , *observed power* = .31.

During immediate recall conditions, participants produced a significantly higher proportion of transposition errors for long words ( $M = .07$ ,  $SD = .06$ ) than short words ( $M = .04$ ,  $SD = .04$ ),  $F(1, 38) = 15.26$ ,  $p < .001$ ,  $\eta_p^2 = .29$ , *observed power* = .97. During delayed recall conditions, there was no significant difference in the proportion of transposition errors produced for short ( $M = .09$ ,  $SD = .04$ ) and long words ( $M = .08$ ,  $SD = .04$ ),  $F(1, 38) = 0.57$ ,  $p = .455$ ,  $\eta_p^2 = .02$ , *observed power* = .11.

**Significant 3-way interaction.** A significant 3-way interaction between word length, recall interval, and age emerged,  $F(1, 38) = 4.42$ ,  $MSE = 0.02$ ,  $p = .042$ ,  $\eta_p^2 = .10$ , *observed power* = .54. When short words were immediately recalled, there was no significant difference in the proportion of transposition errors made by young ( $M = .04$ ,  $SD = .04$ ) and older adults ( $M = .05$ ,  $SD = .04$ ),  $F(1, 38) = 1.56$ ,  $p = .219$ ,  $\eta_p^2 = .04$ , *observed power* = .23. When short words were recalled after a delayed interval, there was no significant difference in the proportion of transposition errors made by young ( $M = .07$ ,  $SD = .04$ ) and older adults ( $M = .09$ ,  $SD = .05$ ),  $F(1, 38) = 2.50$ ,  $p = .122$ ,  $\eta_p^2 = .06$ , *observed power* = .34. When long words were immediately recalled, older adults ( $M = .09$ ,  $SD = .07$ ) produced a significantly higher proportion of transposition errors compared with young adults ( $M = .05$ ,  $SD = .04$ ),  $F(1, 38) = 6.18$ ,  $p = .017$ ,  $\eta_p^2 = .14$ , *observed power* = .38. However, when long words were recalled after a delayed interval, there was no significant difference in the proportion of transposition errors made by young ( $M = .08$ ,  $SD = .03$ ) and older adults ( $M = .09$ ,  $SD = .05$ ),  $F(1, 38) = 0.19$ ,  $p = .669$ ,  $\eta_p^2 = .01$ , *observed power* = .07.

There was no significant difference in the proportion of transposition errors young adults produced during immediate recall conditions for short ( $M = .04$ ,  $SD = .04$ ) and long words ( $M = .05$ ,  $SD = .04$ ),  $F(1, 38) = 1.75$ ,  $p = .194$ ,  $\eta_p^2 = .04$ , *observed power* = .25. There was also no significant difference in the proportion of transposition errors young adults produced after a delayed interval for short ( $M = .07$ ,  $SD = .04$ ) and long words ( $M = .08$ ,  $SD = .03$ ),  $F(1, 38) = 1.86$ ,  $p = .181$ ,  $\eta_p^2 = .05$ , *observed power* = .27. Older adults produced a significantly higher proportion of transposition errors in immediate recall conditions for long words ( $M = .09$ ,  $SD = .05$ ) compared with short words ( $M = .05$ ,  $SD = .04$ ),  $F(1, 38) = 17.67$ ,  $p < .001$ ,  $\eta_p^2 = .32$ , *observed power* = .98. However, there was no significant difference in the proportion of transposition errors older adults produced after a delayed interval for short ( $M = .09$ ,  $SD = .05$ ) and long words ( $M = .09$ ,  $SD = .05$ ),  $F(1, 38) = 0.09$ ,  $p = .768$ ,  $\eta_p^2 = .00$ , *observed power* = .06.

Young adults produced a significantly higher proportion of transposition errors for short words after a delayed interval ( $M = .07$ ,  $SD = .04$ ) than in immediate recall conditions ( $M = .04$ ,  $SD = .04$ ),  $F(1, 38) = 8.50$ ,  $p = .006$ ,  $\eta_p^2 = .18$ , *observed power* = .81. Young adults produced a significantly higher proportion of transposition errors for long words after a delayed interval ( $M = .08$ ,  $SD = .03$ ) than in immediate recall conditions ( $M = .05$ ,  $SD = .04$ ),  $F(1, 38) = 6.76$ ,  $p = .013$ ,  $\eta_p^2 = .15$ , *observed power* = .72. Older adults produced a significantly higher proportion of transposition errors for short words after a delayed interval ( $M = .09$ ,  $SD = .05$ ) than in immediate recall conditions ( $M = .05$ ,  $SD = .04$ ),  $F(1, 38) = 12.78$ ,  $p = .001$ ,  $\eta_p^2 = .00$ , *observed power* = .04. However, there was no significant difference in the proportion of transposition errors older adults produced for long words in immediate recall



conditions ( $M = .09$ ,  $SD = .05$ ) and after a delayed interval ( $M = .09$ ,  $SD = .05$ ),  $F(1, 38) = 0.23$ ,  $p = .633$ ,  $\eta_p^2 = .01$ , *observed power* = .08.

### ***Omission errors***

***Significant 2-way interactions.*** A significant 2-way interaction emerged for word length and recall interval,  $F(1, 38) = 8.48$ ,  $MSE = 0.05$ ,  $p = .006$ ,  $\eta_p^2 = .18$ , *observed power* = .81. Participants omitted a significantly higher proportion of short words when recall was required after a delayed interval ( $M = .23$ ,  $SD = .12$ ) compared with immediate recall ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 112.55$ ,  $p < .001$ ,  $\eta_p^2 = .75$ , *observed power* = 1.00. Participants also omitted a significantly higher proportion of long words when recall was required after a delayed interval ( $M = .33$ ,  $SD = .13$ ) compared with immediate recall ( $M = .13$ ,  $SD = .08$ ),  $F(1, 38) = 212.64$ ,  $p < .001$ ,  $\eta_p^2 = .85$ , *observed power* = 1.00.

Participants, under immediate recall conditions, omitted a significantly higher proportion of long words ( $M = .13$ ,  $SD = .08$ ) than short words ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 59.86$ ,  $p < .001$ ,  $\eta_p^2 = .61$ , *observed power* = 1.00. Participants, under delayed recall conditions, also omitted a significantly higher proportion of long words ( $M = .33$ ,  $SD = .13$ ) compared with short words ( $M = .23$ ,  $SD = .12$ ),  $F(1, 38) = 78.95$ ,  $p < .001$ ,  $\eta_p^2 = .68$ , *observed power* = 1.00.

A significant 2-way interaction also emerged between recall interval and presentation rate,  $F(1, 38) = 5.84$ ,  $MSE = 0.05$ ,  $p = .021$ ,  $\eta_p^2 = .13$ , *observed power* = .65. There was no significant difference in the proportion of omitted words during immediate recall conditions when words were presented during the two-second ( $M = .09$ ,  $SD = .07$ ) and one-second presentation rates ( $M = .11$ ,  $SD = .08$ ),  $F(1, 38) = 3.92$ ,  $p = .055$ ,  $\eta_p^2 = .09$ , *observed power* = .49. There was no significant difference in the proportion of omitted words during delayed

recall conditions when words were presented every two seconds ( $M = .27$ ,  $SD = .12$ ) and every second ( $M = .29$ ,  $SD = .13$ ),  $F(1, 38) = 1.33$ ,  $p = .256$ ,  $\eta_p^2 = .03$ , *observed power* = .20.

Participants, under the two-second presentation rate, omitted a significantly higher proportion of words after a delayed interval ( $M = .27$ ,  $SD = .12$ ) compared with immediate recall conditions ( $M = .11$ ,  $SD = .08$ ),  $F(1, 38) = 124.11$ ,  $p < .001$ ,  $\eta_p^2 = .77$ , *observed power* = 1.00. Similarly, participants, under the one-second presentation rate, omitted a significantly higher proportion of words during delayed recall conditions ( $M = .20$ ,  $SD = .13$ ) compared with immediate recall conditions ( $M = .09$ ,  $SD = .07$ ),  $F(1, 38) = 168.45$ ,  $p < .001$ ,  $\eta_p^2 = .82$ , *observed power* = 1.00.

**Significant 3-way interactions.** A significant 3-way interaction emerged between word length, recall interval, and study condition,  $F(1, 38) = 8.96$ ,  $MSE = 0.03$ ,  $p = .005$ ,  $\eta_p^2 = .19$ , *observed power* = .83. When short words were immediately recalled, there was no significant difference in the proportion of words participants omitted under silence ( $M = .07$ ,  $SD = .07$ ) and irrelevant speech ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 0.11$ ,  $p = .740$ ,  $\eta_p^2 = .00$ , *observed power* = .06. When short words were recalled after a delayed interval, there was no significant difference in the proportion of words participants omitted under silence ( $M = .22$ ,  $SD = .13$ ) and irrelevant speech ( $M = .24$ ,  $SD = .12$ ),  $F(1, 38) = 2.18$ ,  $p = .148$ ,  $\eta_p^2 = .05$ , *observed power* = .30. When long words were immediately recalled, participants omitted a significantly higher proportion of words during the irrelevant speech conditions ( $M = .14$ ,  $SD = .10$ ) compared with the silence conditions ( $M = .11$ ,  $SD = .08$ ),  $F(1, 38) = 5.03$ ,  $p = .031$ ,  $\eta_p^2 = .12$ , *observed power* = .59. When long words were recalled after a delayed interval, there was no significant difference in the proportion of words participants omitted under silence ( $M = .33$ ,  $SD = .14$ )

and irrelevant speech ( $M = .32$ ,  $SD = .13$ ),  $F(1, 38) = 0.76$ ,  $p = .389$ ,  $\eta_p^2 = .02$ , *observed power* = .14.

For immediate recall, under the silence conditions, participants omitted a significantly higher proportion of long words ( $M = .11$ ,  $SD = .08$ ) than short words ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 27.26$ ,  $p < .001$ ,  $\eta_p^2 = .42$ , *observed power* = 1.00. For immediate recall, under the irrelevant speech conditions, participants omitted a significantly higher proportion of long words ( $M = .14$ ,  $SD = .10$ ) than short words ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 40.88$ ,  $p < .001$ ,  $\eta_p^2 = .32$ , *observed power* = 1.00. For delayed recall, under the silence conditions, participants omitted a significantly higher proportion of long words ( $M = .33$ ,  $SD = .14$ ) than short words ( $M = .22$ ,  $SD = .13$ ),  $F(1, 38) = 50.55$ ,  $p < .001$ ,  $\eta_p^2 = .57$ , *observed power* = 1.00. For delayed recall, under the irrelevant speech conditions, participants omitted a significantly higher proportion of long words ( $M = .32$ ,  $SD = .13$ ) than short words ( $M = .24$ ,  $SD = .12$ ),  $F(1, 38) = 41.03$ ,  $p < .001$ ,  $\eta_p^2 = .52$ , *observed power* = 1.00.

Participants omitted a significantly higher proportion of short words in the silence conditions when recall was required after a delayed interval ( $M = .22$ ,  $SD = .13$ ) compared with immediate recall ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 69.41$ ,  $p < .001$ ,  $\eta_p^2 = .65$ , *observed power* = 1.00. Participants also omitted a significantly higher proportion of short words in the irrelevant speech conditions when recall was required after a delayed interval ( $M = .24$ ,  $SD = .12$ ) compared with immediate recall ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 105.54$ ,  $p < .001$ ,  $\eta_p^2 = .74$ , *observed power* = 1.00. Participants omitted a significantly higher proportion of long words in the irrelevant conditions when recall was required after a delayed interval ( $M = .33$ ,  $SD = .14$ ) compared with immediate recall ( $M = .11$ ,  $SD = .08$ ),  $F(1, 38) = 176.29$ ,  $p < .001$ ,  $\eta_p^2 = .82$ , *observed power* = 1.00. Participants omitted a significantly higher proportion of long

words in the irrelevant speech condition when recall was required after a delayed interval ( $M = .32$ ,  $SD = .13$ ) compared with immediate recall ( $M = .14$ ,  $SD = .10$ ),  $F(1, 38) = 161.26$ ,  $p < .001$ ,  $\eta_p^2 = .81$ , *observed power* = 1.00.

A significant 3-way interaction also emerged between word length, recall interval, and presentation rate,  $F(1, 38) = 7.70$ ,  $MSE = 0.06$ ,  $p = .009$ ,  $\eta_p^2 = .17$ , *observed power* = .77. When short words were immediately recalled, there was no significant difference in the proportion of words participants omitted during the two-second ( $M = .07$ ,  $SD = .07$ ) and one-second presentation rates ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 0.02$ ,  $p = .903$ ,  $\eta_p^2 = .00$ , *observed power* = .05. When short words were recalled after a delayed interval, there was no significant difference in the proportion of words participants omitted during the two-second ( $M = .23$ ,  $SD = .13$ ) and one-second presentation rates ( $M = .23$ ,  $SD = .13$ ),  $F(1, 38) = 0.04$ ,  $p = .851$ ,  $\eta_p^2 = .00$ , *observed power* = .05. For long words that were immediately recalled, participants omitted a significantly higher proportion of words during the two-second presentation rate ( $M = .14$ ,  $SD = .11$ ) compared with the one-second presentation rate ( $M = .11$ ,  $SD = .08$ ),  $F(1, 38) = 5.59$ ,  $p = .023$ ,  $\eta_p^2 = .13$ , *observed power* = .64. When long words were recalled after a delayed interval, there was no significant difference in the proportion of words participants omitted during the two-second ( $M = .31$ ,  $SD = .14$ ) and one-second presentation rates ( $M = .35$ ,  $SD = .15$ ),  $F(1, 38) = 3.67$ ,  $p = .063$ ,  $\eta_p^2 = .09$ , *observed power* = .46.

For immediate recall conditions, during the two-second presentation rate, participants omitted a significantly higher proportion of long words ( $M = .14$ ,  $SD = .11$ ) compared with short words ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 42.76$ ,  $p < .001$ ,  $\eta_p^2 = .53$ , *observed power* = 1.00. For immediate recall conditions, during the one-second presentation rate, participants omitted a significantly higher proportion of long words ( $M = .11$ ,  $SD = .08$ ) compared with short

words ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 12.06$ ,  $p = .001$ ,  $\eta_p^2 = .24$ , *observed power* = .92. In delayed recall conditions, during the two-second presentation rate, participants omitted a significantly higher proportion of long words ( $M = .31$ ,  $SD = .14$ ) compared with short words ( $M = .23$ ,  $SD = .13$ ),  $F(1, 38) = 23.41$ ,  $p < .001$ ,  $\eta_p^2 = .38$ , *observed power* = 1.00. In delayed recall conditions, during the one-second presentation rate, participants omitted a significantly higher proportion of long words ( $M = .35$ ,  $SD = .15$ ) compared with short words ( $M = .23$ ,  $SD = .13$ ),  $F(1, 38) = 63.94$ ,  $p < .001$ ,  $\eta_p^2 = .63$ , *observed power* = 1.00.

For short words presented during the two-second rate, participants omitted a significantly higher proportion of words after a delayed interval ( $M = .23$ ,  $SD = .13$ ) compared with immediate recall conditions ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 104.55$ ,  $p < .001$ ,  $\eta_p^2 = .73$ , *observed power* = 1.00. For short words presented during the one-second rate, participants omitted a significantly higher proportion of words after a delayed interval ( $M = .23$ ,  $SD = .13$ ) compared with immediate recall conditions ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 67.32$ ,  $p < .001$ ,  $\eta_p^2 = .64$ , *observed power* = 1.00. For long words presented during the two-second rate, participants omitted a significantly higher proportion of words after a delayed interval ( $M = .31$ ,  $SD = .14$ ) compared with immediate recall conditions ( $M = .14$ ,  $SD = .11$ ),  $F(1, 38) = 80.92$ ,  $p < .001$ ,  $\eta_p^2 = .68$ , *observed power* = 1.00. For long words presented during the one-second rate, participants omitted a significantly higher proportion of words after a delayed interval ( $M = .35$ ,  $SD = .15$ ) compared with immediate recall conditions ( $M = .11$ ,  $SD = .08$ ),  $F(1, 38) = 222.77$ ,  $p < .001$ ,  $\eta_p^2 = .85$ , *observed power* = 1.00.

**Significant 4-way interaction.** A significant 4-way interaction was evident between word length, recall interval, presentation rate, and age,  $F(1, 38) = 8.23$ ,  $MSE = 0.06$ ,  $p = .007$ ,  $\eta_p^2 = .18$ , *observed power* = .80. For short words that were immediately recalled under the

two-second presentation rate, there was no significant difference in the proportion of words omitted by young ( $M = .05$ ,  $SD = .05$ ) and older adults ( $M = .05$ ,  $SD = .09$ ),  $F(1, 38) = 3.42$ ,  $p = .072$ ,  $\eta_p^2 = .08$ , *observed power* = .44. Similarly, when short words were immediately recalled under the one-second presentation rate, there was no significant difference in the proportion of words omitted by young ( $M = .06$ ,  $SD = .07$ ) and older adults ( $M = .08$ ,  $SD = .08$ ),  $F(1, 38) = 0.65$ ,  $p = .427$ ,  $\eta_p^2 = .02$ , *observed power* = .12. However, when short words were recalled after a delayed interval under the two-second presentation rate, older adults ( $M = .29$ ,  $SD = .13$ ) omitted a significantly higher proportion of words compared with young adults ( $M = .18$ ,  $SD = .11$ ),  $F(1, 38) = 7.65$ ,  $p = .009$ ,  $\eta_p^2 = .17$ , *observed power* = .77. Although, when short words were recalled during delayed conditions under the one-second presentation rate, there was no significant difference in the proportion of words omitted at recall by young ( $M = .21$ ,  $SD = .13$ ) and older adults ( $M = .25$ ,  $SD = .12$ ),  $F(1, 38) = 1.25$ ,  $p = .272$ ,  $\eta_p^2 = .03$ , *observed power* = .19. When long words were immediately recalled during the two-second presentation rate, older adults ( $M = .19$ ,  $SD = .11$ ) omitted a significantly higher proportion of words compared with young adults ( $M = .10$ ,  $SD = .08$ ),  $F(1, 38) = 7.97$ ,  $p = .008$ ,  $\eta_p^2 = .17$ , *observed power* = .79. Although, when long words were immediately recalled during the one-second presentation rate, there was no significant difference in the proportion of words omitted by young ( $M = .09$ ,  $SD = .09$ ) and older adults ( $M = .12$ ,  $SD = .07$ ),  $F(1, 38) = 1.10$ ,  $p = .301$ ,  $\eta_p^2 = .03$ , *observed power* = .18. When long words were recalled during delayed conditions under the two-second presentation rate, there was no significant difference in the proportion of words omitted by young ( $M = .28$ ,  $SD = .15$ ) and older adults ( $M = .34$ ,  $SD = .13$ ),  $F(1, 38) = 1.73$ ,  $p = .196$ ,  $\eta_p^2 = .04$ , *observed power* = .25. When long words were recalled during delayed conditions under the one-second presentation rate, older adults ( $M =$

.40,  $SD = .15$ ) omitted a significantly higher proportion of words compared with young adults ( $M = .29$ ,  $SD = .14$ ),  $F(1, 38) = 5.99$ ,  $p = .019$ ,  $\eta_p^2 = .14$ , *observed power* = .67.

Young adults, under immediate recall conditions during the two-second presentation rate, omitted a significantly higher proportion of long words ( $M = .10$ ,  $SD = .08$ ) compared with short words ( $M = .05$ ,  $SD = .05$ ),  $F(1, 38) = 7.98$ ,  $p = .003$ ,  $\eta_p^2 = .21$ , *observed power* =

.87. Young adults, under immediate recall conditions during the one-second presentation rate, omitted a significantly higher proportion of long words ( $M = .09$ ,  $SD = .09$ ) compared with short words ( $M = .06$ ,  $SD = .07$ ),  $F(1, 38) = 5.14$ ,  $p = .020$ ,  $\eta_p^2 = .12$ , *observed power* = .60.

Young adults, under delayed recall conditions during the two-second presentation rate, omitted a significantly higher proportion of long words ( $M = .28$ ,  $SD = .15$ ) compared with short words ( $M = .18$ ,  $SD = .11$ ),  $F(1, 38) = 20.11$ ,  $p < .001$ ,  $\eta_p^2 = .35$ , *observed power* = .99.

Young adults, under delayed recall conditions during the one-second presentation rate, omitted a significantly higher proportion of long words ( $M = .29$ ,  $SD = .14$ ) compared with short words ( $M = .21$ ,  $SD = .13$ ),  $F(1, 38) = 16.13$ ,  $p < .001$ ,  $\eta_p^2 = .30$ , *observed power* = .98. Older

adults, under immediate recall conditions during the two-second presentation rate, omitted a significantly higher proportion of long words ( $M = .19$ ,  $SD = .11$ ) compared with short words ( $M = .09$ ,  $SD = .08$ ),  $F(1, 38) = 37.07$ ,  $p < .001$ ,  $\eta_p^2 = .49$ , *observed power* = 1.00. Older

adults, under immediate recall conditions during the one-second presentation rate, omitted a significantly higher proportion of long words ( $M = .12$ ,  $SD = .07$ ) compared with short words ( $M = .08$ ,  $SD = .08$ ),  $F(1, 38) = 6.70$ ,  $p = .012$ ,  $\eta_p^2 = .16$ , *observed power* = .73. Older adults,

under delayed recall conditions during the two-second presentation rate, omitted a significantly higher proportion of long words ( $M = .34$ ,  $SD = .13$ ) compared with short words ( $M = .29$ ,  $SD = .13$ ),  $F(1, 38) = 5.56$ ,  $p = .024$ ,  $\eta_p^2 = .13$ , *observed power* = .63. Older adults,

during delayed recall conditions under the one-second presentation rate, omitted a significantly higher proportion of long words ( $M = .40$ ,  $SD = .15$ ) compared with short words ( $M = .25$ ,  $SD = .12$ ),  $F(1, 38) = 53.17$ ,  $p < .001$ ,  $\eta_p^2 = .58$ , *observed power* = 1.00.

Young adults did not significantly differ in the proportion of short words omitted under immediate recall conditions during the two-second ( $M = .05$ ,  $SD = .05$ ) and one-second presentation rates ( $M = .06$ ,  $SD = .07$ ),  $F(1, 38) = 0.37$ ,  $p = .547$ ,  $\eta_p^2 = .01$ , *observed power* = .09. Young adults also did not significantly differ in the proportion of short words omitted under delayed recall conditions during the two-second ( $M = .18$ ,  $SD = .11$ ) and one-second presentation rates ( $M = .21$ ,  $SD = .13$ ),  $F(1, 38) = 1.27$ ,  $p = .267$ ,  $\eta_p^2 = .03$ , *observed power* = .20. Young adults did not significantly differ in the proportion of long words omitted under immediate recall conditions during the two-second ( $M = .10$ ,  $SD = .08$ ) and one-second presentation rates ( $M = .09$ ,  $SD = .09$ ),  $F(1, 38) = 0.06$ ,  $p = .816$ ,  $\eta_p^2 = .00$ , *observed power* = .06. Young adults also did not significantly differ in the proportion of long words omitted under delayed recall conditions during the two-second ( $M = .28$ ,  $SD = .15$ ) and one-second presentation rates ( $M = .29$ ,  $SD = .13$ ),  $F(1, 38) = 0.14$ ,  $p = .715$ ,  $\eta_p^2 = .00$ , *observed power* = .07. Older adults did not significantly differ in the proportion of short words omitted under immediate recall conditions during the two-second ( $M = .09$ ,  $SD = .08$ ) and one-second presentation rates ( $M = .08$ ,  $SD = .08$ ),  $F(1, 38) = 0.61$ ,  $p = .439$ ,  $\eta_p^2 = .02$ , *observed power* = .12. Older adults also did not significantly differ in the proportion of short words omitted under delayed recall conditions during the two-second ( $M = .29$ ,  $SD = .13$ ) and one-second presentation rates ( $M = .25$ ,  $SD = .12$ ),  $F(1, 38) = 1.94$ ,  $p = .171$ ,  $\eta_p^2 = .05$ , *observed power* = .27. Although, older adults omitted a significantly higher proportion of long words under immediate recall conditions during the two-second presentation rate ( $M = .19$ ,  $SD = .11$ ) than



the one-second presentation rate ( $M = .12$ ,  $SD = .07$ ),  $F(1, 38) = 9.67$ ,  $p = .004$ ,  $\eta_p^2 = .20$ , *observed power* = .86. Also, older adults omitted a significantly higher proportion of long words under delayed recall conditions during the one-second presentation rate ( $M = .40$ ,  $SD = .15$ ) compared with the two-second presentation rate ( $M = .34$ ,  $SD = .13$ ),  $F(1, 38) = 5.48$ ,  $p = .025$ ,  $\eta_p^2 = .13$ , *observed power* = .63.

Young adults omitted a significantly higher proportion of short words, under the two-second presentation rate, after a delayed interval ( $M = .18$ ,  $SD = .11$ ) compared with immediate recall ( $M = .05$ ,  $SD = .05$ ),  $F(1, 38) = 34.21$ ,  $p < .001$ ,  $\eta_p^2 = .47$ , *observed power* = 1.00. Similarly, young adults omitted a significantly higher proportion of short words, under the one-second presentation rate, after a delayed interval ( $M = .21$ ,  $SD = .13$ ) compared with immediate recall ( $M = .06$ ,  $SD = .07$ ),  $F(1, 38) = 28.75$ ,  $p < .001$ ,  $\eta_p^2 = .43$ , *observed power* = 1.00. Young adults omitted a significantly higher proportion of long words, under the two-second presentation rate, after a delayed interval ( $M = .28$ ,  $SD = .15$ ) compared with immediate recall ( $M = .10$ ,  $SD = .08$ ),  $F(1, 38) = 48.09$ ,  $p < .001$ ,  $\eta_p^2 = .56$ , *observed power* = 1.00. Young adults omitted a significantly higher proportion of long words, under the one-second presentation rate, after a delayed interval ( $M = .29$ ,  $SD = .13$ ) compared with immediate recall ( $M = .09$ ,  $SD = .09$ ),  $F(1, 38) = 75.26$ ,  $p < .001$ ,  $\eta_p^2 = .66$ , *observed power* = 1.00. Older adults omitted a significantly higher proportion of short words, under the two-second presentation rate, after a delayed interval ( $M = .29$ ,  $SD = .13$ ) compared with immediate recall ( $M = .09$ ,  $SD = .08$ ),  $F(1, 38) = 74.16$ ,  $p < .001$ ,  $\eta_p^2 = .66$ , *observed power* = 1.00. Older adults also omitted a significantly higher proportion of short words, under the one-second presentation rate, after a delayed interval ( $M = .25$ ,  $SD = .12$ ) compared with immediate recall ( $M = .09$ ,  $SD = .08$ ),  $F(1, 38) = 38.95$ ,  $p < .001$ ,  $\eta_p^2 = .51$ , *observed power* =

1.00. Older adults omitted a significantly higher proportion of long words, under the two-second presentation rate, after a delayed interval ( $M = .34$ ,  $SD = .13$ ) compared with immediate recall ( $M = .19$ ,  $SD = .11$ ),  $F(1, 38) = 33.48$ ,  $p < .001$ ,  $\eta_p^2 = .81$ , *observed power* = 1.00. Older adults also omitted a significantly higher proportion of long words, under the one-second presentation rate, after a delayed interval ( $M = .40$ ,  $SD = .15$ ) compared with immediate recall ( $M = .12$ ,  $SD = .07$ ),  $F(1, 38) = 154.57$ ,  $p < .001$ ,  $\eta_p^2 = .80$ , *observed power* = 1.00.

## **Appendix C – 2.2: Non-significant interactions**

### ***Correct-in-position recall***

**Non-significant main effects.** The remaining main effects were not significant: study condition,  $F(1, 38) = 0.11$ ,  $MSE = 0.00$ ,  $p = .745$ ,  $\eta_p^2 = .00$ , *observed power* = .06; and presentation rate,  $F(1, 38) = 0.62$ ,  $MSE = 0.02$ ,  $p = .435$ ,  $\eta_p^2 = .02$ , *observed power* = .12.

**Non-significant 2-way interactions.** The remaining 2-way interactions were not significant: word length and age,  $F(1, 38) = 3.19$ ,  $MSE = 0.05$ ,  $p = .082$ ,  $\eta_p^2 = .08$ , *observed power* = .41; recall interval and age,  $F(1, 38) = 0.46$ ,  $MSE = 0.02$ ,  $p = .504$ ,  $\eta_p^2 = .01$ , *observed power* = .10; study condition and age,  $F(1, 38) = 0.24$ ,  $MSE = 0.00$ ,  $p = .626$ ,  $\eta_p^2 = .01$ , *observed power* = .08; presentation rate and age,  $F(1, 38) = 1.34$ ,  $MSE = 0.04$ ,  $p = .254$ ,  $\eta_p^2 = .03$ , *observed power* = .20; word length and recall interval,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .946$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word length and study condition,  $F(1, 38) = 0.89$ ,  $MSE = 0.02$ ,  $p = .352$ ,  $\eta_p^2 = .02$ , *observed power* = .15; recall interval and study condition,  $F(1, 38) = 0.95$ ,  $MSE = 0.02$ ,  $p = .335$ ,  $\eta_p^2 = .02$ , *observed power* = .16; word length and presentation rate,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .927$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between study condition and presentation rate,  $F(1, 38) = 1.00$ ,  $MSE = 0.01$ ,  $p = .324$ ,  $\eta_p^2 = .03$ , *observed power* = .16.

**Non-significant 3-way interactions.** The remaining 3-way interactions were not significant: word length, study condition, and age,  $F(1, 38) = 0.16$ ,  $MSE = 0.00$ ,  $p = .692$ ,  $\eta_p^2 = .00$ , *observed power* = .07; recall interval, study condition, and age,  $F(1, 38) = 0.21$ ,  $MSE = 0.01$ ,  $p = .647$ ,  $\eta_p^2 = .01$ , *observed power* = .07; word length, presentation rate, and age,  $F(1, 38) = 0.02$ ,  $MSE = 0.00$ ,  $p = .903$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval, presentation rate, and age,  $F(1, 38) = 0.15$ ,  $MSE = 0.00$ ,  $p = .698$ ,  $\eta_p^2 = .00$ , *observed power* = .07; word

length, recall interval, and presentation rate,  $F(1, 38) = 1.89$ ,  $MSE = 0.04$ ,  $p = .178$ ,  $\eta_p^2 = .05$ , *observed power* = .27; study condition, presentation rate, and age,  $F(1, 38) = 1.22$ ,  $MSE = 0.02$ ,  $p = .277$ ,  $\eta_p^2 = .03$ , *observed power* = .19; word length, study condition, and presentation rate,  $F(1, 38) = 3.88$ ,  $MSE = 0.05$ ,  $p = .056$ ,  $\eta_p^2 = .09$ , *observed power* = .48; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 0.04$ ,  $MSE = 0.00$ ,  $p = .839$ ,  $\eta_p^2 = .00$ , *observed power* = .06.

***Non-significant 4-way interactions.*** The remaining 4-way interactions were not significant: word length, recall interval, study condition, and age,  $F(1, 38) = 3.39$ ,  $MSE = 0.04$ ,  $p = .074$ ,  $\eta_p^2 = .08$ , *observed power* = .43; word length, study condition, presentation rate, and age,  $F(1, 38) = 0.06$ ,  $MSE = 0.00$ ,  $p = .807$ ,  $\eta_p^2 = .00$ , *observed power* = .06; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 0.09$ ,  $MSE = 0.00$ ,  $p = .771$ ,  $\eta_p^2 = .00$ , *observed power* = .06; and between word length, recall interval, study condition, and presentation rate,  $F(1, 38) = 2.68$ ,  $MSE = 0.05$ ,  $p = .110$ ,  $\eta_p^2 = .07$ , *observed power* = .36.

***Non-significant 5-way interaction.*** The 5-way interaction between word length, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 1.91$ ,  $MSE = 0.04$ ,  $p = .175$ ,  $\eta_p^2 = .05$ , *observed power* = .27.

### ***Item recall***

***Non-significant main effects.*** The remaining main effects were not significant: study condition,  $F(1, 38) = 1.23$ ,  $MSE = 0.01$ ,  $p = .275$ ,  $\eta_p^2 = .03$ , *observed power* = .19; and presentation rate,  $F(1, 38) = 0.24$ ,  $MSE = 0.01$ ,  $p = .624$ ,  $\eta_p^2 = .01$ , *observed power* = .08.

***Non-significant 2-way interactions.*** The remaining 2-way interactions were not significant: word length and age,  $F(1, 38) = 1.32$ ,  $MSE = 0.10$ ,  $p = .259$ ,  $\eta_p^2 = .03$ , *observed*

power = .20; recall interval and age,  $F(1, 38) = 1.39$ ,  $MSE = 0.04$ ,  $p = .246$ ,  $\eta_p^2 = .04$ , *observed power* = .21; study condition and age,  $F(1, 38) = 0.92$ ,  $MSE = 0.01$ ,  $p = .343$ ,  $\eta_p^2 = .02$ , *observed power* = .16; presentation rate and age,  $F(1, 38) = 1.42$ ,  $MSE = 0.03$ ,  $p = .241$ ,  $\eta_p^2 = .04$ , *observed power* = .21; word length and study condition,  $F(1, 38) = 0.32$ ,  $MSE = 0.01$ ,  $p = .575$ ,  $\eta_p^2 = .01$ , *observed power* = .09; recall interval and study condition,  $F(1, 38) = 0.60$ ,  $MSE = 0.01$ ,  $p = .445$ ,  $\eta_p^2 = .02$ , *observed power* = .12; word length and presentation rate,  $F(1, 38) = 0.03$ ,  $MSE = 0.00$ ,  $p = .875$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between study condition and presentation rate,  $F(1, 38) = 0.57$ ,  $MSE = 0.01$ ,  $p = .454$ ,  $\eta_p^2 = .02$ , *observed power* = .11.

***Non-significant 3-way interactions.*** The remaining 3-way interactions were not significant: word length, recall interval, and age,  $F(1, 38) = 1.56$ ,  $MSE = 0.01$ ,  $p = .220$ ,  $\eta_p^2 = .04$ , *observed power* = .23; word length, study condition, and age,  $F(1, 38) = 0.25$ ,  $MSE = 0.00$ ,  $p = .621$ ,  $\eta_p^2 = .01$ , *observed power* = .08; recall interval, study condition, and age,  $F(1, 38) = 0.83$ ,  $MSE = 0.01$ ,  $p = .367$ ,  $\eta_p^2 = .02$ , *observed power* = .15; word length, presentation rate, and age,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .937$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval, presentation rate, and age,  $F(1, 38) = 0.14$ ,  $MSE = 0.00$ ,  $p = .708$ ,  $\eta_p^2 = .00$ , *observed power* = .07; word length, recall interval, and presentation rate,  $F(1, 38) = 3.11$ ,  $MSE = 0.04$ ,  $p = .086$ ,  $\eta_p^2 = .08$ , *observed power* = .40; study condition, presentation rate, and age,  $F(1, 38) = 0.84$ ,  $MSE = 0.01$ ,  $p = .366$ ,  $\eta_p^2 = .02$ , *observed power* = .15; word length, study condition, and presentation rate,  $F(1, 38) = 0.03$ ,  $MSE = 0.00$ ,  $p = .869$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 0.42$ ,  $MSE = 0.01$ ,  $p = .522$ ,  $\eta_p^2 = .01$ , *observed power* = .10.

**Non-significant 4-way interactions.** All 4-way interactions were not significant: word length, recall interval, study condition, and age,  $F(1, 38) = 3.95$ ,  $MSE = 0.03$ ,  $p = .054$ ,  $\eta_p^2 = .09$ , *observed power* = .49; word length, recall interval, presentation rate, and age,  $F(1, 38) = 3.11$ ,  $MSE = 0.04$ ,  $p = .086$ ,  $\eta_p^2 = .08$ , *observed power* = .49; word length, study condition, presentation rate, and age,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .94$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .970$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between word length, recall interval, study condition, and presentation rate,  $F(1, 38) = 1.77$ ,  $MSE = 0.30$ ,  $p = .192$ ,  $\eta_p^2 = .04$ , *observed power* = .25.

**Non-significant 5-way interaction.** The 5-way interaction between word length, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.62$ ,  $MSE = 0.01$ ,  $p = .437$ ,  $\eta_p^2 = .02$ , *observed power* = .12.

### **Order accuracy**

**Non-significant main effects.** The remaining main effects were not significant: study condition,  $F(1, 38) = 0.43$ ,  $MSE = 0.01$ ,  $p = .516$ ,  $\eta_p^2 = .01$ , *observed power* = .10; and presentation rate,  $F(1, 38) = 2.94$ ,  $MSE = 0.05$ ,  $p = .095$ ,  $\eta_p^2 = .07$ , *observed power* = .39.

**Non-significant 2-way interactions.** All 2-way interactions were not significant: word length and age,  $F(1, 38) = 1.78$ ,  $MSE = 0.04$ ,  $p = .190$ ,  $\eta_p^2 = .05$ , *observed power* = .26; recall interval and age,  $F(1, 38) = 0.68$ ,  $MSE = 0.02$ ,  $p = .414$ ,  $\eta_p^2 = .02$ , *observed power* = .13; study condition and age,  $F(1, 38) = 2.77$ ,  $MSE = 0.04$ ,  $p = .105$ ,  $\eta_p^2 = .07$ , *observed power* = .37; presentation rate and age,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .977$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word length and recall interval,  $F(1, 38) = 0.09$ ,  $MSE = 0.00$ ,  $p = .761$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

$power = .06$ ; word length and study condition,  $F(1, 38) = 2.53$ ,  $MSE = 0.05$ ,  $p = .120$ ,  $\eta_p^2 = .06$ , *observed power* = .34; recall interval and study condition,  $F(1, 38) = 0.42$ ,  $MSE = 0.01$ ,  $p = .523$ ,  $\eta_p^2 = .01$ , *observed power* = .10; word length and presentation rate,  $F(1, 38) = 0.09$ ,  $MSE = 0.00$ ,  $p = .771$ ,  $\eta_p^2 = .00$ , *observed power* = .06; recall interval and presentation rate,  $F(1, 38) = 0.31$ ,  $MSE = 0.01$ ,  $p = .582$ ,  $\eta_p^2 = .01$ , *observed power* = .08; and between study condition and presentation rate,  $F(1, 38) = 0.65$ ,  $MSE = 0.01$ ,  $p = .427$ ,  $\eta_p^2 = .02$ , *observed power* = .12.

***Non-significant 3-way interactions.*** The remaining 3-way interactions were not significant: word length, study condition, and age,  $F(1, 38) = 0.13$ ,  $MSE = 0.00$ ,  $p = .721$ ,  $\eta_p^2 = .00$ , *observed power* = .06; recall interval, study condition, and age,  $F(1, 38) = 0.05$ ,  $MSE = 0.00$ ,  $p = .829$ ,  $\eta_p^2 = .00$ , *observed power* = .06; word length, recall interval, and study condition,  $F(1, 38) = 0.44$ ,  $MSE = 0.01$ ,  $p = .510$ ,  $\eta_p^2 = .01$ , *observed power* = .10; word length, presentation rate, and age,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .918$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval, presentation rate, and age,  $F(1, 38) = 0.26$ ,  $MSE = 0.01$ ,  $p = .617$ ,  $\eta_p^2 = .01$ , *observed power* = .08; word length, recall interval, and presentation rate,  $F(1, 38) = 0.05$ ,  $MSE = 0.00$ ,  $p = .826$ ,  $\eta_p^2 = .00$ , *observed power* = .06; study condition, presentation rate, and age,  $F(1, 38) = 0.62$ ,  $MSE = 0.01$ ,  $p = .437$ ,  $\eta_p^2 = .02$ , *observed power* = .12; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 0.33$ ,  $MSE = 0.00$ ,  $p = .571$ ,  $\eta_p^2 = .01$ , *observed power* = .09.

***Non-significant 4-way interactions.*** All 4-way interactions were not significant: word length, recall interval, study condition, and age,  $F(1, 38) = 0.55$ ,  $MSE = 0.01$ ,  $p = .462$ ,  $\eta_p^2 = .01$ , *observed power* = .11; word length, recall interval, presentation rate, and age,  $F(1, 38) = 2.11$ ,  $MSE = 0.03$ ,  $p = .154$ ,  $\eta_p^2 = .05$ , *observed power* = .29; word length, study condition,

presentation rate, and age,  $F(1, 38) = 0.14$ ,  $MSE = 0.00$ ,  $p = .712$ ,  $\eta_p^2 = .00$ , *observed power* = .07; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 0.27$ ,  $MSE = 0.00$ ,  $p = .607$ ,  $\eta_p^2 = .01$ , *observed power* = .08; and between word length, recall interval, study condition, and presentation rate,  $F(1, 38) = 0.74$ ,  $MSE = 0.01$ ,  $p = .394$ ,  $\eta_p^2 = .02$ , *observed power* = .13.

***Non-significant 5-way interaction.*** The 5-way interaction between word length, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.94$ ,  $MSE = 0.02$ ,  $p = .337$ ,  $\eta_p^2 = .02$ , *observed power* = .16.

### ***Transposition errors***

***Non-significant main effects.*** The remaining main effects were not significant: study condition,  $F(1, 38) = 0.24$ ,  $MSE = 0.00$ ,  $p = .629$ ,  $\eta_p^2 = .01$ , *observed power* = .08; and presentation rate,  $F(1, 38) = 1.69$ ,  $MSE = 0.01$ ,  $p = .202$ ,  $\eta_p^2 = .04$ , *observed power* = .25.

***Non-significant 2-way interactions.*** The remaining 2-way interactions were not significant: word length and age,  $F(1, 38) = 0.43$ ,  $MSE = 0.00$ ,  $p = .518$ ,  $\eta_p^2 = .01$ , *observed power* = .10; recall interval and age,  $F(1, 38) = 1.55$ ,  $MSE = 0.01$ ,  $p = .220$ ,  $\eta_p^2 = .04$ , *observed power* = .23; study condition and age,  $F(1, 38) = 2.79$ ,  $MSE = 0.01$ ,  $p = .103$ ,  $\eta_p^2 = .07$ , *observed power* = .37; presentation rate and age,  $F(1, 38) = 0.63$ ,  $MSE = 0.00$ ,  $p = .432$ ,  $\eta_p^2 = .02$ , *observed power* = .12; word length and study condition,  $F(1, 38) = 0.14$ ,  $MSE = 0.00$ ,  $p = .707$ ,  $\eta_p^2 = .00$ , *observed power* = .07; recall interval and study condition,  $F(1, 38) = 3.09$ ,  $MSE = 0.01$ ,  $p = .087$ ,  $\eta_p^2 = .08$ , *observed power* = .40; word length and presentation rate,  $F(1, 38) = 1.55$ ,  $MSE = 0.01$ ,  $p = .220$ ,  $\eta_p^2 = .04$ , *observed power* = .23; recall interval and presentation rate,  $F(1, 38) = 2.10$ ,  $MSE = 0.01$ ,  $p = .156$ ,  $\eta_p^2 = .05$ , *observed power* = .29; and



between study condition and presentation rate,  $F(1, 38) = 3.55$ ,  $MSE = 0.02$ ,  $p = .067$ ,  $\eta_p^2 = .09$ , *observed power* = .45.

***Non-significant 3-way interactions.*** The remaining 3-way interactions were not significant: word length, study condition, and age,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = 1.00$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval, study condition, and age,  $F(1, 38) = 2.48$ ,  $MSE = 0.01$ ,  $p = .123$ ,  $\eta_p^2 = .06$ , *observed power* = .34; word length, recall interval, and study condition,  $F(1, 38) = 1.94$ ,  $MSE = 0.01$ ,  $p = .172$ ,  $\eta_p^2 = .05$ , *observed power* = .27; word length, presentation rate, and age,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .962$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word length, recall interval, and presentation rate,  $F(1, 38) = 2.01$ ,  $MSE = 0.01$ ,  $p = .164$ ,  $\eta_p^2 = .05$ , *observed power* = .28; study condition, presentation rate, and age,  $F(1, 38) = 0.30$ ,  $MSE = 0.00$ ,  $p = .589$ ,  $\eta_p^2 = .01$ , *observed power* = .08; word length, study condition, and presentation rate,  $F(1, 38) = 2.70$ ,  $MSE = 0.01$ ,  $p = .108$ ,  $\eta_p^2 = .07$ , *observed power* = .36; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .915$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

***Non-significant 4-way interactions.*** All 4-way interactions were not significant: word length, recall interval, study condition, and age,  $F(1, 38) = 0.06$ ,  $MSE = 0.00$ ,  $p = .810$ ,  $\eta_p^2 = .00$ , *observed power* = .06; word length, recall interval, presentation rate, and age,  $F(1, 38) = 3.14$ ,  $MSE = 0.01$ ,  $p = .084$ ,  $\eta_p^2 = .08$ , *observed power* = .41; word length, study condition, presentation rate, and age,  $F(1, 38) = 0.12$ ,  $MSE = 0.00$ ,  $p = .734$ ,  $\eta_p^2 = .00$ , *observed power* = .06; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 0.03$ ,  $MSE = 0.00$ ,  $p = .872$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between word length, recall interval, study condition, and presentation rate,  $F(1, 38) = 0.31$ ,  $MSE = 0.00$ ,  $p = .584$ ,  $\eta_p^2 = .01$ , *observed power* = .08.

**Non-significant 5-way interaction.** The 5-way interaction between word length, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.37$ ,  $MSE = 0.00$ ,  $p = .547$ ,  $\eta_p^2 = .01$ , *observed power* = .09.

### ***Omission errors***

**Non-significant main effects.** The remaining main effects were not significant: study condition,  $F(1, 38) = 1.86$ ,  $MSE = 0.02$ ,  $p = .181$ ,  $\eta_p^2 = .05$ , *observed power* = .26; and presentation rate,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .937$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

**Non-significant 2-way interactions.** The remaining 2-way interactions were not significant: word length and age,  $F(1, 38) = 1.89$ ,  $MSE = 0.01$ ,  $p = .177$ ,  $\eta_p^2 = .05$ , *observed power* = .27; recall interval and age,  $F(1, 38) = 1.80$ ,  $MSE = 0.05$ ,  $p = .188$ ,  $\eta_p^2 = .05$ , *observed power* = .26; study condition and age,  $F(1, 38) = 0.08$ ,  $MSE = 0.00$ ,  $p = .775$ ,  $\eta_p^2 = .00$ , *observed power* = .06; presentation rate and age,  $F(1, 38) = 1.20$ ,  $MSE = 0.02$ ,  $p = .280$ ,  $\eta_p^2 = .03$ , *observed power* = .19; word length and study condition,  $F(1, 38) = 0.14$ ,  $MSE = 0.00$ ,  $p = .709$ ,  $\eta_p^2 = .00$ , *observed power* = .07; recall interval and study condition,  $F(1, 38) = 0.58$ ,  $MSE = 0.00$ ,  $p = .451$ ,  $\eta_p^2 = .02$ , *observed power* = .12; word length and presentation rate,  $F(1, 38) = 0.04$ ,  $MSE = 0.00$ ,  $p = .840$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between study condition and presentation rate,  $F(1, 38) = 0.02$ ,  $MSE = 0.00$ ,  $p = .879$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

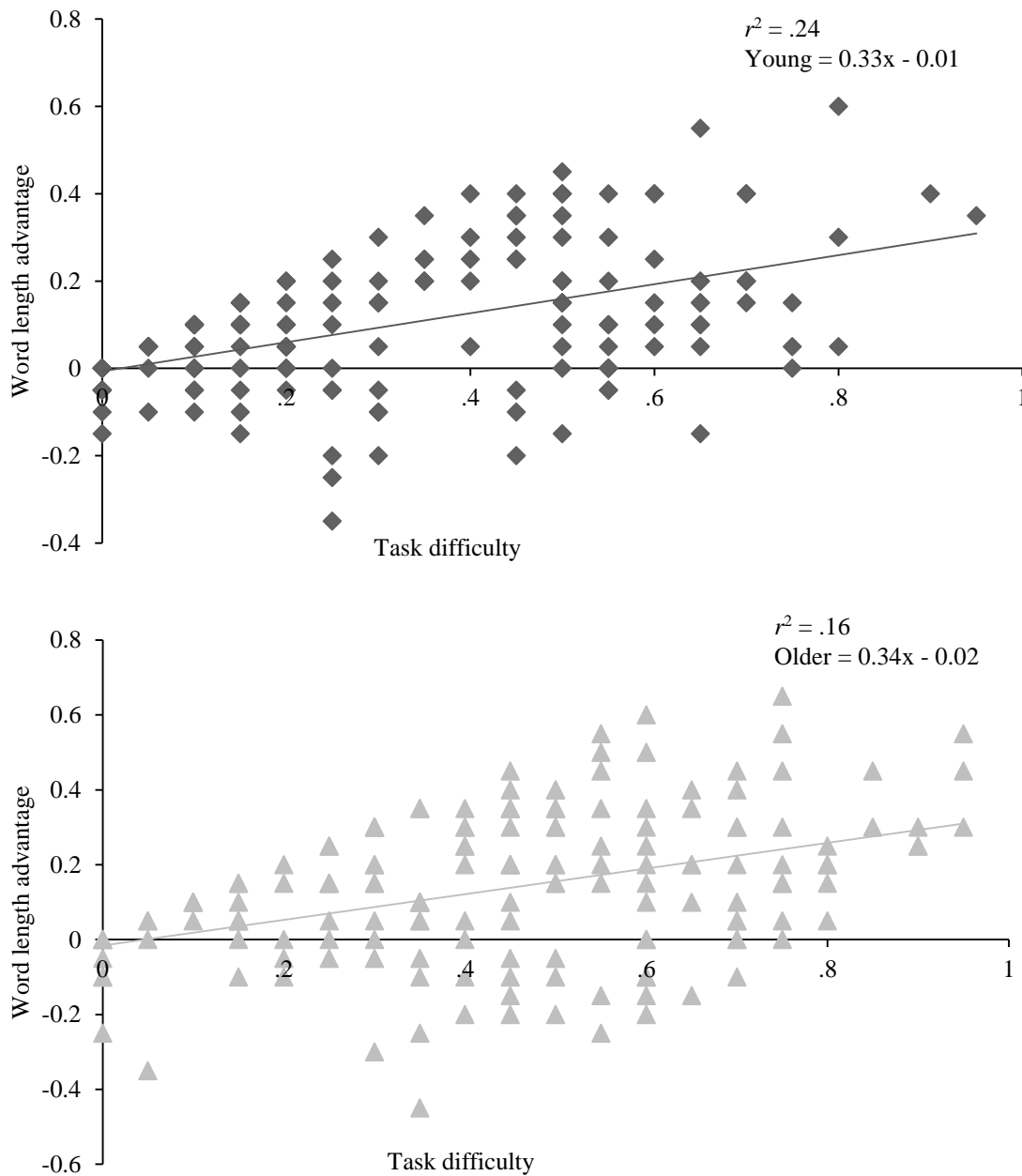
**Non-significant 3-way interactions.** The remaining 3-way interactions were not significant: word length, recall interval, and age,  $F(1, 38) = 0.45$ ,  $MSE = 0.00$ ,  $p = .506$ ,  $\eta_p^2 = .01$ , *observed power* = .10; word length, study condition, and age,  $F(1, 38) = 0.03$ ,  $MSE = 0.00$ ,  $p = .862$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval, study condition, and age,  $F(1,$

38) = 0.10,  $MSE = 0.00$ ,  $p = .751$ ,  $\eta_p^2 = .00$ , *observed power* = .06; word length, presentation rate, and age,  $F(1, 38) = 1.65$ ,  $MSE = 0.01$ ,  $p = .207$ ,  $\eta_p^2 = .04$ , *observed power* = .24; recall interval, presentation rate, and age,  $F(1, 38) = 1.70$ ,  $MSE = 0.02$ ,  $p = .200$ ,  $\eta_p^2 = .04$ , *observed power* = .25; study condition, presentation rate, and age,  $F(1, 38) = 0.97$ ,  $MSE = 0.01$ ,  $p = .330$ ,  $\eta_p^2 = .03$ , *observed power* = .16; word length, study condition, and presentation rate,  $F(1, 38) = 0.04$ ,  $MSE = 0.00$ ,  $p = .847$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 0.15$ ,  $MSE = 0.00$ ,  $p = .698$ ,  $\eta_p^2 = .00$ , *observed power* = .07.

***Non-significant 4-way interactions.*** The remaining 4-way interactions were not significant: word length, recall interval, study condition, and age,  $F(1, 38) = 3.36$ ,  $MSE = 0.01$ ,  $p = .074$ ,  $\eta_p^2 = .08$ , *observed power* = .43; word length, study condition, presentation rate, and age,  $F(1, 38) = 1.06$ ,  $MSE = 0.01$ ,  $p = .311$ ,  $\eta_p^2 = .03$ , *observed power* = .17; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .926$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between word length, recall interval, study condition, and presentation rate,  $F(1, 38) = 0.85$ ,  $MSE = 0.01$ ,  $p = .361$ ,  $\eta_p^2 = .02$ , *observed power* = .15.

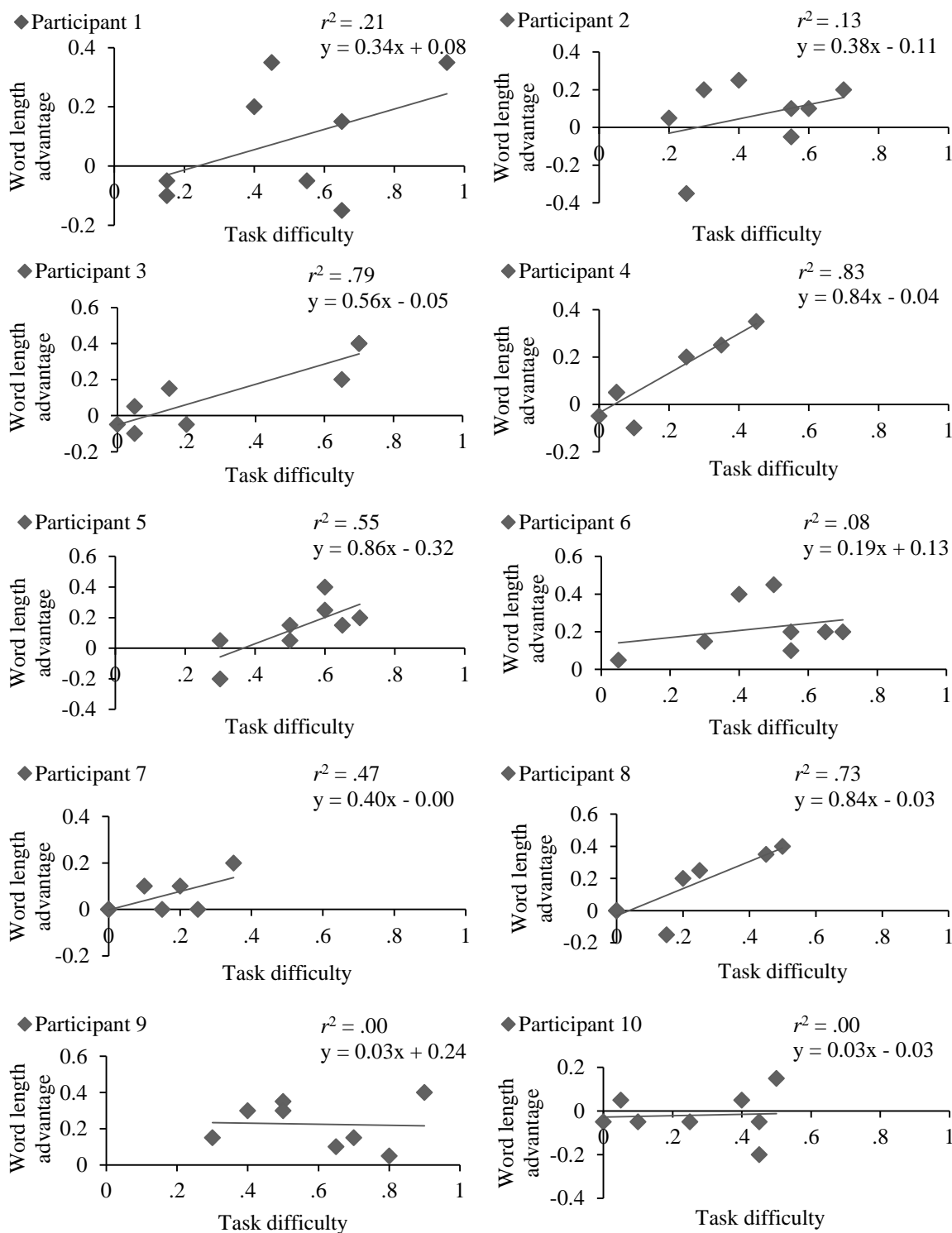
***Non-significant 5-way interaction.*** The 5-way interaction between word length, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.59$ ,  $MSE = 0.01$ ,  $p = .448$ ,  $\eta_p^2 = .02$ , *observed power* = .12.

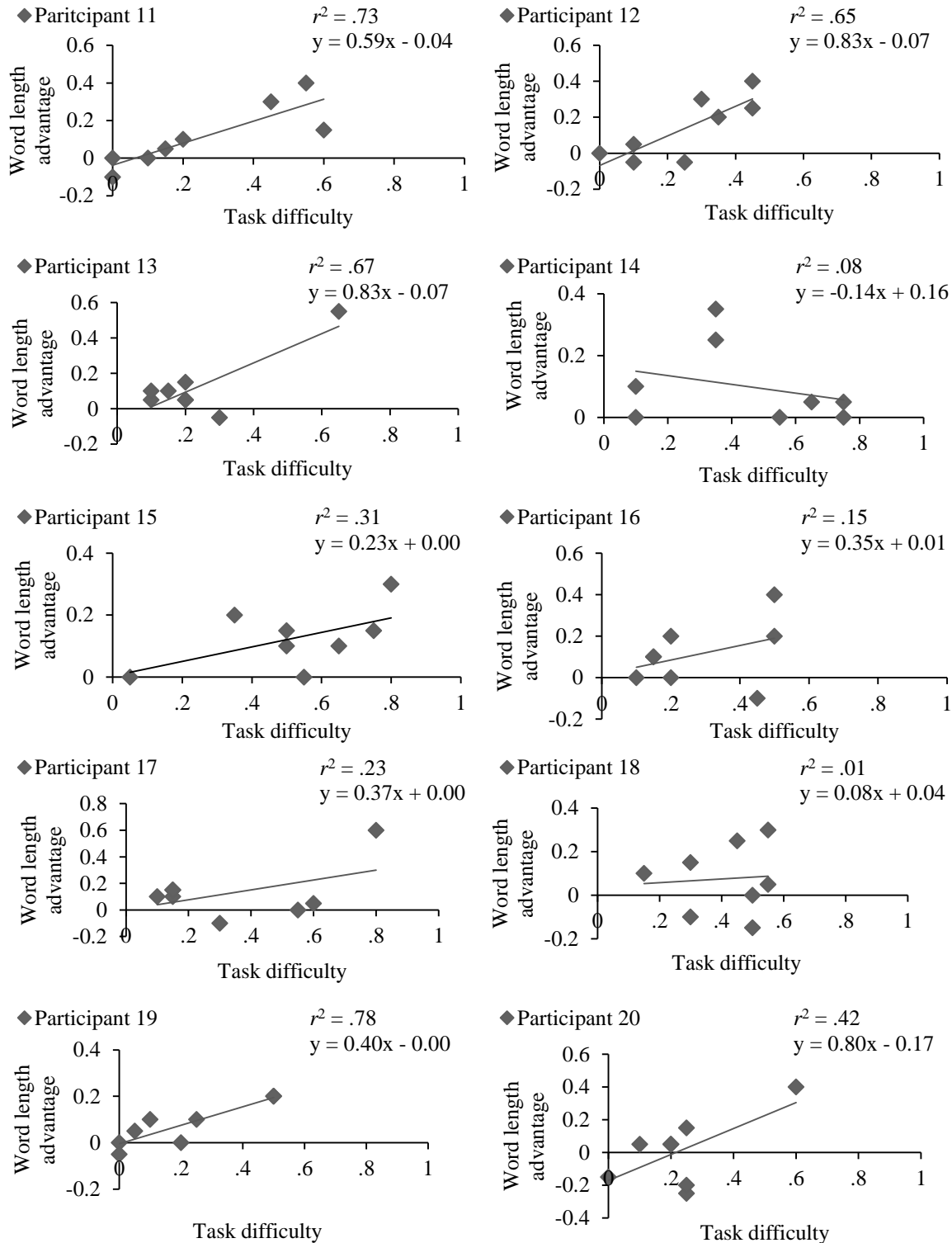
**Appendix C – 2.3: Word length advantage as a function of task difficulty for correct-in-position recall across all young adults (upper graph) and all older adults (lower graph)**



Young adults showed for correct-in-position-recall a weak word length advantage as task difficulty increased. In the lower graph, older adults also displayed a weak word length advantage as task difficulty increased.

**Appendix C – 2.4: Word length advantage as a function of task difficulty for correct-in-position recall for each young adult**

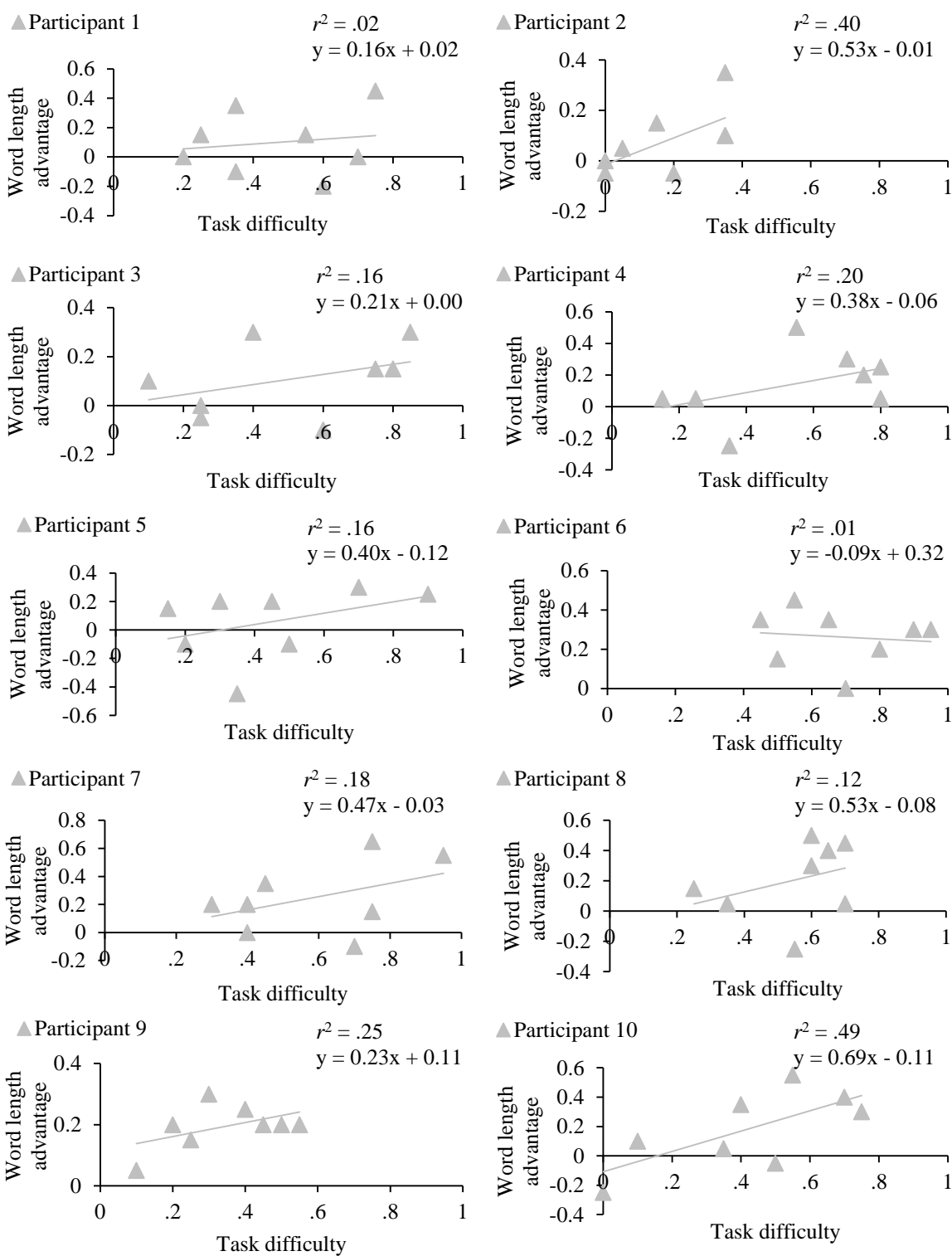




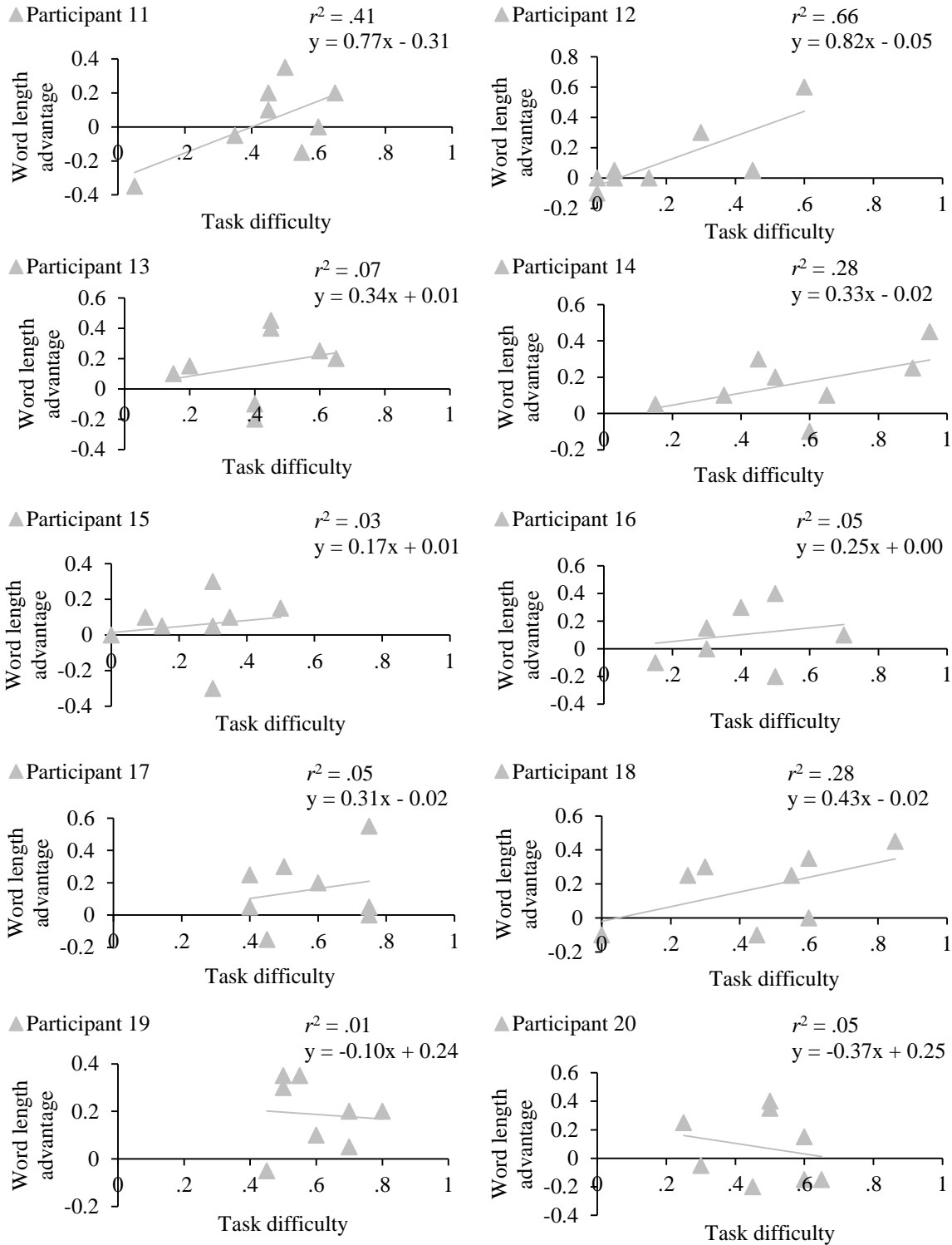
Redintegrative effects were moderately consistent across the young adults. Five young adults demonstrated strong redintegration effects where  $r^2 > .70$  (Participants 3, 4, 8, 11, and 19) whereas seven young adults demonstrated weak redintegration effects where  $r^2 < .30$

(Participants 1, 2, 6, 14, 16, 17, and 18). While two young adults demonstrated no redintegration effects, where  $r^2 = .00$  (Participants 9 and 10), the remaining six participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 5, 7, 12, 13, 15, and 20).

**Appendix C – 2.5: Word length advantage as a function of task difficulty for correct-in-position recall for each older adult**



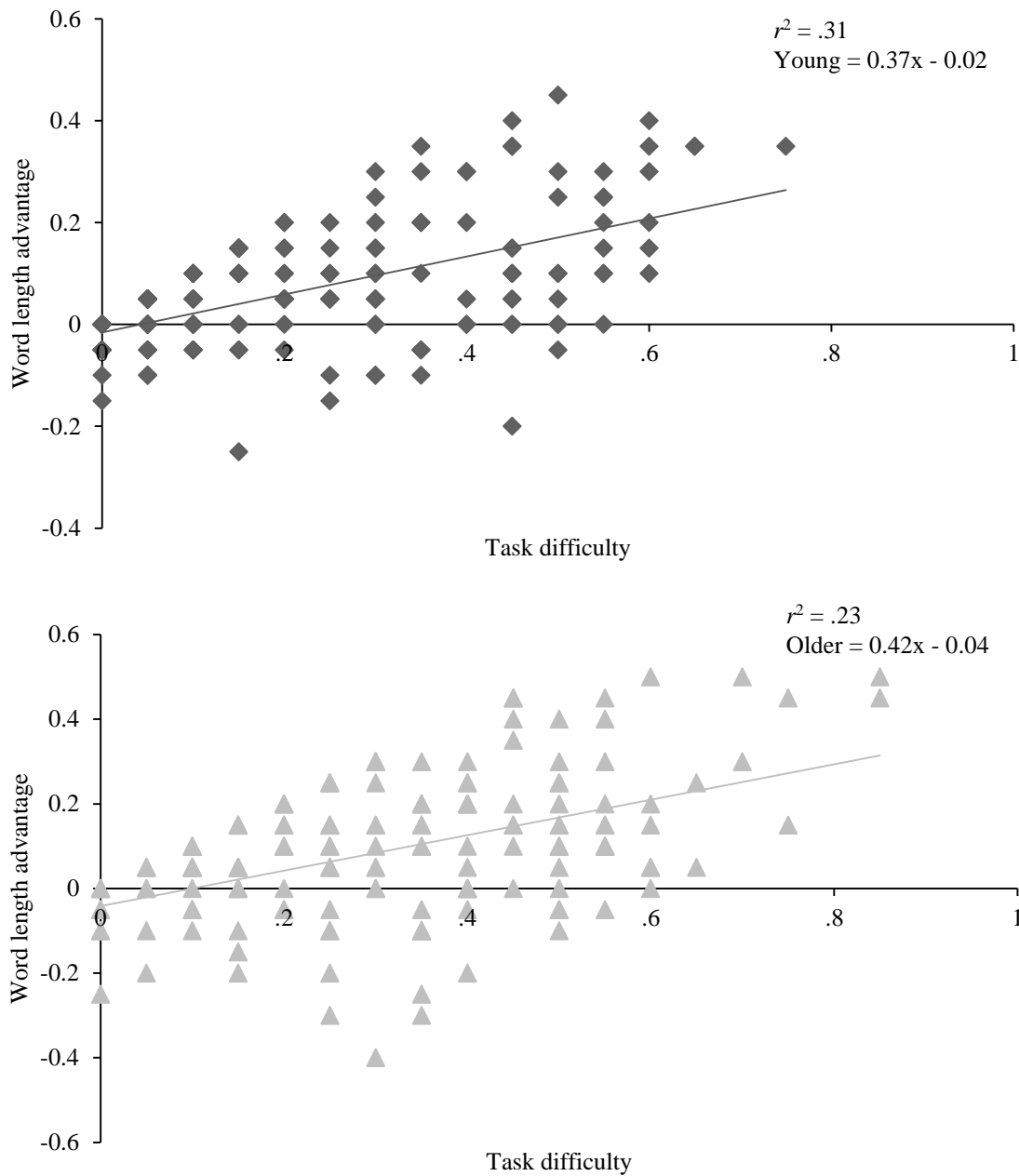




In contrast with the young adults, none of the older adults demonstrated strong redintegrative effects between the word length advantage and task difficulty. Four older adults demonstrated moderate effects of redintegration, where  $r^2$  was between .30 and .70

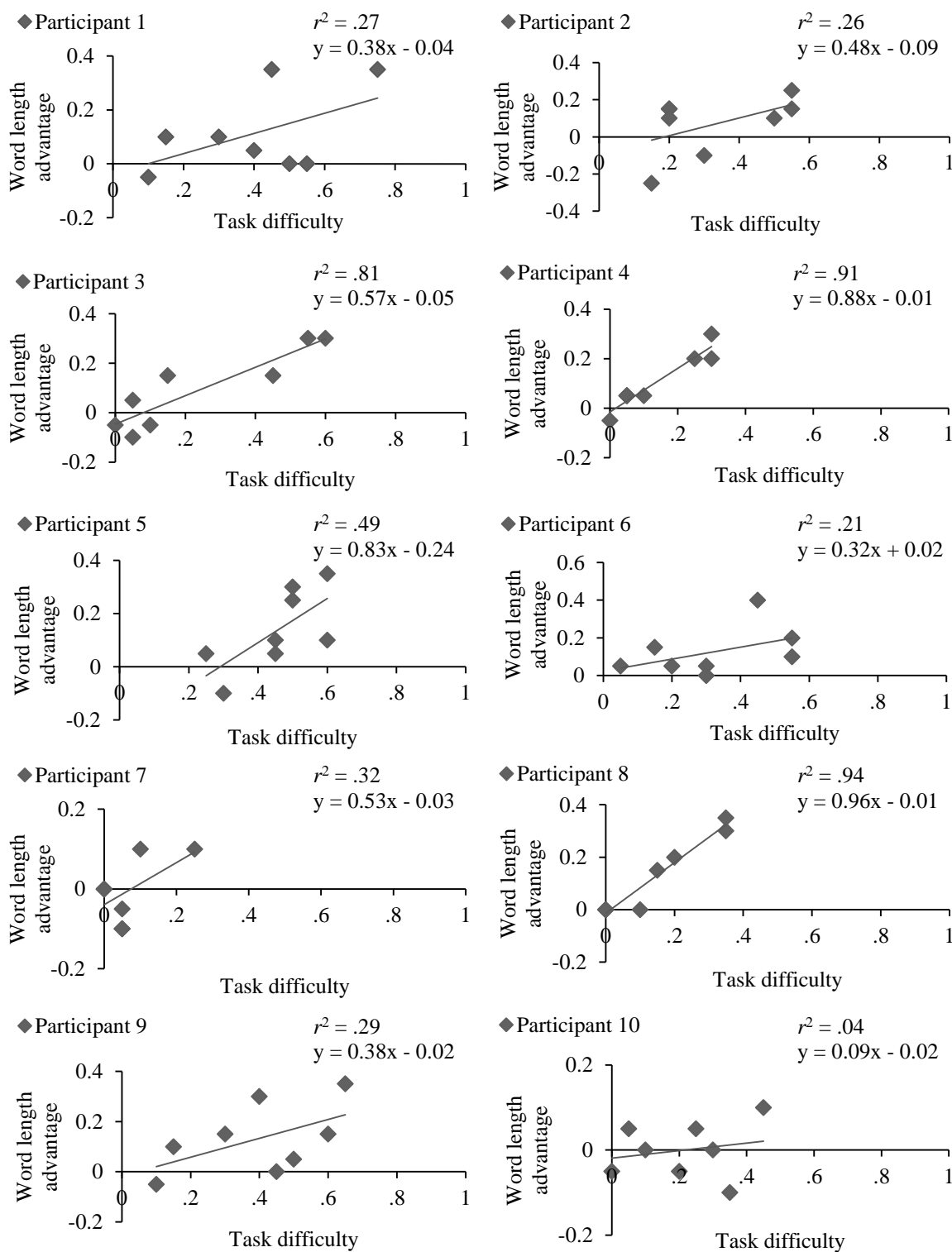
(Participants 2, 10, 11, and 12) and the remaining 16 older adults demonstrated weak redintegration effects where  $r^2 < .30$  (Participants 1, 3, 4, 5, 6, 7, 8, 9, 13, 14, 15, 16, 17, 18, 19, and 20).

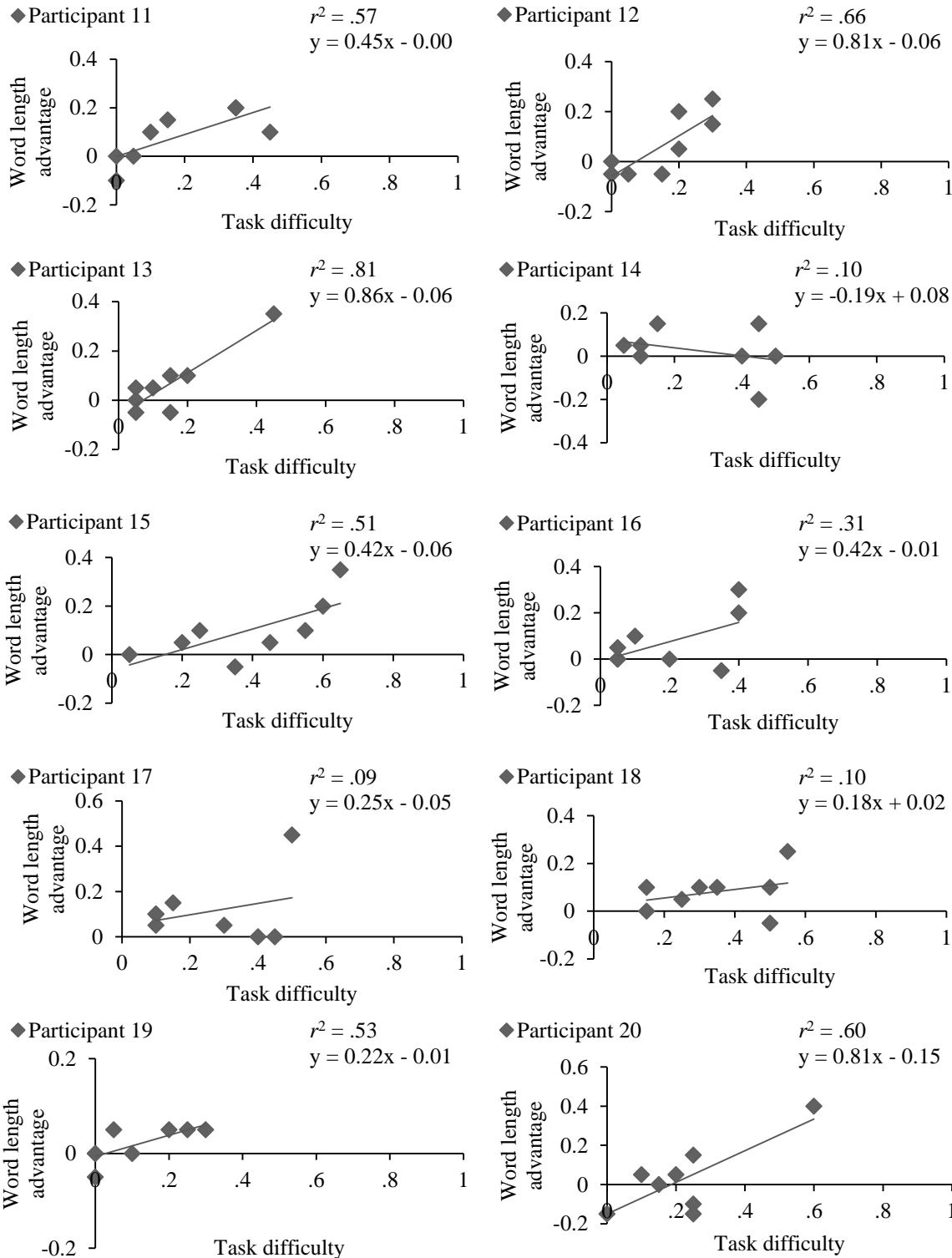
**Appendix C – 2.6: Word length advantage as a function of task difficulty for item recall across all young adults (upper graph) and all older adults (lower graph)**



In the upper graph, all young adults and in the lower graph and all older adults showed a positive word length advantage in item recall as task difficulty increased.

**Appendix C – 2.7: Word length advantage as a function of task difficulty for item recall for each young adult**

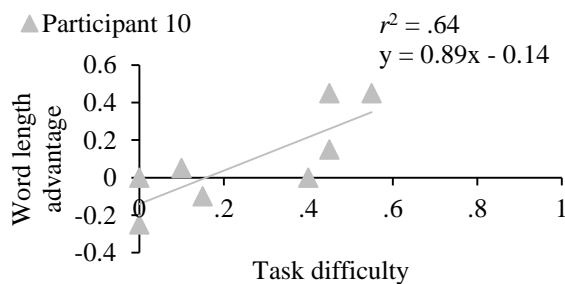
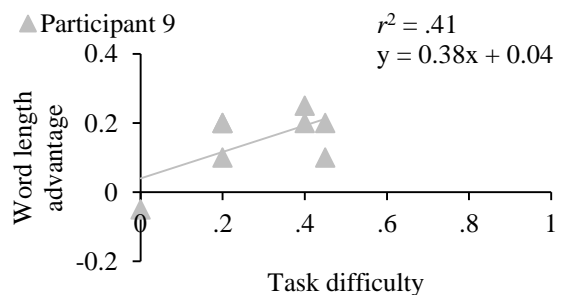
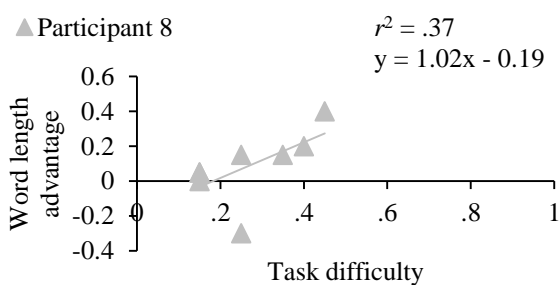
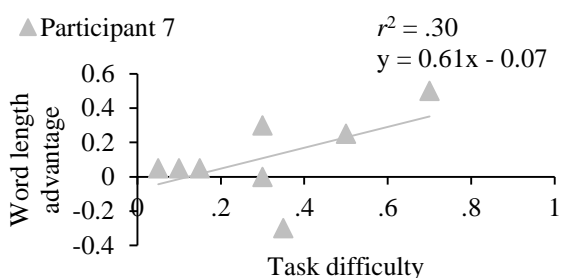
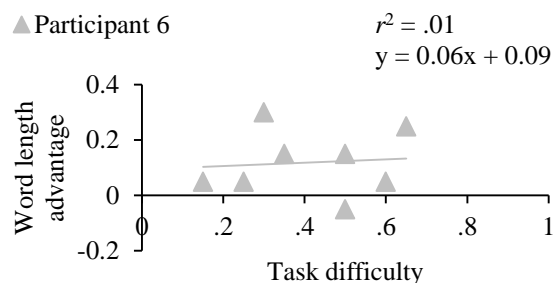
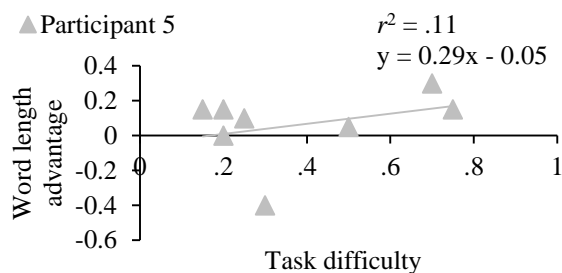
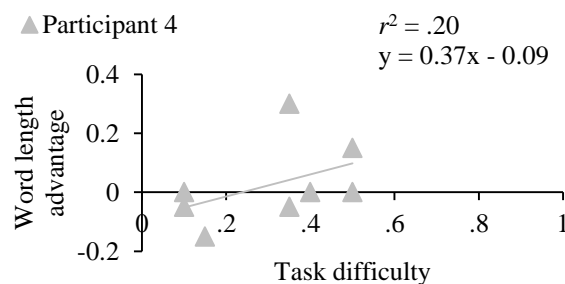
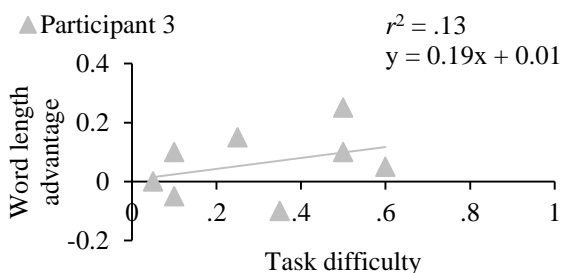
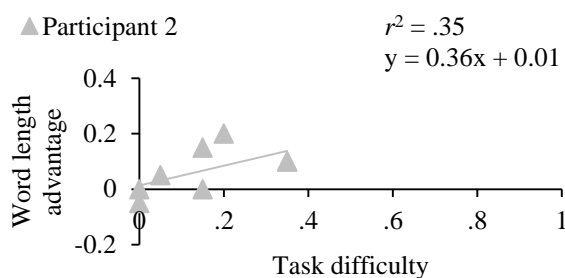
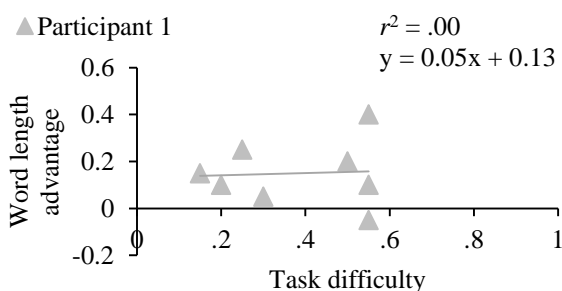


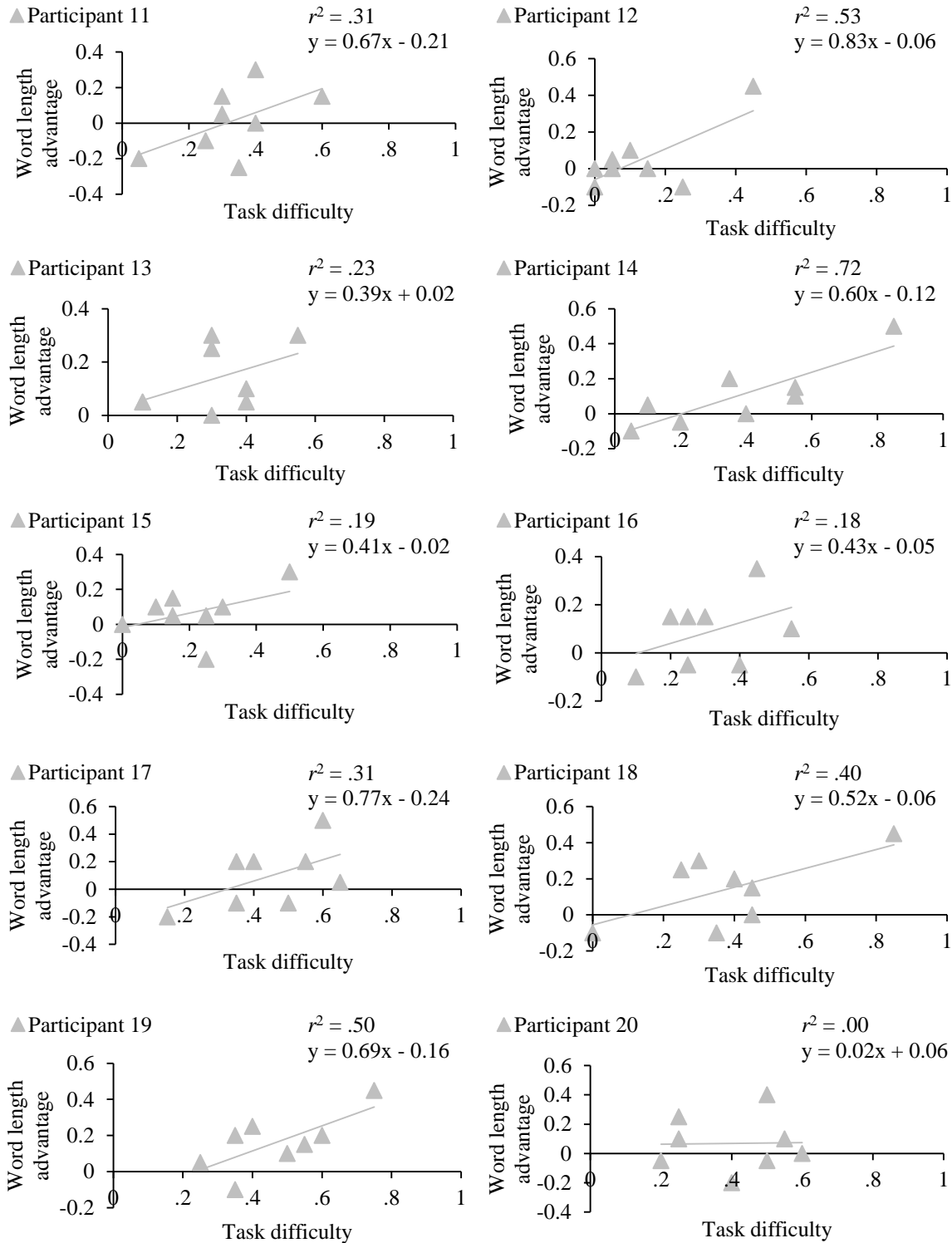


There appears to be a consistent redintegration effect across all participants. Four young adults demonstrated reasonably strong redintegration effects where  $r^2 > .70$  (Participants 3, 4, 8, and 13) whereas eight young adults demonstrated weak redintegration effects where  $r^2 < .30$

(Participants 1, 2, 6, 9, 10, 14, 17, and 18). The remaining eight participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 5, 7, 11, 12, 15, 16, 19, and 20).

**Appendix C – 2.8: Word length advantage as a function of task difficulty for item recall for each older adult**



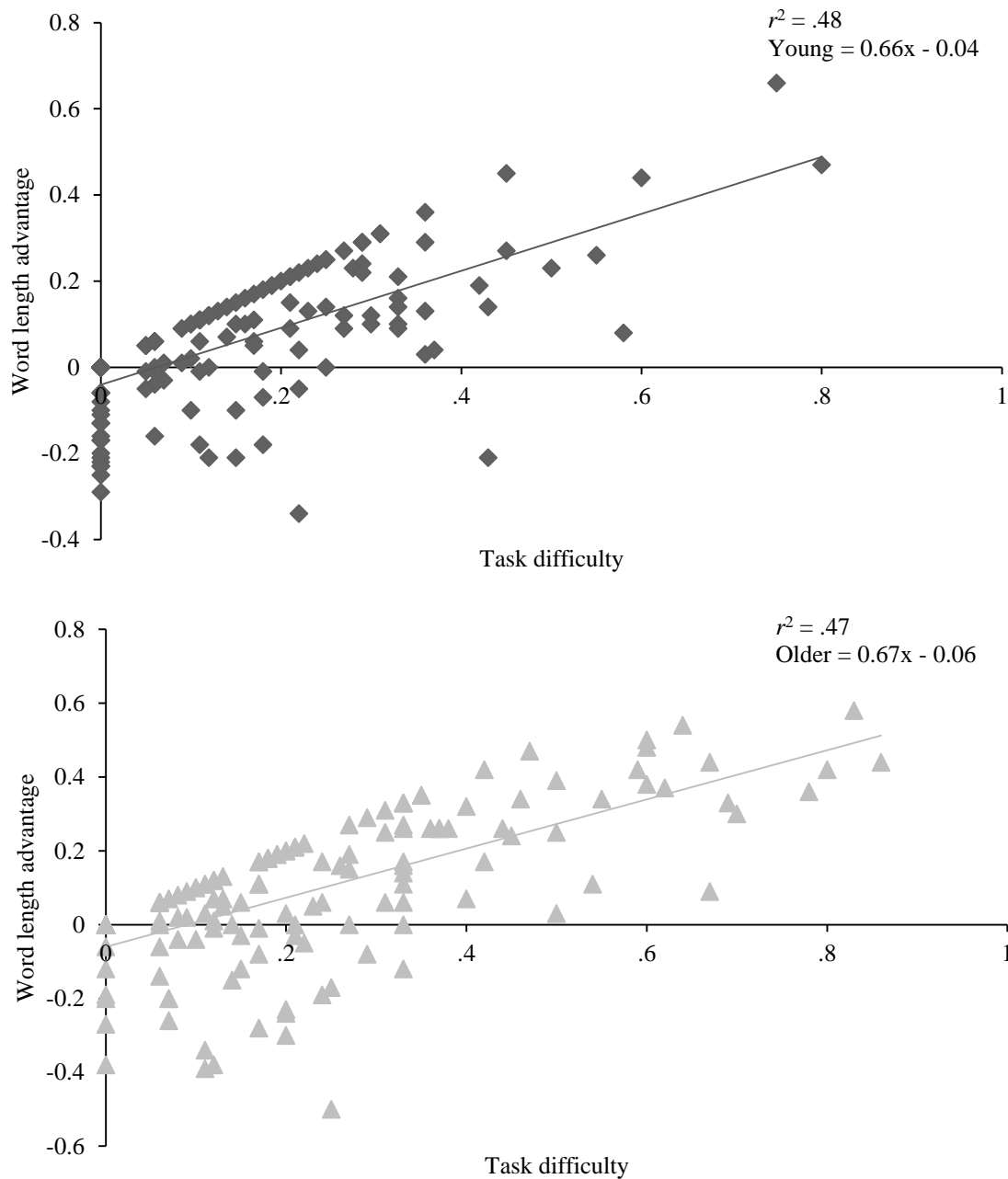


In contrast to the young adults, one older adult demonstrated a strong redintegration effect, where  $r^2 > .70$  (Participant 14) and two older adults demonstrated no redintegration effect, where  $r^2 = .00$  (Participants 1 and 20). Eight older adults demonstrated weak



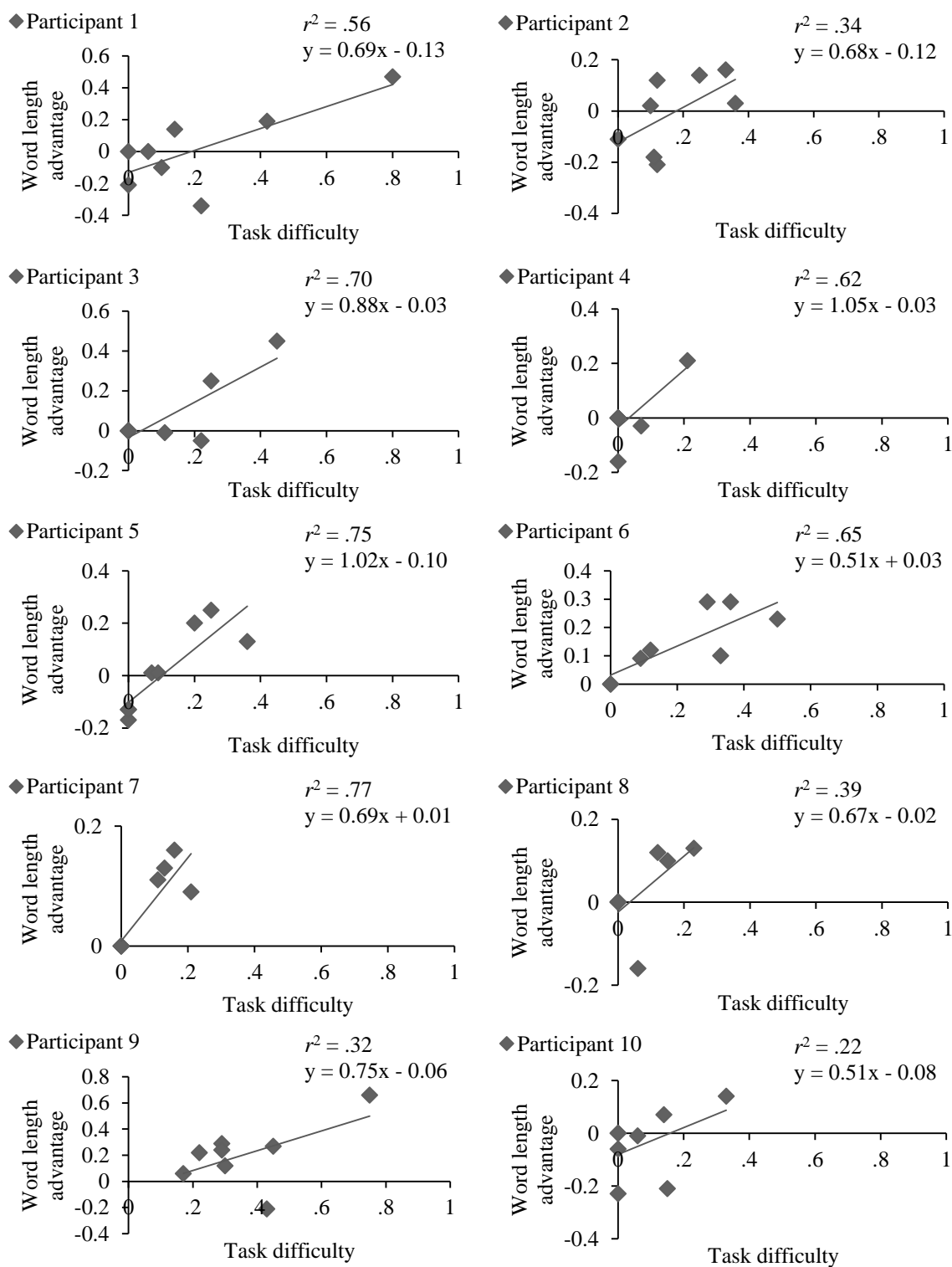
redintegration effects, where  $r^2 < .30$  (Participants 3, 4, 5, 6, 7, 13, 15, and 16). The remaining nine older adults demonstrated moderate redintegration effects, where  $r^2$  was between .30 and .70 (Participants 2, 8, 9, 10, 11, 12, 17, 18, and 19).

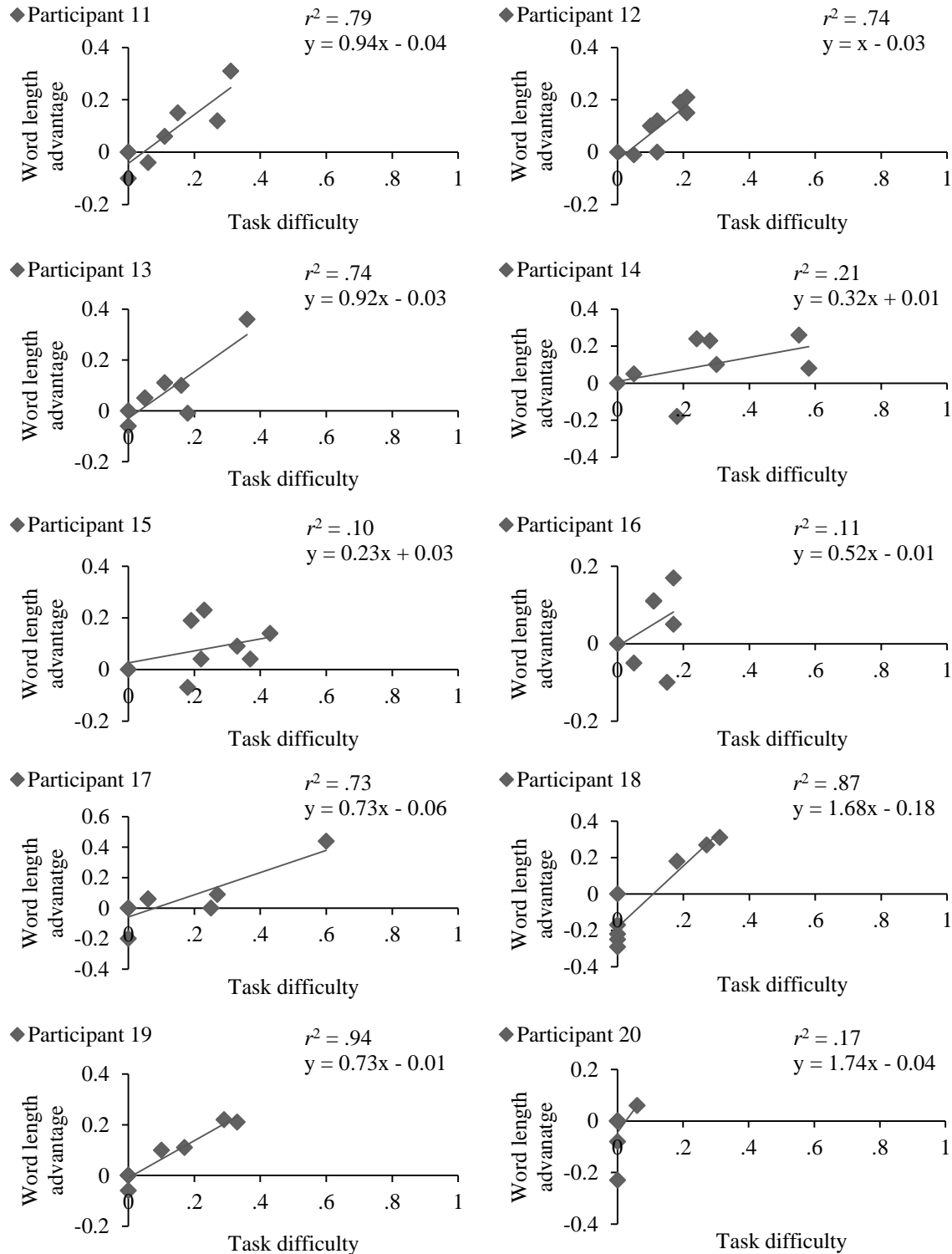
**Appendix C – 2.9: Word length advantage as a function of task difficulty for order accuracy across all young adults (upper graph) and all older adults (lower graph)**



Young adults and older adults, respectively, demonstrated moderately strong reintegration effects between the word length advantage and task difficulty (Upper graph for the young adults and lower graph for the older adults).

**Appendix C – 2.10: Word length advantage for order accuracy as a function of task difficulty for each young adult**

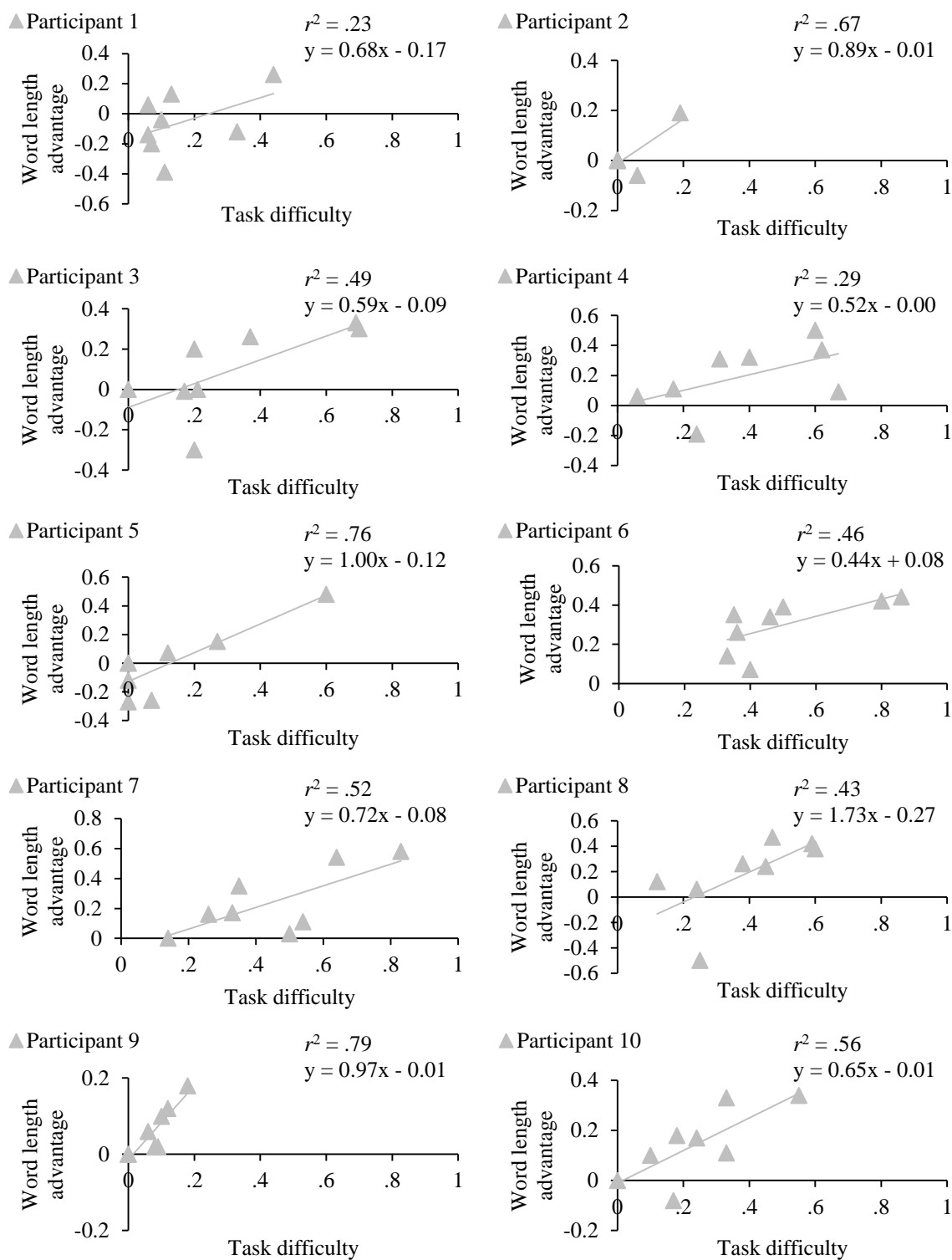


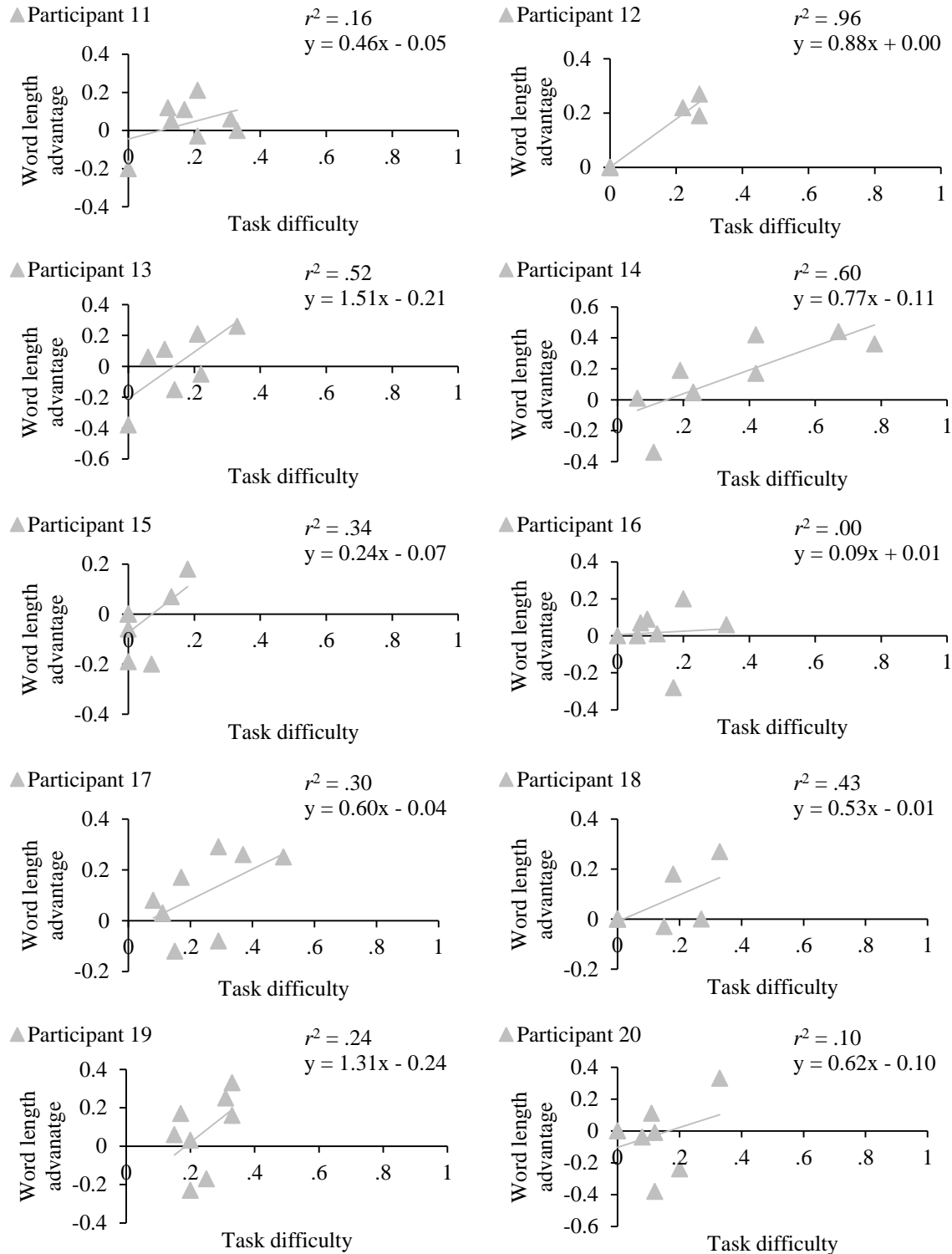


Redintegration effects were consistently moderate. Eight young adults demonstrated reasonably strong effects of redintegration where  $r^2 > .70$  (Participants 5, 7, 11, 12, 13, 17, 18, and 19) whereas five young adults demonstrated weak redintegration effects  $r^2 < .30$

(Participants 10, 14, 15, 16, and 20). The remaining seven participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 1, 2, 3, 4, 6, 8, and 9).

**Appendix C – 2.11: Word length advantage for order accuracy as a function of task difficulty for each older adult**





Similar to the young adults, patterns of order accuracy for the older adults indicated there was a moderate redintegration effect. While three older adults demonstrated reasonably strong effects of redintegration where  $r^2 > .70$  (Participants 5, 9 and 12), one older adult

demonstrated no redintegration effect, where  $r^2 = .00$  (Participants 16). Six older adults demonstrated weak redintegration effects, where  $r^2 < .30$  (Participants 1, 4, 11, 17, 19, and 20), the remaining 10 participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 2, 3, 6, 7, 8, 10, 13, 14, 15, and 18).



### **Appendix C – 3: Additional analyses for chapter seven (Word pairs)**

#### ***Appendix C – 3.1: Significant interactions***

##### ***Correct-in-position recall***

***Significant 2-way interaction.*** There was a significant 2-way interaction between word pair and recall interval,  $F(1, 38) = 6.74$ ,  $MSE = 0.15$ ,  $p = .013$ ,  $\eta_p^2 = .15$ , *observed power* = .72. Participants recalled a significantly a higher proportion of words in the associate pairs in serial position during immediate conditions ( $M = .93$ ,  $SD = .07$ ) compared with after a delayed interval ( $M = .74$ ,  $SD = .17$ ),  $F(1, 38) = 77.22$ ,  $p < .001$ ,  $\eta_p^2 = .67$ , *observed power* = 1.00. Participants recalled a significantly higher proportion of words in the non-associate pairs in serial position during immediate conditions ( $M = .85$ ,  $SD = .12$ ) compared with after a delayed interval ( $M = .60$ ,  $SD = .19$ ),  $F(1, 38) = 123.14$ ,  $p < .001$ ,  $\eta_p^2 = .76$ , *observed power* = 1.00.

In immediate conditions, participants recalled a significantly higher proportion of words in the associate pairs in serial position ( $M = .93$ ,  $SD = .07$ ) than non-associate pairs ( $M = .85$ ,  $SD = .12$ ),  $F(1, 38) = 45.10$ ,  $p < .001$ ,  $\eta_p^2 = .54$ , *observed power* = 1.00. In delayed conditions, participants recalled a significantly higher proportion of words in the associate pairs in serial position ( $M = .74$ ,  $SD = .17$ ) than non-associate pairs ( $M = .60$ ,  $SD = .19$ ),  $F(1, 38) = 66.09$ ,  $p < .001$ ,  $\eta_p^2 = .64$ , *observed power* = 1.00.

***Significant 3-way interactions.*** There was a significant 3-way interaction between recall interval, study condition, and age,  $F(1, 38) = 4.77$ ,  $MSE = 0.04$ ,  $p = .035$ ,  $\eta_p^2 = .11$ , *observed power* = .57. In immediate conditions, under silence, there was no significant difference in the proportion of words recalled in serial position between young ( $M = .91$ ,  $SD = .07$ ) and older adults ( $M = .88$ ,  $SD = .10$ ),  $F(1, 38) = 1.72$ ,  $p = .197$ ,  $\eta_p^2 = .04$ , *observed power* = .25. In immediate conditions, under irrelevant speech, young adults ( $M = .92$ ,  $SD = .09$ ) recalled a

significantly higher proportion of words in serial position compared with older adults ( $M = .85$ ,  $SD = .12$ ),  $F(1, 38) = 4.18$ ,  $p = .048$ ,  $\eta_p^2 = .10$ , *observed power* = .51. In delayed conditions, under silence, young adults ( $M = .72$ ,  $SD = .16$ ) recalled a significantly higher proportion of words in serial position compared with older adults ( $M = .61$ ,  $SD = .19$ ),  $F(1, 38) = 4.26$ ,  $p = .046$ ,  $\eta_p^2 = .10$ , *observed power* = .52. However, in delayed conditions, under irrelevant speech, there was no significant difference in the proportion of words recalled in serial position between young ( $M = .71$ ,  $SD = .14$ ) and older adults ( $M = .63$ ,  $SD = .20$ ),  $F(1, 38) = 2.22$ ,  $p = .145$ ,  $\eta_p^2 = .06$ , *observed power* = .31.

Young adults, under silence, recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .91$ ,  $SD = .07$ ) compared with after a delayed interval ( $M = .72$ ,  $SD = .16$ ),  $F(1, 38) = 45.92$ ,  $p < .001$ ,  $\eta_p^2 = .55$ , *observed power* = 1.00.

Young adults, under irrelevant speech, recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .92$ ,  $SD = .09$ ) compared with after a delayed interval ( $M = .71$ ,  $SD = .14$ ),  $F(1, 38) = 51.78$ ,  $p < .001$ ,  $\eta_p^2 = .28$ , *observed power* = 1.00.

Older adults, under silence, recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .88$ ,  $SD = .10$ ) compared with after a delayed interval ( $M = .61$ ,  $SD = .19$ ),  $F(1, 38) = 90.60$ ,  $p < .001$ ,  $\eta_p^2 = .71$ , *observed power* = 1.00.

Older adults, under irrelevant speech, recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .85$ ,  $SD = .12$ ) compared with after a delayed interval ( $M = .63$ ,  $SD = .20$ ),  $F(1, 38) = 58.98$ ,  $p < .001$ ,  $\eta_p^2 = .61$ , *observed power* = 1.00.

There was no significant difference in the proportion of words young adults recalled in serial position, during immediate conditions, under silence ( $M = .91$ ,  $SD = .07$ ) and irrelevant speech ( $M = .92$ ,  $SD = .09$ ),  $F(1, 38) = 0.13$ ,  $p = .723$ ,  $\eta_p^2 = .00$ , *observed power* = .06. There

was also no significant difference in the proportion of words young adults recalled in serial position, during delayed conditions, under silence ( $M = .72$ ,  $SD = .16$ ) and irrelevant speech ( $M = .71$ ,  $SD = .14$ ),  $F(1, 38) = 0.28$ ,  $p = .601$ ,  $\eta_p^2 = .01$ , *observed power* = .08. There was no significant difference in the proportion of words older adults recalled in serial position, during immediate conditions, under silence ( $M = .88$ ,  $SD = .10$ ) and irrelevant speech ( $M = .85$ ,  $SD = .12$ ),  $F(1, 38) = 4.04$ ,  $p = .052$ ,  $\eta_p^2 = .10$ , *observed power* = .50. Finally, there was no significant difference in the proportion of words older adults recalled in serial position, during delayed conditions, under silence ( $M = .61$ ,  $SD = .19$ ) and irrelevant speech ( $M = .63$ ,  $SD = .20$ ),  $F(1, 38) = 1.35$ ,  $p = .253$ ,  $\eta_p^2 = .03$ , *observed power* = .21.

There was a significant 3-way interaction between recall interval, presentation rate, and age,  $F(1, 38) = 4.61$ ,  $MSE = 0.07$ ,  $p = .038$ ,  $\eta_p^2 = .11$ , *observed power* = .55. In immediate conditions during the two-second presentation rate, young adults ( $M = .94$ ,  $SD = .07$ ) recalled a significantly higher proportion of words in serial position compared with older adults ( $M = .87$ ,  $SD = .11$ ),  $F(1, 38) = 5.42$ ,  $p = .025$ ,  $\eta_p^2 = .13$ , *observed power* = .62. In immediate conditions during the one-second presentation rate, young ( $M = .90$ ,  $SD = .09$ ) and older adults ( $M = .86$ ,  $SD = .11$ ) did not significantly differ in the proportion of words recalled in serial position,  $F(1, 38) = 1.34$ ,  $p = .255$ ,  $\eta_p^2 = .03$ , *observed power* = .20. In delayed conditions during the two-second presentation rate, there was no significant difference in the proportion of words recalled in serial position between young adults ( $M = .73$ ,  $SD = .15$ ) and older adults ( $M = .66$ ,  $SD = .19$ ),  $F(1, 38) = 1.61$ ,  $p = .212$ ,  $\eta_p^2 = .04$ , *observed power* = .24. In delayed conditions during the one-second presentation rate, young adults ( $M = .71$ ,  $SD = .15$ ) recalled a significantly higher proportion of words in serial position compared with older adults ( $M = .58$ ,  $SD = .21$ ),  $F(1, 38) = 4.87$ ,  $p = .033$ ,  $\eta_p^2 = .11$ , *observed power* = .58.

Young adults, during the two-second presentation rate, recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .94$ ,  $SD = .07$ ) than after a delayed interval ( $M = .73$ ,  $SD = .15$ ),  $F(1, 38) = 50.95$ ,  $p < .001$ ,  $\eta_p^2 = .57$ , *observed power* = 1.00. Young adults, under the one-second presentation rate, recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .90$ ,  $SD = .09$ ) than after a delayed interval ( $M = .71$ ,  $SD = .15$ ),  $F(1, 38) = 37.59$ ,  $p < .001$ ,  $\eta_p^2 = .50$ , *observed power* = 1.00. Older adults, under the two-second presentation rate, recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .87$ ,  $SD = .11$ ) than after a delayed interval ( $M = .66$ ,  $SD = .19$ ),  $F(1, 38) = 52.21$ ,  $p < .001$ ,  $\eta_p^2 = .58$ , *observed power* = 1.00. Older adults, under the one-second presentation rate, recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .86$ ,  $SD = .11$ ) than after a delayed interval ( $M = .58$ ,  $SD = .21$ ),  $F(1, 38) = 80.38$ ,  $p < .001$ ,  $\eta_p^2 = .68$ , *observed power* = 1.00.

Young adults, under immediate conditions, recalled a significantly higher proportion of words in serial position during the two-second presentation rate ( $M = .94$ ,  $SD = .07$ ) compared with the one-second presentation rate ( $M = .90$ ,  $SD = .09$ ),  $F(1, 38) = 8.79$ ,  $p = .005$ ,  $\eta_p^2 = .19$ , *observed power* = .82. However, there was no significant difference in the proportion of words young adults recalled in serial position, under delayed conditions, during the two-second ( $M = .73$ ,  $SD = .15$ ) and one-second presentation rates ( $M = .71$ ,  $SD = .15$ ),  $F(1, 38) = 1.41$ ,  $p = .243$ ,  $\eta_p^2 = .04$ , *observed power* = .21. There was no significant difference in the proportion of words older adults recalled in serial position, under immediate conditions, during the two-second ( $M = .87$ ,  $SD = .11$ ) and one-second presentation rates ( $M = .86$ ,  $SD = .11$ ),  $F(1, 38) = 0.48$ ,  $p = .491$ ,  $\eta_p^2 = .01$ , *observed power* = .10. Although, older adults, under delayed

conditions, recalled a significantly higher proportion of words in serial position during the two-second presentation rate ( $M = .66$ ,  $SD = .19$ ) compared with the one-second presentation rate ( $M = .58$ ,  $SD = .21$ ),  $F(1, 38) = 13.06$ ,  $p = .001$ ,  $\eta_p^2 = .26$ , *observed power* = .94.

### ***Item recall***

***Significant 2-way interaction.*** There was a significant 2-way interaction between word pair and recall interval,  $F(1, 38) = 19.77$ ,  $MSE = 0.22$ ,  $p < .001$ ,  $\eta_p^2 = .34$ , *observed power* = .99. Participants recalled a significantly higher proportion of words in the associate pairs during immediate conditions ( $M = .96$ ,  $SD = .05$ ) than after a delayed interval ( $M = .82$ ,  $SD = .13$ ),  $F(1, 38) = 74.10$ ,  $p < .001$ ,  $\eta_p^2 = .66$ , *observed power* = 1.00. Similarly, participants recalled a significantly higher proportion of words in the non-associate pairs during immediate conditions ( $M = .89$ ,  $SD = .09$ ) than after a delayed interval ( $M = .68$ ,  $SD = .17$ ),  $F(1, 38) = 121.70$ ,  $p < .001$ ,  $\eta_p^2 = .76$ , *observed power* = 1.00.

In immediate conditions, participants recalled a significantly higher proportion of words in the associate pairs ( $M = .96$ ,  $SD = .05$ ) compared with non-associate pairs ( $M = .89$ ,  $SD = .09$ ),  $F(1, 38) = 46.81$ ,  $p < .001$ ,  $\eta_p^2 = .55$ , *observed power* = 1.00. In delayed conditions, participants recalled a significantly higher proportion of words in the associate pairs ( $M = .82$ ,  $SD = .13$ ) compared with non-associate pairs ( $M = .68$ ,  $SD = .17$ ),  $F(1, 38) = 98.82$ ,  $p < .001$ ,  $\eta_p^2 = .72$ , *observed power* = 1.00.

***Significant 3-way interaction.*** There was a significant 3-way interaction between recall interval, presentation rate, and age,  $F(1, 38) = 8.10$ ,  $MSE = 0.11$ ,  $p = .007$ ,  $\eta_p^2 = .18$ , *observed power* = .79. In immediate conditions, under the two-second presentation rate, young adults ( $M = .96$ ,  $SD = .05$ ) recalled a significantly higher proportion of words compared with older

adults ( $M = .91$ ,  $SD = .08$ ),  $F(1, 38) = 5.88$ ,  $p = .020$ ,  $\eta_p^2 = .13$ , *observed power* = .66. In immediate conditions, under the one-second presentation rate, there was no significant difference in the proportion of words recalled between young ( $M = .93$ ,  $SD = .07$ ) and older adults ( $M = .91$ ,  $SD = .07$ ),  $F(1, 38) = 0.61$ ,  $p = .441$ ,  $\eta_p^2 = .02$ , *observed power* = .12. In delayed conditions, under the two-second presentation rate, there was no significant difference in the proportion of words recalled between young ( $M = .79$ ,  $SD = .13$ ) and older adults ( $M = .75$ ,  $SD = .15$ ),  $F(1, 38) = 0.88$ ,  $p = .354$ ,  $\eta_p^2 = .23$ , *observed power* = .15. In delayed conditions, under the one-second presentation rate, young adults ( $M = .78$ ,  $SD = .13$ ) recalled a significantly higher proportion of words compared with older adults, ( $M = .67$ ,  $SD = .18$ ),  $F(1, 38) = 5.20$ ,  $p = .028$ ,  $\eta_p^2 = .12$ , *observed power* = .60.

Young adults, under the two-second presentation rate, recalled a significantly higher proportion of words during immediate conditions ( $M = .96$ ,  $SD = .05$ ) compared with after a delayed interval ( $M = .79$ ,  $SD = .13$ ),  $F(1, 38) = 49.08$ ,  $p < .001$ ,  $\eta_p^2 = .56$ , *observed power* = 1.00. Young adults, under the one-second presentation rate, recalled a significantly higher proportion of words during immediate conditions ( $M = .93$ ,  $SD = .07$ ) compared with after a delayed interval ( $M = .78$ ,  $SD = .13$ ),  $F(1, 38) = 27.54$ ,  $p < .001$ ,  $\eta_p^2 = .42$ , *observed power* = 1.00. Older adults, under the two-second presentation rate, recalled a significantly higher proportion of words during immediate conditions ( $M = .91$ ,  $SD = .08$ ) compared with after a delayed interval ( $M = .75$ ,  $SD = .15$ ),  $F(1, 38) = 43.11$ ,  $p < .001$ ,  $\eta_p^2 = .53$ , *observed power* = 1.00. Finally, older adults, under the one-second presentation rate, recalled a significantly higher proportion of words during immediate conditions ( $M = .91$ ,  $SD = .07$ ) compared with after a delayed interval ( $M = .67$ ,  $SD = .18$ ),  $F(1, 38) = 74.54$ ,  $p < .001$ ,  $\eta_p^2 = .66$ , *observed power* = 1.00.

Young adults, under immediate conditions, recalled a significantly higher proportion of words during the two-second presentation rate ( $M = .96$ ,  $SD = .05$ ) compared with the one-second presentation rate ( $M = .93$ ,  $SD = .07$ ),  $F(1, 38) = 9.97$ ,  $p = .003$ ,  $\eta_p^2 = .21$ , *observed power* = .87. However, there was no significant difference in the proportion of words young adults recalled, under delayed conditions, during the two-second ( $M = .79$ ,  $SD = .13$ ) and one-second presentation rates ( $M = .78$ ,  $SD = .13$ ),  $F(1, 38) = 0.21$ ,  $p = .649$ ,  $\eta_p^2 = .01$ , *observed power* = .07. There was no significant difference in the proportion of words older adults recalled, under immediate conditions, during the two-second ( $M = .91$ ,  $SD = .08$ ) and one-second presentation rates ( $M = .91$ ,  $SD = .07$ ),  $F(1, 38) = 0.00$ ,  $p = .953$ ,  $\eta_p^2 = .00$ , *observed power* = .05. Finally, older adults, under delayed conditions, recalled a significantly higher proportion of words during the two-second presentation rate ( $M = .75$ ,  $SD = .15$ ) compared with the one-second presentation rate ( $M = .67$ ,  $SD = .18$ ),  $F(1, 38) = 15.09$ ,  $p < .001$ ,  $\eta_p^2 = .28$ , *observed power* = .97.

### ***Order accuracy***

***Significant 2-way interaction.*** There was a significant 2-way interaction between recall interval and study condition,  $F(1, 38) = 6.80$ ,  $MSE = 0.06$ ,  $p = .013$ ,  $\eta_p^2 = .15$ , *observed power* = .72. For words that were immediately recalled, order accuracy was significantly higher during the silence conditions ( $M = .97$ ,  $SD = .03$ ) than the irrelevant speech conditions ( $M = .95$ ,  $SD = .06$ ),  $F(1, 38) = 6.13$ ,  $p = .018$ ,  $\eta_p^2 = .14$ , *observed power* = .68. For words recalled after a delayed interval, there was no significant difference in order accuracy during silence ( $M = .87$ ,  $SD = .10$ ) and irrelevant speech ( $M = .89$ ,  $SD = .08$ ),  $F(1, 38) = 2.79$ ,  $p = .103$ ,  $\eta_p^2 = .07$ , *observed power* = .37.

For silence conditions, order accuracy was significantly higher during immediate recall ( $M = .97$ ,  $SD = .03$ ) compared with after a delayed interval ( $M = .87$ ,  $SD = .10$ ),  $F(1, 38) = 45.55$ ,  $p < .001$ ,  $\eta_p^2 = .55$ , *observed power* = 1.00. For irrelevant speech conditions, order accuracy was significantly higher during immediate recall ( $M = .95$ ,  $SD = .06$ ) compared with after a delayed interval ( $M = .89$ ,  $SD = .08$ ),  $F(1, 38) = 28.42$ ,  $p < .001$ ,  $\eta_p^2 = .43$ , *observed power* = 1.00.

### ***Transposition errors***

***Significant 2-way interaction.*** There was a significant 2-way interaction between recall interval and study condition,  $F(1, 38) = 12.36$ ,  $MSE = 0.04$ ,  $p = .001$ ,  $\eta_p^2 = .25$ , *observed power* = .93. In immediate recall conditions, participants produced a significantly higher proportion of transposition errors when words were presented in the irrelevant speech conditions ( $M = .04$ ,  $SD = .06$ ) compared with the silence conditions ( $M = .02$ ,  $SD = .02$ ).  $F(1, 38) = 8.32$ ,  $p = .006$ ,  $\eta_p^2 = .18$ , *observed power* = .80. In delayed recall conditions, participants produced a significantly higher proportion of transposition errors when words were presented in the silence conditions ( $M = .06$ ,  $SD = .03$ ) compared with the irrelevant speech conditions ( $M = .04$ ,  $SD = .03$ ),  $F(1, 38) = 6.42$ ,  $p = .016$ ,  $\eta_p^2 = .14$ , *observed power* = .69.

In silence conditions, participants produced a significantly higher proportion of transposition errors after a delayed interval ( $M = .06$ ,  $SD = .03$ ) compared with immediate recall ( $M = .02$ ,  $SD = .02$ ),  $F(1, 38) = 21.37$ ,  $p < .001$ ,  $\eta_p^2 = .36$ , *observed power* = 1.00. In irrelevant speech conditions, there was no significant difference in the proportion of transposition errors participants produced during immediate recall ( $M = .04$ ,  $SD = .06$ ) and after a delayed interval ( $M = .04$ ,  $SD = .03$ ),  $F(1, 38) = 0.15$ ,  $p = .700$ ,  $\eta_p^2 = .00$ , *observed power* = .07.



### ***Omission errors***

***Significant 2-way interaction.*** There was a significant 2-way interaction between word pair and recall interval,  $F(1, 38) = 19.18$ ,  $MSE = 0.21$ ,  $p < .001$ ,  $\eta_p^2 = .34$ , *observed power* = .99. Participants omitted a significantly higher proportion of words in the associate pairs after a delayed interval ( $M = .14$ ,  $SD = .11$ ) compared with immediate recall conditions ( $M = .03$ ,  $SD = .03$ ),  $F(1, 38) = 53.91$ ,  $p < .001$ ,  $\eta_p^2 = .59$ , *observed power* = 1.00. Participants omitted a significantly higher proportion of words in the non-associate pairs after a delayed interval ( $M = .25$ ,  $SD = .16$ ) compared with immediate recall conditions ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 84.78$ ,  $p < .001$ ,  $\eta_p^2 = .69$ , *observed power* = 1.00.

Participants, under immediate recall conditions, omitted a significantly higher proportion of words in the non-associate pairs ( $M = .07$ ,  $SD = .07$ ) compared with the associate pairs ( $M = .03$ ,  $SD = .03$ ),  $F(1, 38) = 24.41$ ,  $p < .001$ ,  $\eta_p^2 = .39$ , *observed power* = 1.00. Participants, under delayed recall conditions, omitted a significantly higher proportion of words in the non-associate pairs ( $M = .25$ ,  $SD = .16$ ) compared with associate pairs ( $M = .14$ ,  $SD = .11$ ),  $F(1, 38) = 59.55$ ,  $p < .001$ ,  $\eta_p^2 = .61$ , *observed power* = 1.00.

***Significant 3-way interactions.*** There was a significant 3-way interaction between recall interval, presentation rate, and age,  $F(1, 38) = 4.98$ ,  $MSE = 0.06$ ,  $p = .032$ ,  $\eta_p^2 = .12$ , *observed power* = .59. In immediate recall conditions, during the two-second presentation rate, older adults ( $M = .06$ ,  $SD = .06$ ) omitted a significantly higher proportion of words compared with young adults ( $M = .03$ ,  $SD = .04$ ),  $F(1, 38) = 4.32$ ,  $p = .044$ ,  $\eta_p^2 = .10$ , *observed power* = .53. In immediate recall conditions, during the one-second presentation rate, young ( $M = .04$ ,  $SD = .04$ ) and older adults ( $M = .05$ ,  $SD = .05$ ) did not significantly differ in the proportion of words they omitted,  $F(1, 38) = 0.38$ ,  $p = .544$ ,  $\eta_p^2 = .01$ , *observed power* = .09. In delayed recall

conditions, during the two-second presentation rate, young ( $M = .15$ ,  $SD = .10$ ) and older adults ( $M = .19$ ,  $SD = .13$ ) did not significantly differ in the proportion of words they omitted,  $F(1, 38) = 1.52$ ,  $p = .225$ ,  $\eta_p^2 = .04$ , *observed power* = .23. In delayed recall conditions, during the one-second presentation rate, older adults ( $M = .26$ ,  $SD = .17$ ) omitted a significantly higher proportion of words compared with young adults ( $M = .16$ ,  $SD = .12$ ),  $F(1, 38) = 4.51$ ,  $p = .040$ ,  $\eta_p^2 = .11$ , *observed power* = .54.

Young adults, under the two-second presentation rate, omitted a significantly higher proportion of words after a delayed interval ( $M = .15$ ,  $SD = .10$ ) compared with immediate recall conditions ( $M = .03$ ,  $SD = .04$ ),  $F(1, 38) = 29.27$ ,  $p < .001$ ,  $\eta_p^2 = .44$ , *observed power* = 1.00. Young adults, under the one-second presentation rate, omitted a significantly higher proportion of words after a delayed interval ( $M = .16$ ,  $SD = .12$ ) compared with immediate recall conditions ( $M = .04$ ,  $SD = .04$ ),  $F(1, 38) = 18.82$ ,  $p < .001$ ,  $\eta_p^2 = .33$ , *observed power* = .99. Older adults, under the two-second presentation rate, omitted a significantly higher proportion of words after a delayed interval ( $M = .19$ ,  $SD = .13$ ) compared with immediate recall conditions ( $M = .06$ ,  $SD = .06$ ),  $F(1, 38) = 35.29$ ,  $p < .001$ ,  $\eta_p^2 = .48$ , *observed power* = 1.00. Older adults, under the one-second presentation rate, omitted a significantly higher proportion of words after a delayed interval ( $M = .26$ ,  $SD = .17$ ) compared with immediate recall conditions ( $M = .05$ ,  $SD = .05$ ),  $F(1, 38) = 57.99$ ,  $p < .001$ ,  $\eta_p^2 = .60$ , *observed power* = 1.00.

There was no significant difference in the proportion of words young adults omitted, under immediate recall conditions, during the two-second ( $M = .03$ ,  $SD = .04$ ) and one-second presentation rates ( $M = .04$ ,  $SD = .04$ ),  $F(1, 38) = 2.68$ ,  $p = .110$ ,  $\eta_p^2 = .07$ , *observed power* = .36. There was also no significant difference in the proportion of words young adults omitted,

under delayed recall conditions, during the two-second ( $M = .15$ ,  $SD = .10$ ) and one-second presentation rates ( $M = .16$ ,  $SD = .12$ ),  $F(1, 38) = 0.41$ ,  $p = .528$ ,  $\eta_p^2 = .01$ , *observed power* = .10. There was no significant difference in the proportion of words older adults omitted, under immediate recall conditions, during the two-second ( $M = .06$ ,  $SD = .06$ ) and one-second presentation rates ( $M = .05$ ,  $SD = .05$ ),  $F(1, 38) = 0.67$ ,  $p = .418$ ,  $\eta_p^2 = .02$ , *observed power* = .13. However, older adults omitted a significantly higher proportion of words, under delayed recall conditions, during the one-second presentation rate ( $M = .26$ ,  $SD = .17$ ) compared with the two-second presentation rate ( $M = .19$ ,  $SD = .13$ ),  $F(1, 38) = 10.96$ ,  $p = .002$ ,  $\eta_p^2 = .22$ , *observed power* = .90.

There was a significant 3-way interaction between word pair, study condition, and presentation rate,  $F(1, 38) = 4.14$ ,  $MSE = 0.02$ ,  $p = .049$ ,  $\eta_p^2 = .10$ , *observed power* = .51. When words in the associate pairs were presented under the silence conditions, participants omitted a significantly higher proportion of words during the one-second presentation rate ( $M = .09$ ,  $SD = .08$ ) compared with the two-second presentation rate ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 6.38$ ,  $p = .016$ ,  $\eta_p^2 = .14$ , *observed power* = .70. When words in the associate word pairs were presented under the irrelevant speech conditions, there was no significant difference in the proportion of words participants omitted during the one-second ( $M = .08$ ,  $SD = .09$ ) and two-second presentation rates ( $M = .08$ ,  $SD = .08$ ),  $F(1, 38) = 0.19$ ,  $p = .665$ ,  $\eta_p^2 = .01$ , *observed power* = .07. When words in the non-associate pairs were presented under the silence conditions, there was no significant difference in the proportion of words participants omitted during the one-second ( $M = .17$ ,  $SD = .14$ ) and two-second presentation rates ( $M = .15$ ,  $SD = .11$ ),  $F(1, 38) = 2.80$ ,  $p = .102$ ,  $\eta_p^2 = .07$ , *observed power* = .37. When words in the non-associate word pairs were presented under the irrelevant speech conditions, participants

omitted a significantly higher proportion of words during the one-second presentation rate ( $M = .18$ ,  $SD = .12$ ) compared with the two-second presentation rate ( $M = .14$ ,  $SD = .10$ ),  $F(1, 38) = 6.43$ ,  $p = .015$ ,  $\eta_p^2 = .15$ , *observed power* = .70.

In silence conditions, during the two-second presentation rate, participants omitted a significantly higher proportion of words in the non-associate pairs ( $M = .15$ ,  $SD = .11$ ) compared with associate pairs ( $M = .07$ ,  $SD = .07$ ),  $F(1, 38) = 31.23$ ,  $p < .001$ ,  $\eta_p^2 = .45$ , *observed power* = 1.00. In silence conditions, during the one-second presentation rate, participants omitted a significantly higher proportion of words in the non-associate pairs ( $M = .17$ ,  $SD = .14$ ) compared with associate pairs ( $M = .09$ ,  $SD = .08$ ),  $F(1, 38) = 25.77$ ,  $p < .001$ ,  $\eta_p^2 = .40$ , *observed power* = 1.00. In irrelevant speech conditions, during the two-second presentation rate, participants omitted a significantly higher proportion of words in the non-associate pairs ( $M = .14$ ,  $SD = .10$ ) compared with associate pairs ( $M = .08$ ,  $SD = .08$ ),  $F(1, 38) = 16.37$ ,  $p < .001$ ,  $\eta_p^2 = .30$ , *observed power* = .98. In irrelevant speech conditions, during the one-second presentation rate, participants omitted a significantly higher proportion of words in the non-associate pairs ( $M = .18$ ,  $SD = .12$ ) compared with associate pairs ( $M = .08$ ,  $SD = .09$ ),  $F(1, 38) = 47.57$ ,  $p < .001$ ,  $\eta_p^2 = .56$ , *observed power* = 1.00.

There was no significant difference in the proportion of words in the associate pairs participants omitted, during the two-second presentation rate, under silence ( $M = .07$ ,  $SD = .07$ ) and irrelevant speech ( $M = .08$ ,  $SD = .08$ ),  $F(1, 38) = 1.87$ ,  $p = .179$ ,  $\eta_p^2 = .05$ , *observed power* = .27. Similarly, there was no significant difference in the proportion of words in the associate pairs participants omitted, during the one-second presentation rate, under silence ( $M = .09$ ,  $SD = .08$ ) and irrelevant speech ( $M = .08$ ,  $SD = .09$ ),  $F(1, 38) = 1.63$ ,  $p = .210$ ,  $\eta_p^2 = .04$ , *observed power* = .24. There was no significant difference in the proportion of words in the

non-associate pairs participants omitted, during the two-second presentation rate, under silence ( $M = .15$ ,  $SD = .11$ ) and irrelevant speech ( $M = .14$ ,  $SD = .10$ ),  $F(1, 38) = 0.20$ ,  $p = .659$ ,  $\eta_p^2 = .01$ , *observed power* = .07. Finally, there was no significant difference in the proportion of words in the non-associate pairs participants omitted, during the one-second presentation rate, under silence ( $M = .17$ ,  $SD = .14$ ) and irrelevant speech ( $M = .18$ ,  $SD = .12$ ),  $F(1, 38) = 0.27$ ,  $p = .605$ ,  $\eta_p^2 = .01$ , *observed power* = .08.

### **Appendix C – 3.2: Non-significant interactions**

#### **Correct-in-position recall**

**Non-significant main effects.** The remaining main effects were not significant main: study condition,  $F(1, 38) = 0.12$ ,  $MSE = 0.00$ ,  $p = .735$ ,  $\eta_p^2 = .00$ , *observed power* = .06; and age,  $F(1, 38) = 3.74$ ,  $MSE = 0.88$ ,  $p = .061$ ,  $\eta_p^2 = .09$ , *observed power* = .47.

**Non-significant 2-way interactions.** The remaining 2-way interactions were not significant: word pair and age,  $F(1, 38) = 0.47$ ,  $MSE = 0.01$ ,  $p = .499$ ,  $\eta_p^2 = .01$ , *observed power* = .10; recall interval and age,  $F(1, 38) = 1.48$ ,  $MSE = 0.08$ ,  $p = .231$ ,  $\eta_p^2 = .04$ , *observed power* = .22; study condition and age,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .929$ ,  $\eta_p^2 = .00$ , *observed power* = .05; presentation rate and age,  $F(1, 38) = 0.50$ ,  $MSE = 0.01$ ,  $p = .484$ ,  $\eta_p^2 = .01$ , *observed power* = .11; word pair and study condition,  $F(1, 38) = 0.03$ ,  $MSE = 0.00$ ,  $p = .870$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval and study condition,  $F(1, 38) = 1.41$ ,  $MSE = 0.01$ ,  $p = .242$ ,  $\eta_p^2 = .04$ , *observed power* = .21; word pair and presentation rate,  $F(1, 38) = 1.95$ ,  $MSE = 0.02$ ,  $p = .171$ ,  $\eta_p^2 = .05$ , *observed power* = .28; recall interval and presentation rate,  $F(1, 38) = 2.22$ ,  $MSE = 0.04$ ,  $p = .145$ ,  $\eta_p^2 = .06$ , *observed power* = .31; and between study condition and presentation rate,  $F(1, 38) = 0.36$ ,  $MSE = 0.00$ ,  $p = .550$ ,  $\eta_p^2 = .01$ , *observed power* = .09.

**Non-significant 3-way interactions.** The remaining 3-way interactions were not significant: word pair, recall interval, and age,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .990$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word pair, study condition, and age,  $F(1, 38) = 0.05$ ,  $MSE = 0.00$ ,  $p = .824$ ,  $\eta_p^2 = .00$ , *observed power* = .06; word pair, recall interval, and study condition,  $F(1, 38) = 0.63$ ,  $MSE = 0.01$ ,  $p = .433$ ,  $\eta_p^2 = .02$ , *observed power* = .12; word pair, presentation rate, and age,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .986$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word

pair, recall interval, and presentation rate,  $F(1, 38) = 0.67$ ,  $MSE = 0.01$ ,  $p = .408$ ,  $\eta_p^2 = .02$ , *observed power* = .13; study condition, presentation rate, and age,  $F(1, 38) = 0.18$ ,  $MSE = 0.00$ ,  $p = .677$ ,  $\eta_p^2 = .01$ , *observed power* = .07; word pair, study condition, and presentation rate,  $F(1, 38) = 0.03$ ,  $MSE = 0.00$ ,  $p = .874$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 1.27$ ,  $MSE = 0.02$ ,  $p = .268$ ,  $\eta_p^2 = .03$ , *observed power* = .20.

***Non-significant 4-way interactions.*** All 4-way interactions were not significant: word pair, recall interval, study condition, and age,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .987$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word pair, recall interval, presentation rate, and age,  $F(1, 38) = 2.03$ ,  $MSE = 0.02$ ,  $p = .163$ ,  $\eta_p^2 = .05$ , *observed power* = .28; word pair, study condition, presentation rate, and age,  $F(1, 38) = 2.35$ ,  $MSE = 0.02$ ,  $p = .134$ ,  $\eta_p^2 = .06$ , *observed power* = .32; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 1.52$ ,  $MSE = 0.02$ ,  $p = .226$ ,  $\eta_p^2 = .04$ , *observed power* = .23; and between word pair, recall interval, study condition, and presentation rate,  $F(1, 38) = 2.70$ ,  $MSE = 0.04$ ,  $p = .109$ ,  $\eta_p^2 = .07$ , *observed power* = .36.

***Non-significant 5-way interaction.*** The 5-way interaction between word pair, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.09$ ,  $MSE = 0.00$ ,  $p = .770$ ,  $\eta_p^2 = .00$ , *observed power* = .06.

### ***Item recall***

***Non-significant main effects.*** The remaining main effects were not significant: study condition,  $F(1, 38) = 0.07$ ,  $MSE = 0.00$ ,  $p = .799$ ,  $\eta_p^2 = .00$ , *observed power* = .06; and age,  $F(1, 38) = 3.29$ ,  $MSE = 0.50$ ,  $p = .078$ ,  $\eta_p^2 = .08$ , *observed power* = .42.

**Non-significant 2-way interactions.** The remaining 2-way interactions were not significant: word pair and age,  $F(1, 38) = 0.29$ ,  $MSE = 0.00$ ,  $p = .592$ ,  $\eta_p^2 = .01$ , *observed power* = .08; recall interval and age,  $F(1, 38) = 1.69$ ,  $MSE = 0.07$ ,  $p = .202$ ,  $\eta_p^2 = .04$ , *observed power* = .24; study condition and age,  $F(1, 38) = 0.84$ ,  $MSE = 0.01$ ,  $p = .365$ ,  $\eta_p^2 = .02$ , *observed power* = .15; presentation rate and age,  $F(1, 38) = 1.61$ ,  $MSE = 0.01$ ,  $p = .212$ ,  $\eta_p^2 = .04$ , *observed power* = .24; word pair and study condition,  $F(1, 38) = 0.80$ ,  $MSE = 0.01$ ,  $p = .378$ ,  $\eta_p^2 = .02$ , *observed power* = .14; recall interval and study condition,  $F(1, 38) = 0.81$ ,  $MSE = 0.01$ ,  $p = .373$ ,  $\eta_p^2 = .02$ , *observed power* = .14; word pair and presentation rate,  $F(1, 38) = 3.52$ ,  $MSE = 0.03$ ,  $p = .068$ ,  $\eta_p^2 = .09$ , *observed power* = .45; recall interval and presentation rate,  $F(1, 38) = 2.17$ ,  $MSE = 0.03$ ,  $p = .149$ ,  $\eta_p^2 = .05$ , *observed power* = .30; and between study condition and presentation rate,  $F(1, 38) = 1.41$ ,  $MSE = 0.01$ ,  $p = .243$ ,  $\eta_p^2 = .04$ , *observed power* = .21.

**Non-significant 3-way interactions.** The remaining 3-way interactions were not significant: word pair, recall interval, and age,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .970$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word pair, study condition, and age,  $F(1, 38) = 0.66$ ,  $MSE = 0.01$ ,  $p = .423$ ,  $\eta_p^2 = .02$ , *observed power* = .12; recall interval, study condition, and age,  $F(1, 38) = 0.81$ ,  $MSE = 0.01$ ,  $p = .373$ ,  $\eta_p^2 = .02$ , *observed power* = .14; word pair, recall interval, and study condition,  $F(1, 38) = 0.64$ ,  $MSE = 0.01$ ,  $p = .428$ ,  $\eta_p^2 = .02$ , *observed power* = .12; word pair, presentation rate, and age,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = 1.00$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word pair, recall interval, and presentation rate,  $F(1, 38) = 1.06$ ,  $MSE = 0.01$ ,  $p = .309$ ,  $\eta_p^2 = .03$ , *observed power* = .17; study condition, presentation rate, and age,  $F(1, 38) = 0.24$ ,  $MSE = 0.00$ ,  $p = .624$ ,  $\eta_p^2 = .01$ , *observed power* = .08; word pair, study condition, and presentation rate,  $F(1, 38) = 1.22$ ,  $MSE = 0.01$ ,  $p = .276$ ,  $\eta_p^2 = .03$ , *observed power* = .19; and



between recall interval, study condition, and presentation rate,  $F(1, 38) = 1.01$ ,  $MSE = 0.01$ ,  $p = .323$ ,  $\eta_p^2 = .03$ , *observed power* = .16.

***Non-significant 4-way interactions.*** All 4-way interactions were not significant: word pair, recall interval, study condition, and age,  $F(1, 38) = 0.23$ ,  $MSE = 0.00$ ,  $p = .633$ ,  $\eta_p^2 = .01$ , *observed power* = .08; word pair, study condition, presentation rate, and age,  $F(1, 38) = 0.47$ ,  $MSE = 0.00$ ,  $p = .498$ ,  $\eta_p^2 = .01$ , *observed power* = .10; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 1.01$ ,  $MSE = 0.01$ ,  $p = .323$ ,  $\eta_p^2 = .03$ , *observed power* = .16; and between word pair, recall interval, study condition, and presentation rate,  $F(1, 38) = 3.98$ ,  $MSE = 0.04$ ,  $p = .053$ ,  $\eta_p^2 = .10$ , *observed power* = .49.

***Non-significant 5-way interaction.*** The 5-way interaction between word pair, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .970$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

### ***Order accuracy***

***Non-significant main effect.*** The remaining main effect was not significant: study condition,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .985$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

***Non-significant 2-way interactions.*** The remaining 2-way interactions were not significant: word pair and age,  $F(1, 38) = 1.90$ ,  $MSE = 0.02$ ,  $p = .176$ ,  $\eta_p^2 = .05$ , *observed power* = .27; recall interval and age,  $F(1, 38) = 2.52$ ,  $MSE = 0.05$ ,  $p = .121$ ,  $\eta_p^2 = .06$ , *observed power* = .34; study condition and age,  $F(1, 38) = 2.89$ ,  $MSE = 0.02$ ,  $p = .097$ ,  $\eta_p^2 = .07$ , *observed power* = .38; presentation rate and age,  $F(1, 38) = 0.08$ ,  $MSE = 0.00$ ,  $p = .773$ ,  $\eta_p^2 = .00$ , *observed power* = .06; word pair and recall interval,  $F(1, 38) = 0.58$ ,  $MSE = 0.01$ ,  $p = .452$ ,  $\eta_p^2 = .02$ , *observed power* = .12; word pair and study condition,  $F(1, 38) = 0.43$ ,  $MSE =$

0.01,  $p = .515$ ,  $\eta_p^2 = .01$ , *observed power* = .10; word pair and presentation rate,  $F(1, 38) = 0.50$ ,  $MSE = 0.00$ ,  $p = .484$ ,  $\eta_p^2 = .01$ , *observed power* = .11; word pair and presentation rate,  $F(1, 38) = 0.50$ ,  $MSE = 0.00$ ,  $p = .484$ ,  $\eta_p^2 = .01$ , *observed power* = .11; recall interval and presentation rate,  $F(1, 38) = 0.97$ ,  $MSE = 0.01$ ,  $p = .330$ ,  $\eta_p^2 = .03$ , *observed power* = .16; and between study condition and presentation rate,  $F(1, 38) = 0.04$ ,  $MSE = 0.00$ ,  $p = .851$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

***Non-significant 3-way interactions.*** All 3-way interactions were not significant: word pair, recall interval, and age,  $F(1, 38) = 0.60$ ,  $MSE = 0.01$ ,  $p = .442$ ,  $\eta_p^2 = .02$ , *observed power* = .12; word pair, study condition, and age,  $F(1, 38) = 2.05$ ,  $MSE = 0.02$ ,  $p = .160$ ,  $\eta_p^2 = .05$ , *observed power* = .29; word pair, recall interval, and study condition,  $F(1, 38) = 0.02$ ,  $MSE = 0.00$ ,  $p = .896$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word pair, presentation rate, and age,  $F(1, 38) = 0.60$ ,  $MSE = 0.01$ ,  $p = .444$ ,  $\eta_p^2 = .02$ , *observed power* = .12; recall interval, presentation rate, and age,  $F(1, 38) = 0.02$ ,  $MSE = 0.00$ ,  $p = .892$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word pair, recall interval, and presentation rate,  $F(1, 38) = 0.24$ ,  $MSE = 0.00$ ,  $p = .625$ ,  $\eta_p^2 = .01$ , *observed power* = .08; study condition, presentation rate, and age,  $F(1, 38) = 0.19$ ,  $MSE = 0.00$ ,  $p = .666$ ,  $\eta_p^2 = .01$ , *observed power* = .07; word pair, study condition, and presentation rate,  $F(1, 38) = 2.21$ ,  $MSE = 0.02$ ,  $p = .146$ ,  $\eta_p^2 = .06$ , *observed power* = .20; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 1.04$ ,  $MSE = 0.01$ ,  $p = .315$ ,  $\eta_p^2 = .03$ , *observed power* = .17.

***Non-significant 4-way interactions.*** All 4-way interactions were not significant: word pair, recall interval, study condition, and age,  $F(1, 38) = 0.41$ ,  $MSE = 0.00$ ,  $p = .527$ ,  $\eta_p^2 = .01$ , *observed power* = .10; word pair, study condition, presentation rate, and age,  $F(1, 38) = 0.42$ ,  $MSE = 0.00$ ,  $p = .521$ ,  $\eta_p^2 = .01$ , *observed power* = .10; recall interval, study condition,

presentation rate, and age,  $F(1, 38) = 1.38$ ,  $MSE = 0.01$ ,  $p = .247$ ,  $\eta_p^2 = .04$ , *observed power* = .21; and between word pair, recall interval, study condition, and presentation rate,  $F(1, 38) = 0.46$ ,  $MSE = 0.00$ ,  $p = .503$ ,  $\eta_p^2 = .01$ , *observed power* = .10.

***Non-significant 5-way interaction.*** The 5-way interaction between word pair, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .951$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

### ***Transposition errors***

***Non-significant main effects.*** The remaining main effects were not significant: study condition,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .968$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and presentation rate,  $F(1, 38) = 1.23$ ,  $MSE = 0.00$ ,  $p = .274$ ,  $\eta_p^2 = .03$ , *observed power* = .19.

***Non-significant 2-way interactions.*** The remaining 2-way interactions were not significant: word pair and age,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .929$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval and age,  $F(1, 38) = 1.19$ ,  $MSE = 0.01$ ,  $p = .282$ ,  $\eta_p^2 = .03$ , *observed power* = .19; study condition and age,  $F(1, 38) = 2.68$ ,  $MSE = 0.01$ ,  $p = .110$ ,  $\eta_p^2 = .07$ , *observed power* = .36; presentation rate and age,  $F(1, 38) = 1.07$ ,  $MSE = 0.00$ ,  $p = .308$ ,  $\eta_p^2 = .03$ , *observed power* = .17; word pair and recall interval,  $F(1, 38) = 0.15$ ,  $MSE = 0.00$ ,  $p = .697$ ,  $\eta_p^2 = .00$ , *observed power* = .07; word pair and study condition,  $F(1, 38) = 0.17$ ,  $MSE = 0.00$ ,  $p = .685$ ,  $\eta_p^2 = .00$ , *observed power* = .07; word pair and presentation rate,  $F(1, 38) = 0.16$ ,  $MSE = 0.00$ ,  $p = .687$ ,  $\eta_p^2 = .00$ , *observed power* = .07; recall interval and presentation rate,  $F(1, 38) = 0.20$ ,  $MSE = 0.00$ ,  $p = .661$ ,  $\eta_p^2 = .01$ , *observed power* = .07; and between study condition and presentation rate,  $F(1, 38) = 0.30$ ,  $MSE = 0.00$ ,  $p = .587$ ,  $\eta_p^2 = .01$ , *observed power* = .08.

**Non-significant 3-way interactions.** All 3-way interactions were not significant: word pair, recall interval and age,  $F(1, 38) = 0.07$ ,  $MSE = 0.00$ ,  $p = .787$ ,  $\eta_p^2 = .00$ , *observed power* = .06; word pair, study condition, and age,  $F(1, 38) = 1.83$ ,  $MSE = 0.01$ ,  $p = .184$ ,  $\eta_p^2 = .05$ , *observed power* = .26; recall interval, study condition, and age,  $F(1, 38) = 1.89$ ,  $MSE = 0.01$ ,  $p = .178$ ,  $\eta_p^2 = .05$ , *observed power* = .27; word pair, recall interval, and study condition,  $F(1, 38) = 3.22$ ,  $MSE = 0.01$ ,  $p = .081$ ,  $\eta_p^2 = .08$ , *observed power* = .42; word pair, presentation rate, and age,  $F(1, 38) = 0.10$ ,  $MSE = 0.00$ ,  $p = .926$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval, presentation rate, and age,  $F(1, 38) = 0.94$ ,  $MSE = 0.00$ ,  $p = .337$ ,  $\eta_p^2 = .02$ , *observed power* = .16, word pair, recall interval, and presentation rate,  $F(1, 38) = 0.60$ ,  $MSE = 0.00$ ,  $p = .445$ ,  $\eta_p^2 = .02$ , *observed power* = .12; study condition, presentation rate, and age,  $F(1, 38) = 0.23$ ,  $MSE = 0.00$ ,  $p = .637$ ,  $\eta_p^2 = .01$ , *observed power* = .08; word pair, study condition, and presentation rate,  $F(1, 38) = 1.21$ ,  $MSE = 0.00$ ,  $p = .279$ ,  $\eta_p^2 = .03$ , *observed power* = .19; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 0.91$ ,  $MSE = 0.00$ ,  $p = .348$ ,  $\eta_p^2 = .02$ , *observed power* = .15.

**Non-significant 4-way interactions.** All 4-way interactions were not significant: word pair, recall interval, study condition, and age,  $F(1, 38) = 0.45$ ,  $MSE = 0.00$ ,  $p = .508$ ,  $\eta_p^2 = .01$ , *observed power* = .10; word pair, recall interval, presentation rate, and age,  $F(1, 38) = 0.10$ ,  $MSE = 0.00$ ,  $p = .752$ ,  $\eta_p^2 = .00$ , *observed power* = .06; word pair, study condition, presentation rate, and age,  $F(1, 38) = 0.03$ ,  $MSE = 0.00$ ,  $p = .860$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 0.02$ ,  $MSE = 0.00$ ,  $p = .902$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between word pair, recall interval, study condition, and presentation rate,  $F(1, 38) = 0.36$ ,  $MSE = 0.00$ ,  $p = .554$ ,  $\eta_p^2 = .10$ , *observed power* = .09.

**Non-significant 5-way interaction.** The 5-way interaction between word pair, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .906$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

### ***Omission errors***

**Non-significant main effects.** The remaining main effects were not significant: study condition,  $F(1, 38) = 0.02$ ,  $MSE = 0.00$ ,  $p = .878$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and age,  $F(1, 38) = 3.39$ ,  $MSE = 0.35$ ,  $p = .074$ ,  $\eta_p^2 = .08$ , *observed power* = .03.

**Non-significant 2-way interactions.** The remaining 2-way interactions were not significant: word pair and age,  $F(1, 38) = 0.41$ ,  $MSE = 0.01$ ,  $p = .528$ ,  $\eta_p^2 = .01$ , *observed power* = .10; recall interval and age,  $F(1, 38) = 2.70$ ,  $MSE = 0.10$ ,  $p = .109$ ,  $\eta_p^2 = .07$ , *observed power* = .36; study condition and age,  $F(1, 38) = 0.67$ ,  $MSE = 0.01$ ,  $p = .418$ ,  $\eta_p^2 = .02$ , *observed power* = .13; presentation rate and age,  $F(1, 38) = 1.06$ ,  $MSE = 0.01$ ,  $p = .310$ ,  $\eta_p^2 = .03$ , *observed power* = .17; word pair and study condition,  $F(1, 38) = 0.00$ ,  $MSE = 0.00$ ,  $p = .984$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval and study condition,  $F(1, 38) = 1.46$ ,  $MSE = 0.01$ ,  $p = .235$ ,  $\eta_p^2 = .04$ , *observed power* = .22; word pair and presentation rate,  $F(1, 38) = 2.42$ ,  $MSE = 0.01$ ,  $p = .127$ ,  $\eta_p^2 = .06$ , *observed power* = .33; recall interval and presentation rate,  $F(1, 38) = 4.05$ ,  $MSE = 0.05$ ,  $p = .051$ ,  $\eta_p^2 = .10$ , *observed power* = .50; and between study condition and presentation rate,  $F(1, 38) = 0.50$ ,  $MSE = 0.00$ ,  $p = .484$ ,  $\eta_p^2 = .01$ , *observed power* = .11.

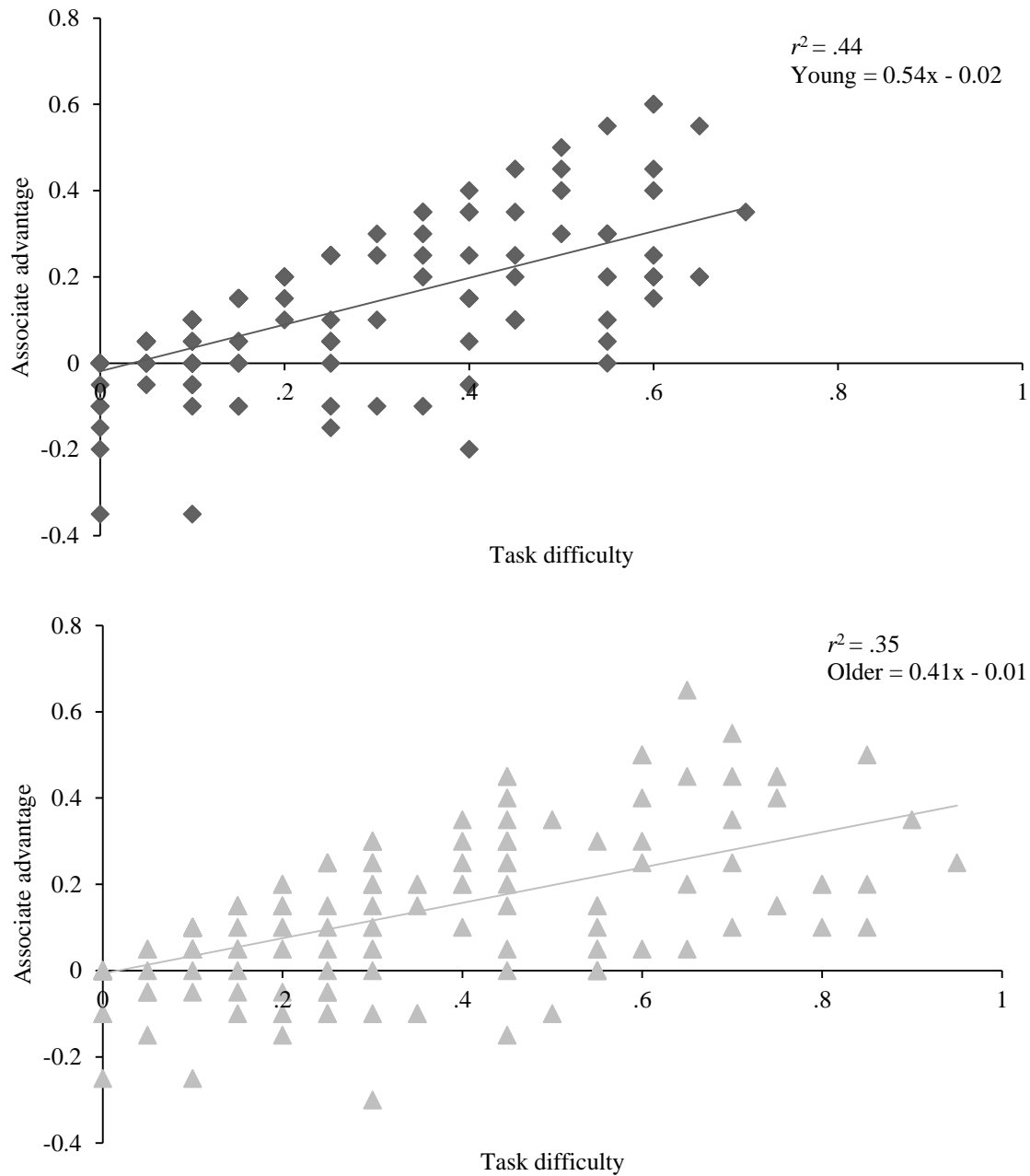
**Non-significant 3-way interactions.** The remaining 3-way interactions were not significant: word pair, recall interval, and age,  $F(1, 38) = 0.50$ ,  $MSE = 0.01$ ,  $p = .484$ ,  $\eta_p^2 = .01$ , *observed power* = .11, word pair, study condition, and age,  $F(1, 38) = 1.72$ ,  $MSE = 0.02$ ,  $p$

$= .197$ ,  $\eta_p^2 = .04$ , *observed power* = .25; recall interval, study condition, and age,  $F(1, 38) = 0.50$ ,  $MSE = 0.00$ ,  $p = .484$ ,  $\eta_p^2 = .01$ , *observed power* = .11; word pair, recall interval, and study condition,  $F(1, 38) = 2.33$ ,  $MSE = 0.02$ ,  $p = .135$ ,  $\eta_p^2 = .06$ , *observed power* = .32; word pair, recall interval, and presentation rate,  $F(1, 38) = 0.13$ ,  $MSE = 0.00$ ,  $p = .721$ ,  $\eta_p^2 = .00$ , *observed power* = .06; study condition, presentation rate, and age,  $F(1, 38) = 1.35$ ,  $MSE = 0.01$ ,  $p = .252$ ,  $\eta_p^2 = .03$ , *observed power* = .21; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 0.67$ ,  $MSE = 0.00$ ,  $p = .418$ ,  $\eta_p^2 = .02$ , *observed power* = .13.

***Non-significant 4-way interactions.*** All 4-way interactions were not significant: word pair, recall interval, study condition, and age,  $F(1, 38) = 0.29$ ,  $MSE = 0.00$ ,  $p = .592$ ,  $\eta_p^2 = .01$ , *observed power* = .08; word pair, study condition, presentation rate, and age,  $F(1, 38) = 0.09$ ,  $MSE = 0.00$ ,  $p = .773$ ,  $\eta_p^2 = .00$ , *observed power* = .06; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 1.25$ ,  $MSE = 0.01$ ,  $p = .272$ ,  $\eta_p^2 = .03$ , *observed power* = .19; and between word pair, recall interval, study condition, and presentation rate,  $F(1, 38) = 2.88$ ,  $MSE = 0.02$ ,  $p = .098$ ,  $\eta_p^2 = .07$ , *observed power* = .38.

***Non-significant 5-way interaction.*** The 5-way interaction between word pair, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 1.95$ ,  $MSE = 0.02$ ,  $p = .171$ ,  $\eta_p^2 = .05$ , *observed power* = .28.

**Appendix C – 3.3: Associate advantage as a function of task difficulty for correct-in-position recall across all young adults (upper graph) and all older adults (lower graph)**

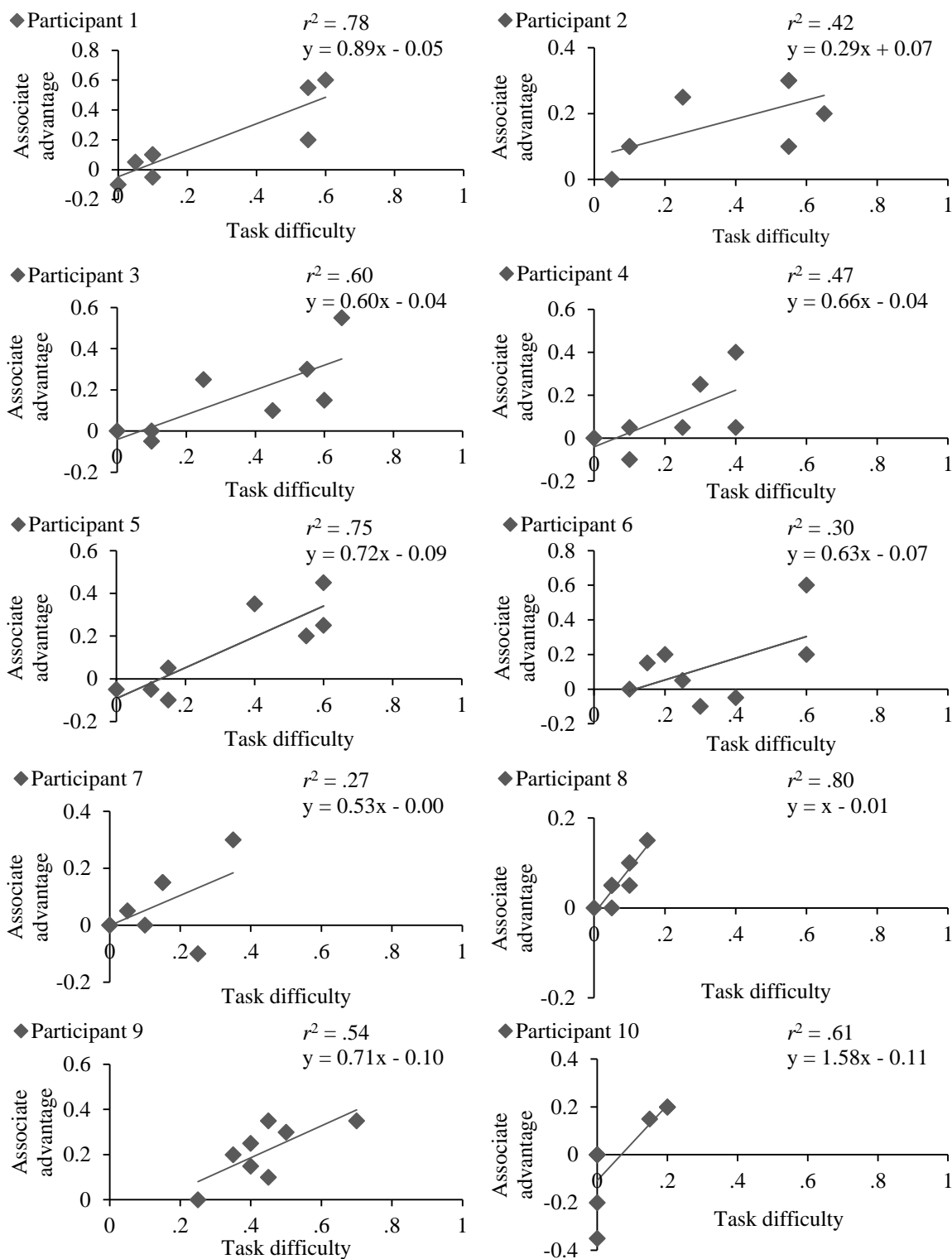


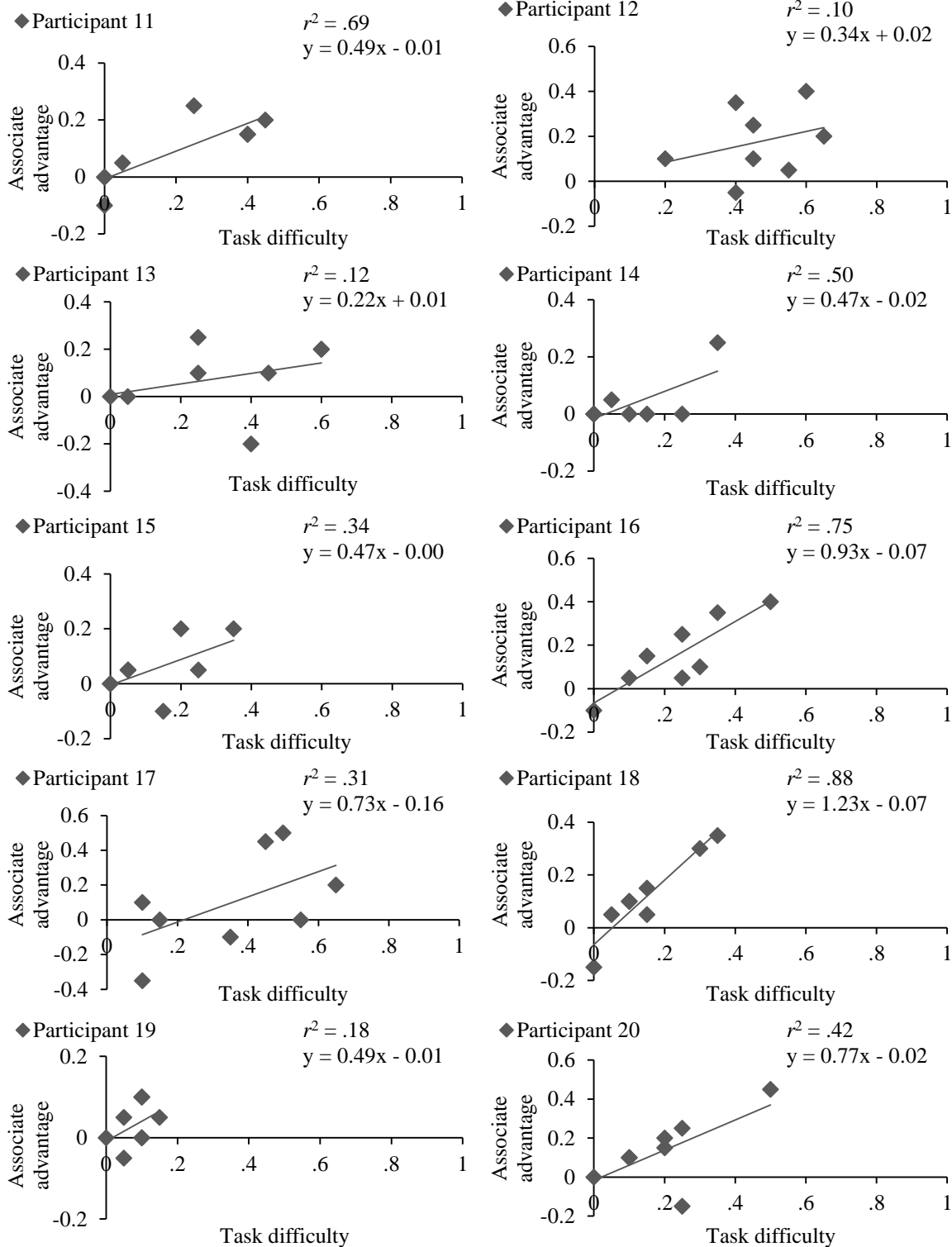
Examining performance at the sample level, young adults demonstrated that as task difficulty increased, so too did the associate advantage. The older adults, in the lower graph

also showed an increase in the associate advantage as task difficulty increased. This relationship was moderately strong for young adults and older adults.



**Appendix C – 3.4: Associate advantage as a function of task difficulty for correct-in-position recall for each young adult**

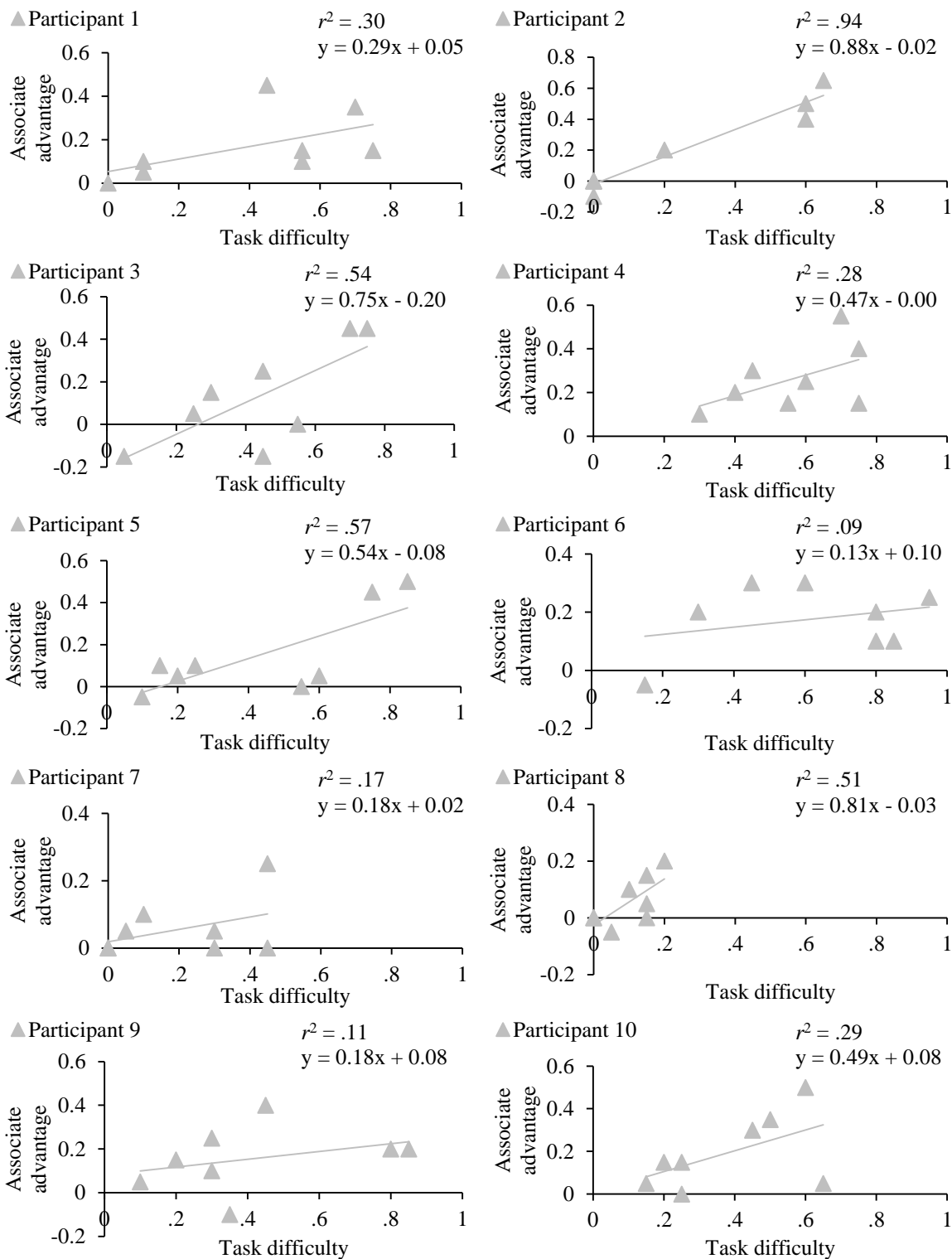


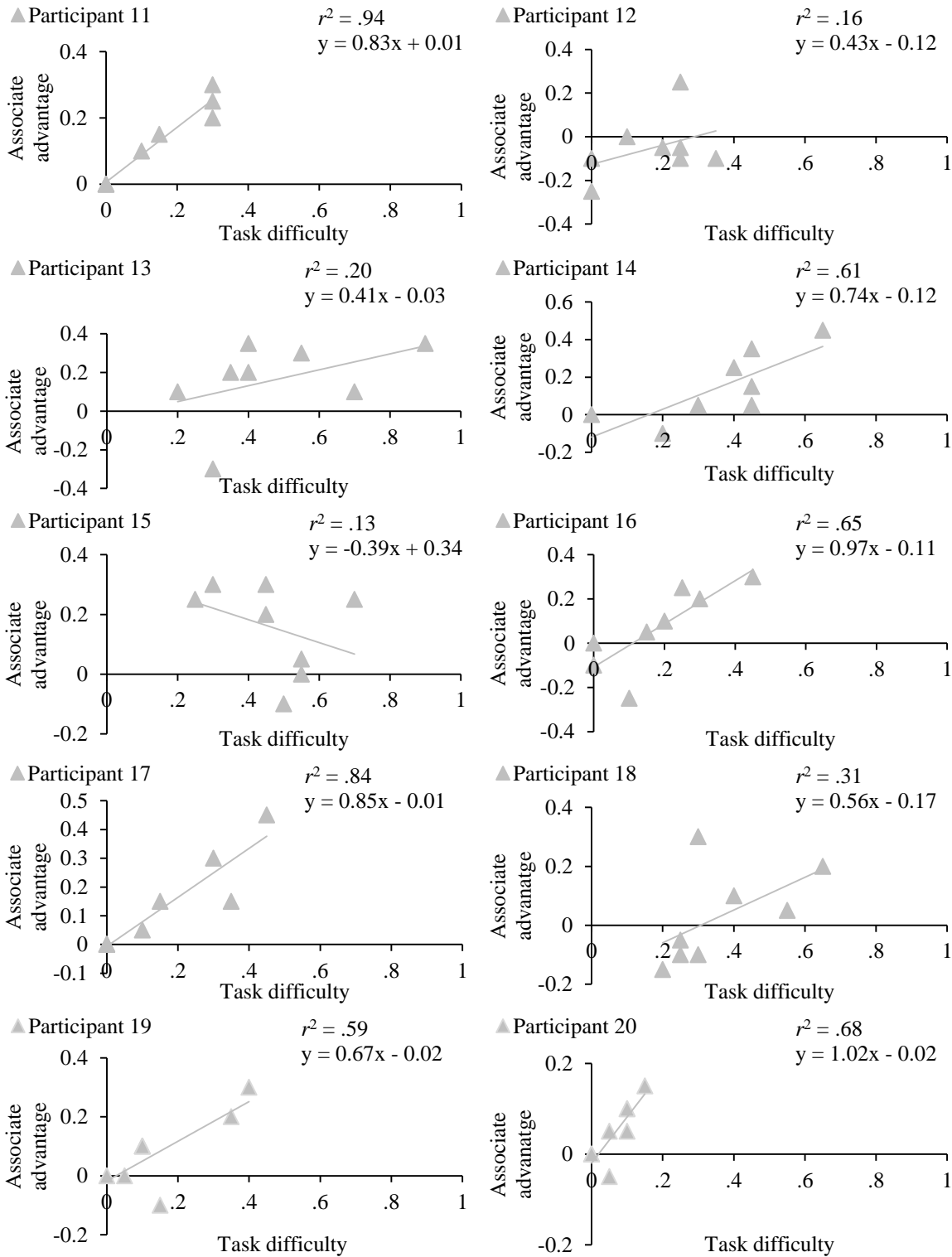


It is evident that all participants used redintegration, particularly during the difficult task conditions. Five participants demonstrated reasonably strong redintegration effects where  $r^2 >$

.70 (Participants 1, 5, 8, 16, and 18) whereas five participants demonstrated weak redintegration effects where  $r^2 < .30$  (Participants 6, 7, 12, 13, and 19). The remaining 10 participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 2, 3, 4, 9, 10, 11, 14, 15, 17, and 20).

**Appendix C – 3.5: Associate advantage as a function of task difficulty for correct-in-position recall for each older adult**

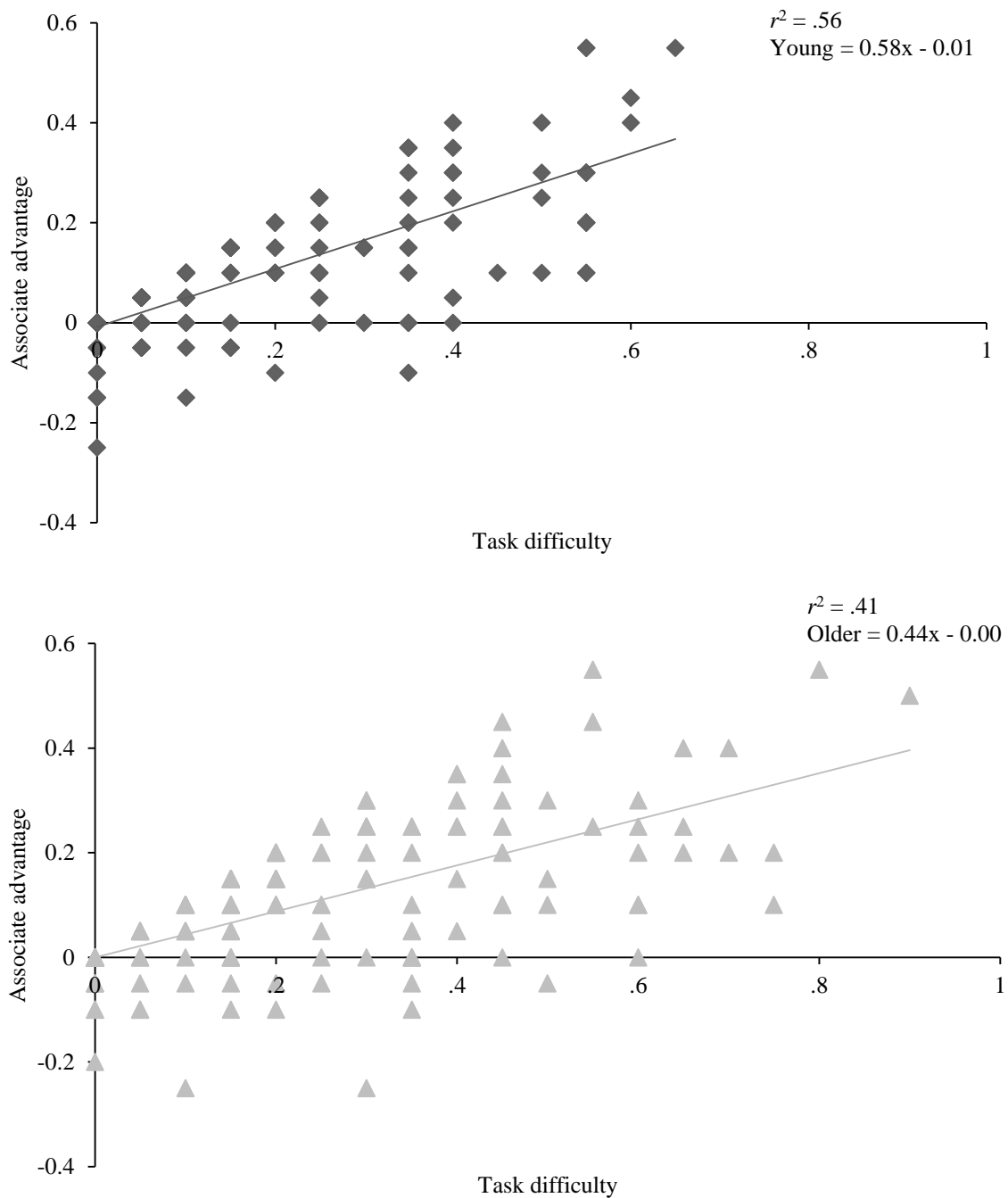




Older adults used redintegration for correct-in-position recall. Three participants demonstrated strong redintegration effects where  $r^2 > .70$  (Participants 2, 11, and 17) and nine participants demonstrated weak redintegration effects where  $r^2 < .30$  (Participants 1, 4, 6, 7, 9,

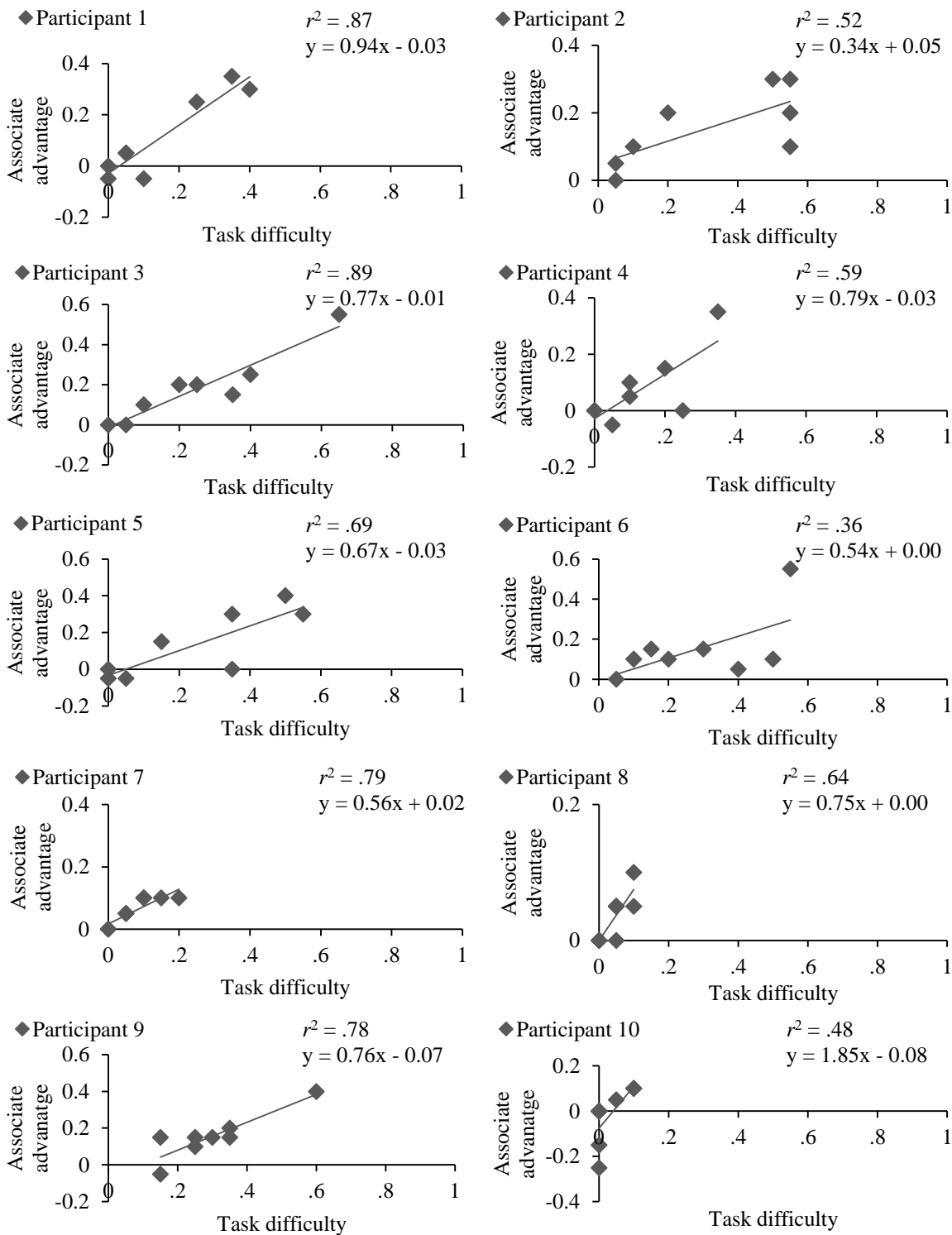
10, 12, 13, and 15). The remaining eight participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 3, 5, 8, 14, 16, 18, 19, and 20).

**Appendix C – 3.6: Associate advantage as a function of task difficulty for item recall for young adults (upper graph) and older adults (lower graph)**

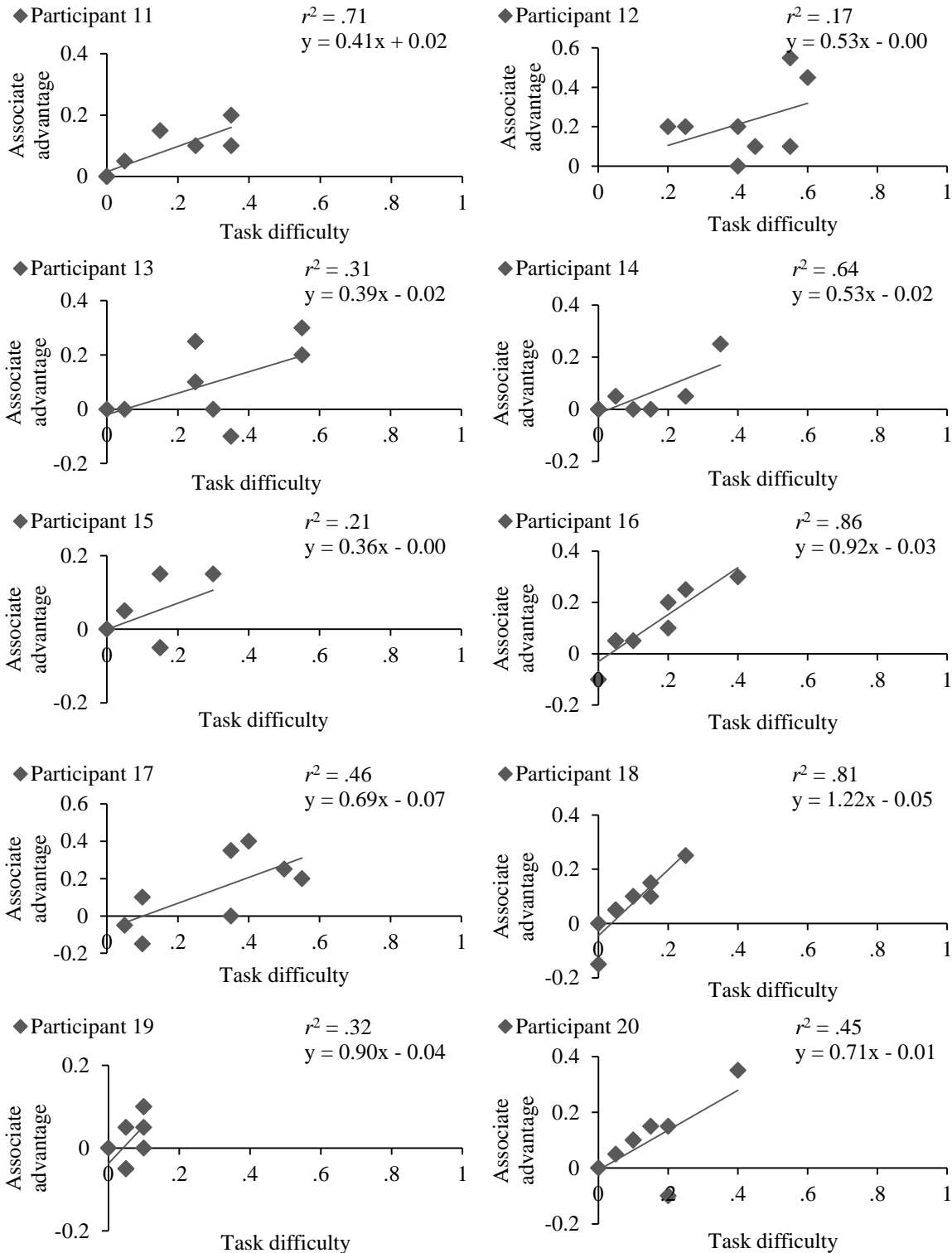


At the sample level, young adults demonstrated that as task difficulty increased, there was a moderate increase in the associate advantage. The older adults also showed a moderate increase in the relationship between the associate advantage and task difficulty.

**Appendix C – 3.7: Associate advantage as a function of task difficulty for item recall for each young adult**



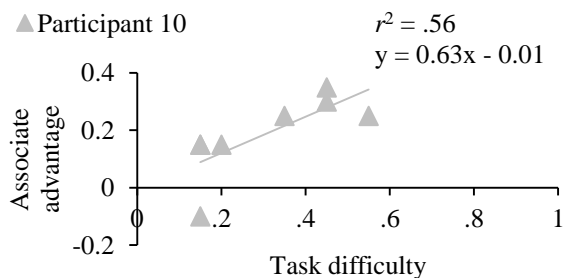
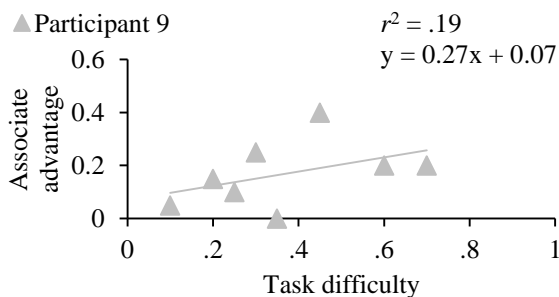
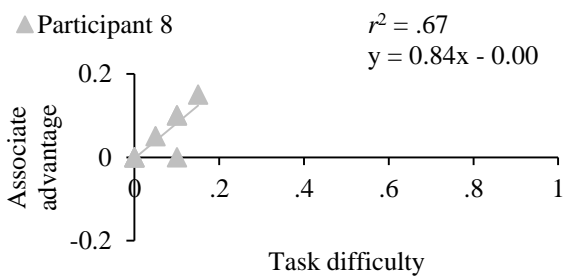
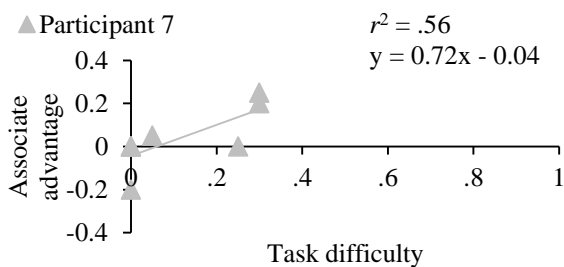
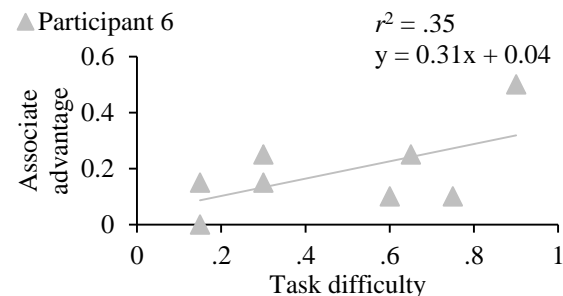
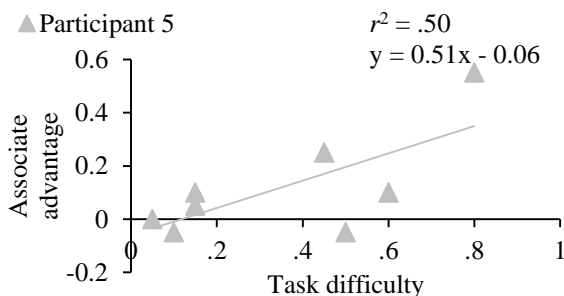
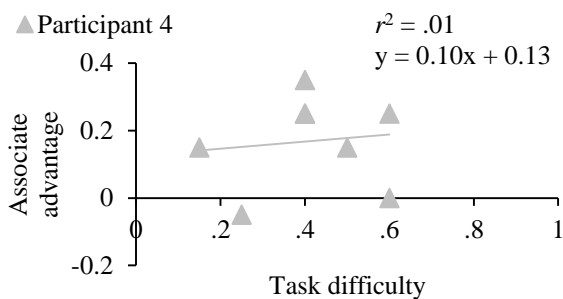
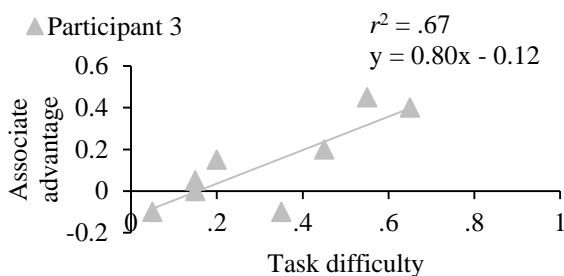
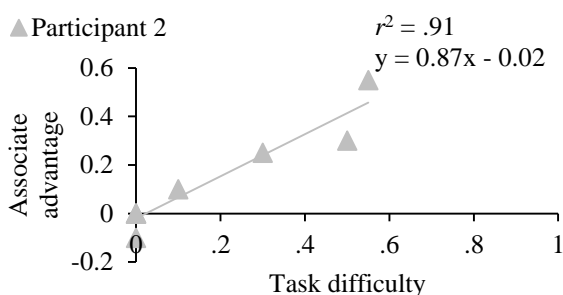
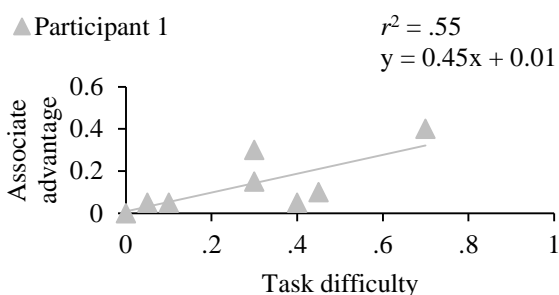


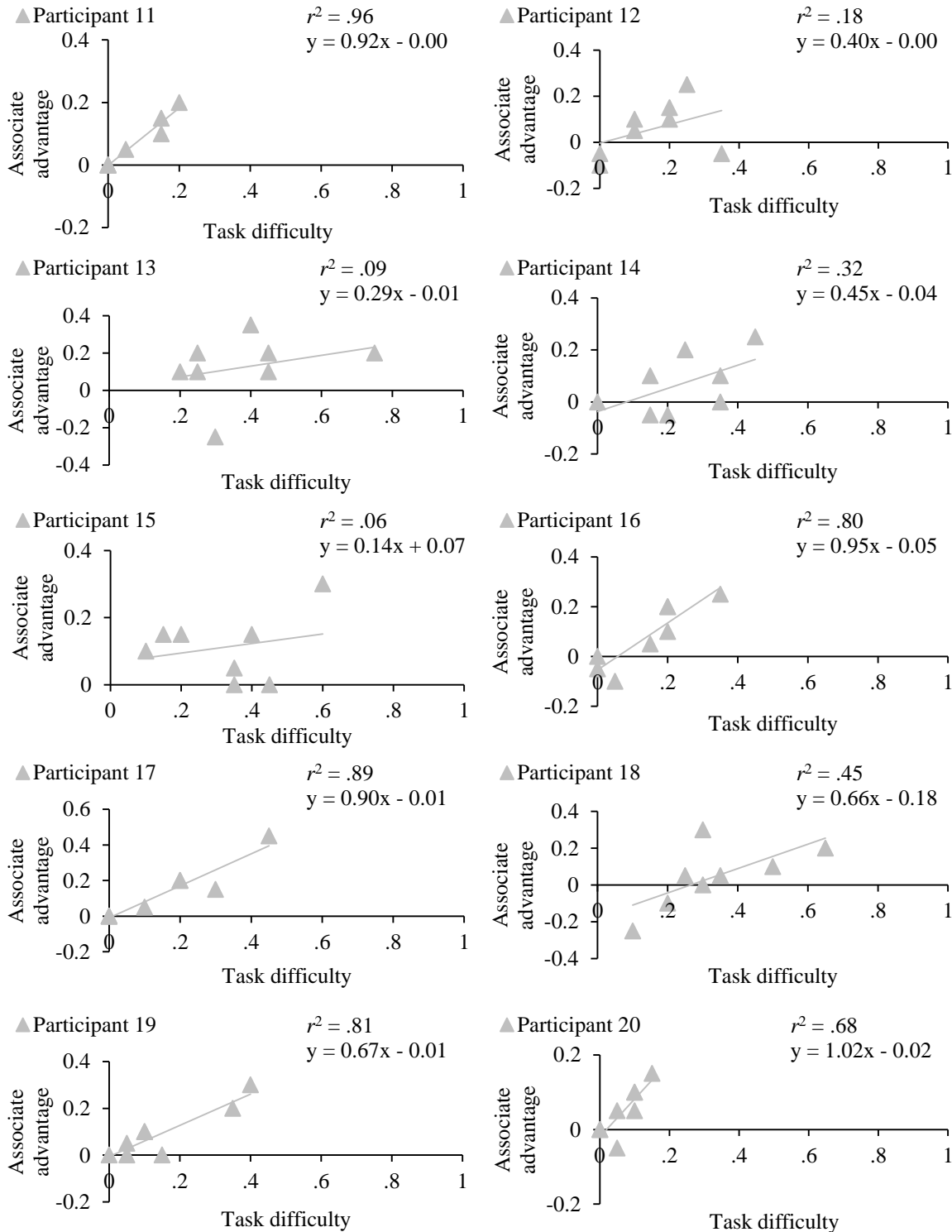


Seven participants demonstrated reasonably strong reintegration effects where  $r^2 > .70$  (Participants 1, 3, 7, 9, 11, 16, and 18) whereas two participants demonstrated weak reintegration effects where  $r^2 < .30$  (Participants 12 and 15). The remaining 11 participants

demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 2, 4, 5, 6, 8, 10, 13, 14, 17, 19, and 20).

**Appendix C – 3.8: Associate advantage as a function of task difficulty for item recall for each older adult**

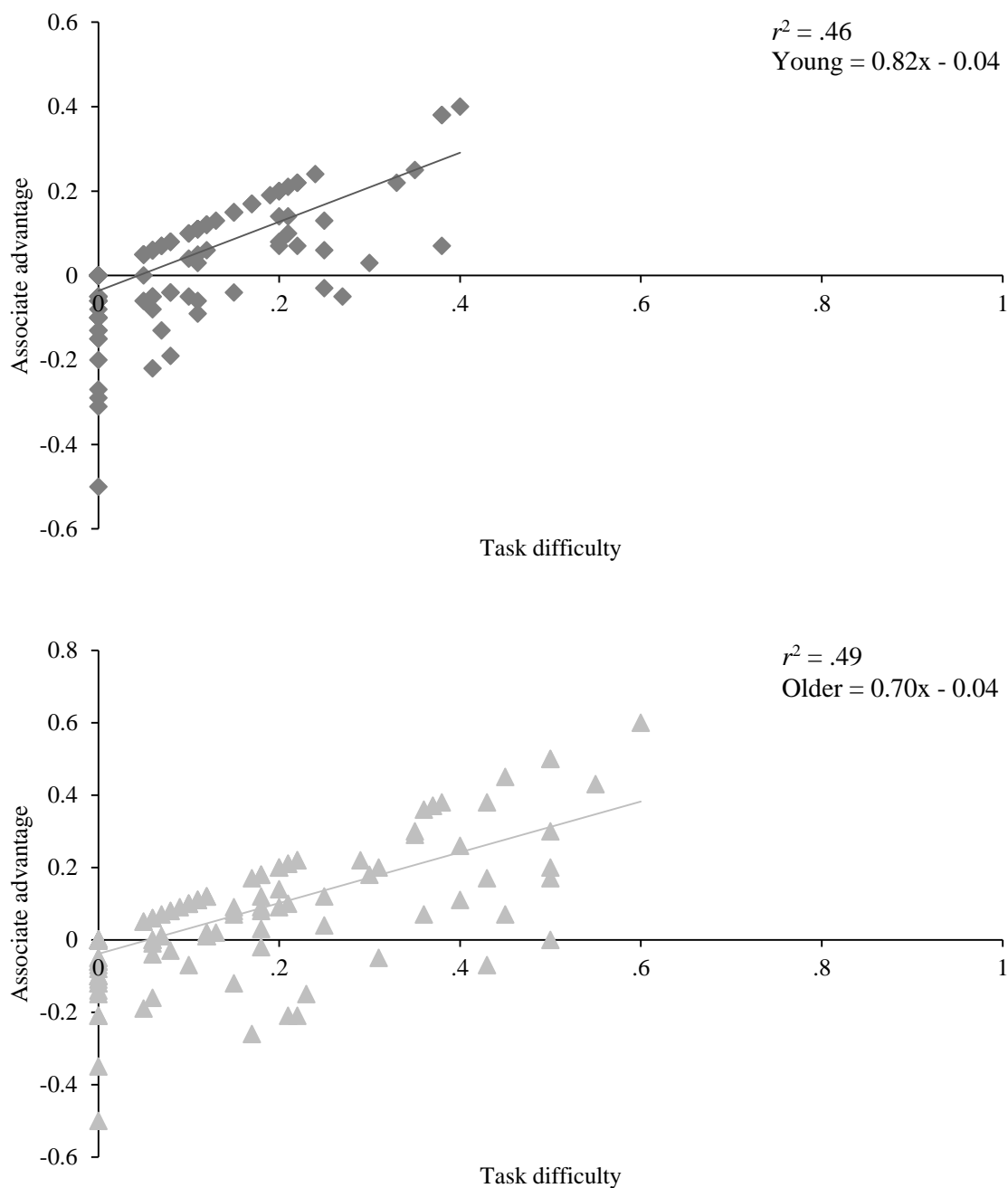




There was a consistent redintegration effect observed across all older adults. Five participants demonstrated reasonably strong redintegration effects where  $r^2 > .70$  (Participants 2, 11, 16, 17, and 19) and five participants demonstrated weak redintegration effects where  $r^2$

< .30 (Participants 4, 9, 12, 13, and 15). The remaining 10 participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 1, 3, 5, 6, 7, 8, 10, 14, 18, and 20).

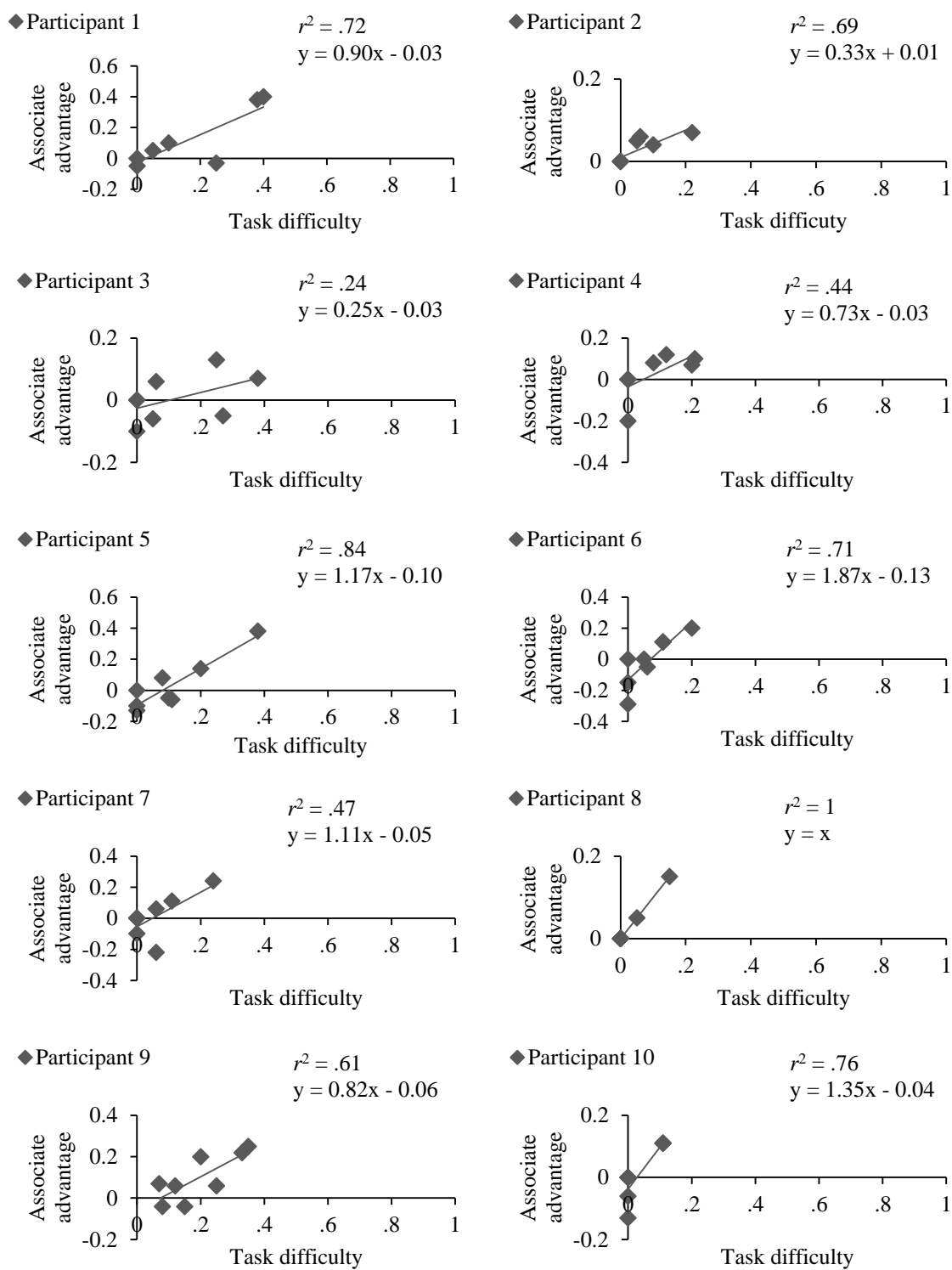
**Appendix C – 3.9: Associate advantage as a function of task difficulty for order accuracy across all young adults (upper graph) and across all older adults (lower graph)**



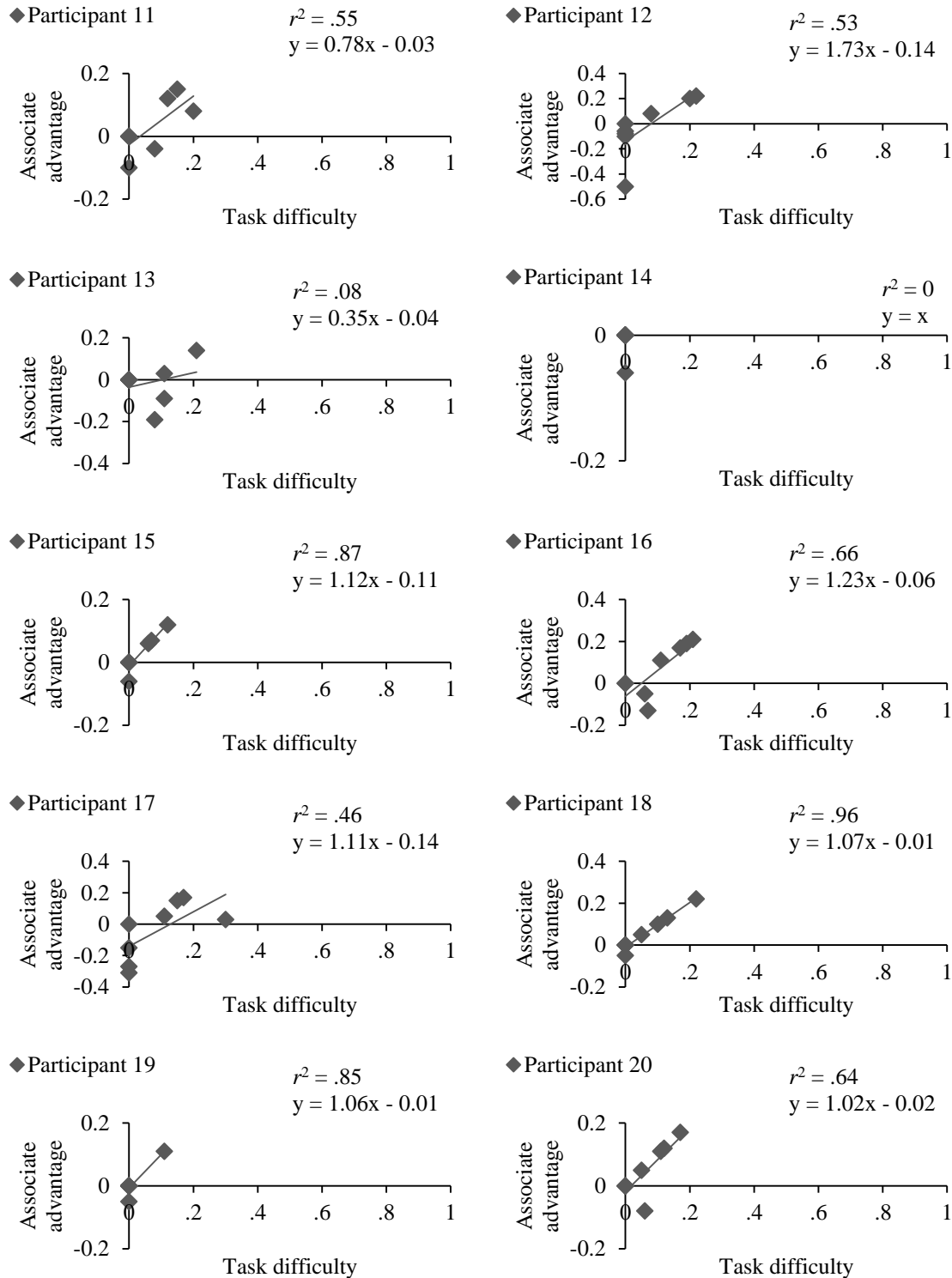
Examining performance at the sample level, young adults demonstrated that as task difficulty increased, the associate advantage moderately increased the likelihood of accurately

recalling the word pairs in their serial position (Upper graph). The older adults also displayed a moderate increase in the likelihood of accurately recalling the word pairs in their serial position as task difficulty increased (Lower graph).

**Appendix C – 3.10: Associate advantage as a function of task difficulty for order accuracy for each young adult**



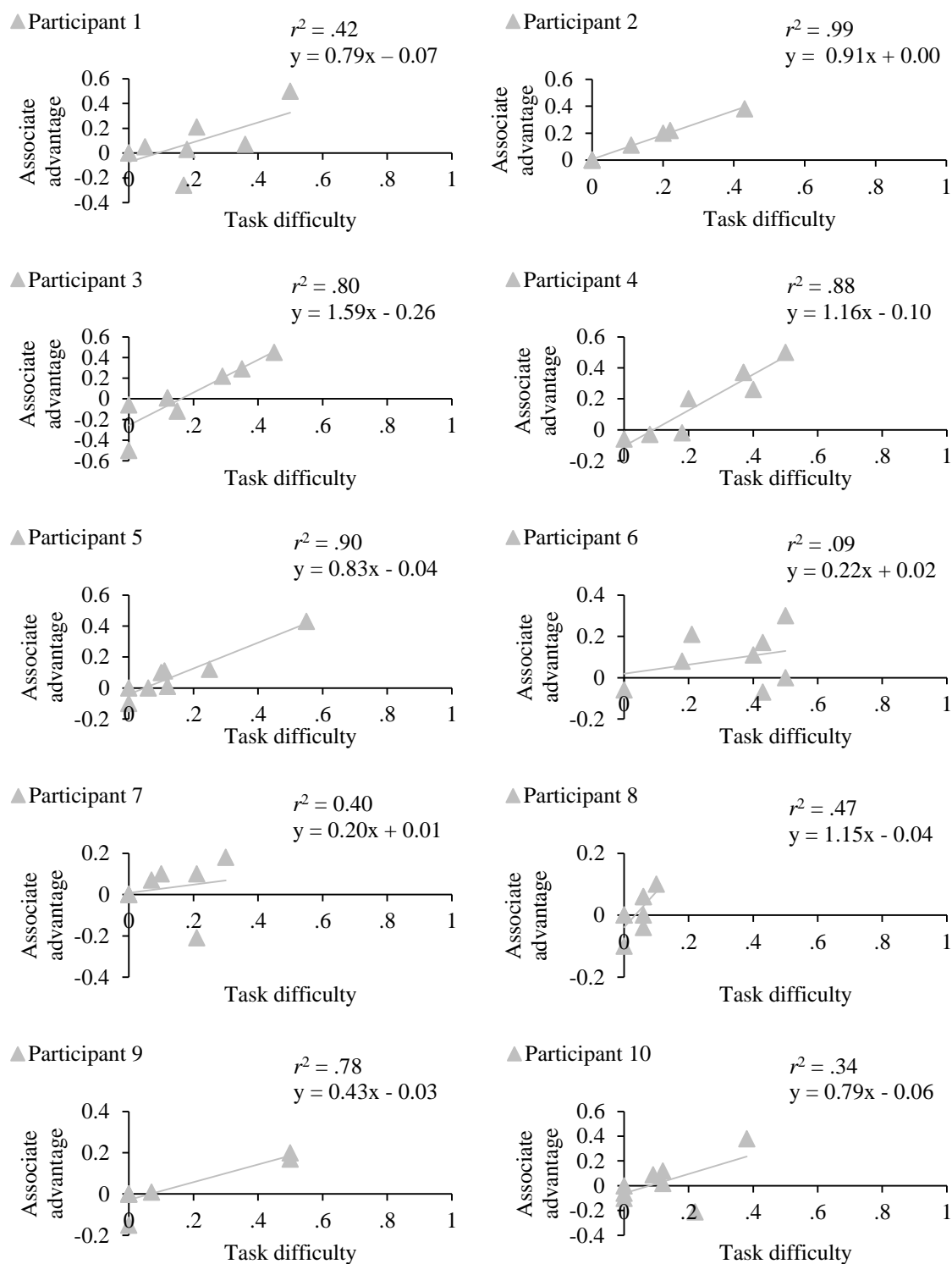




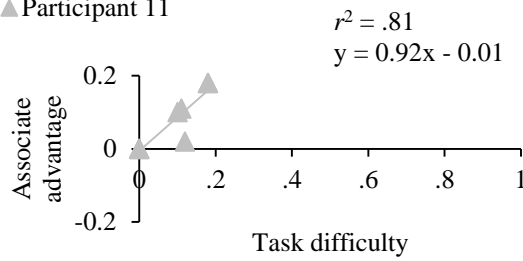
Eight participants displayed strong effects of redintegration where  $r^2 > .70$  (Participants 1, 5, 6, 8, 10, 15, 18, and 19), and two participants displayed weak redintegration effects where  $r^2 < .30$  (Participants 3 and 13). Surprisingly, one participant did not display

redintegrative effects where  $r^2 = .00$  (Participant 14). The remaining nine participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 2, 4, 7, 9, 11, 12, 16, 17, and 20).

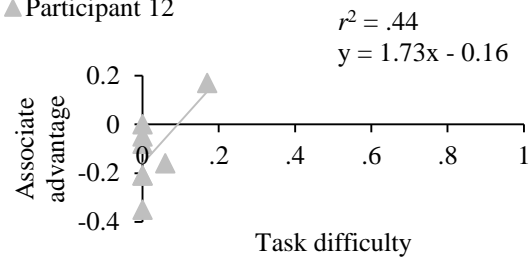
**Appendix C – 3.11: Associate advantage as a function of task difficulty for order accuracy for each older adult**



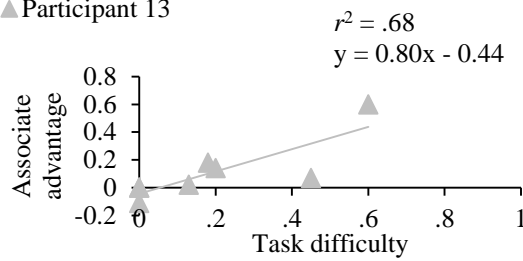
▲ Participant 11



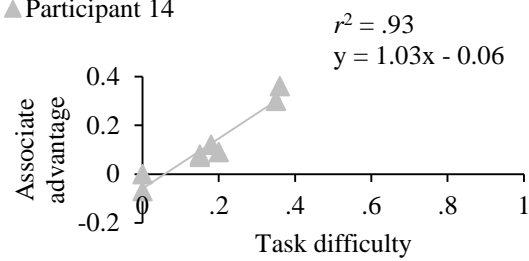
▲ Participant 12



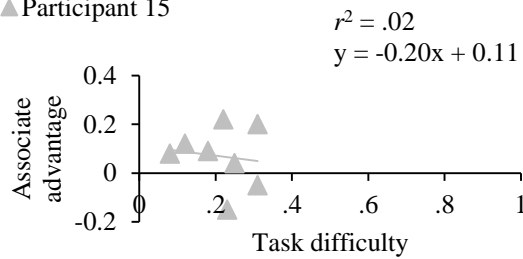
▲ Participant 13



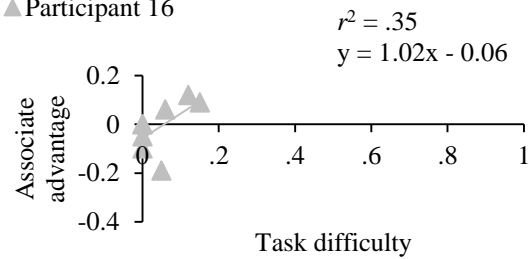
▲ Participant 14



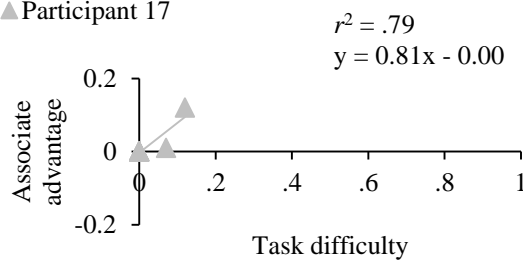
▲ Participant 15



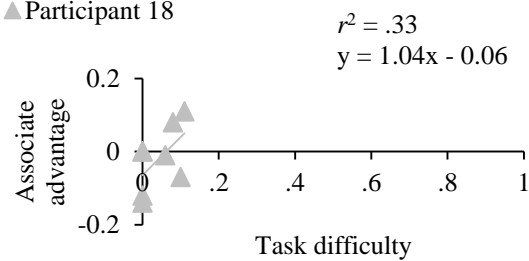
▲ Participant 16



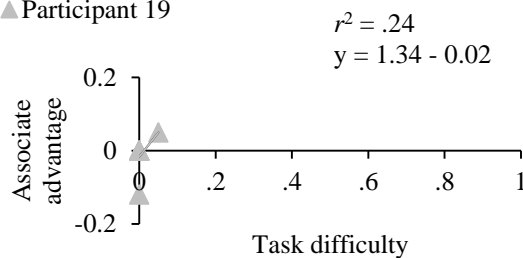
▲ Participant 17



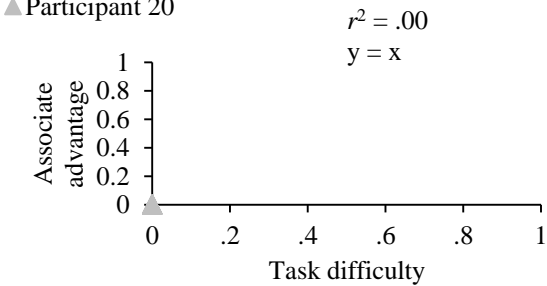
▲ Participant 18



▲ Participant 19



▲ Participant 20



Similar to young adults' order accuracy, eight participants displayed strong redintegration effects where  $r^2 > .70$  (Participants 2, 3, 4, 5, 9, 11, 14, and 17) and three participants displayed weak redintegration effects where  $r^2 < .30$  (Participants 6, 15 and 19).

One participant did not display redintegrative effects where  $r^2 = .00$  (Participant 20) and the remaining eight participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 1, 7, 8, 10, 12, 13, 16, and 18).

## **Appendix C – 4: Additional analyses for chapter eight (False memory)**

### ***Appendix C – 4:1: Significant interactions***

#### ***Correct-in-position recall***

***Significant 2-way interactions.*** There was a significant 2-way interaction between presentation rate and age,  $F(1, 38) = 11.50$ ,  $MSE = 0.52$ ,  $p = .002$ ,  $\eta_p^2 = .23$ , *observed power* = .91. During the two-second presentation rate, young adults recalled a significantly higher proportion of words in serial position ( $M = .79$ ,  $SD = .13$ ) compared with older adults ( $M = .66$ ,  $SD = .17$ ),  $F(1, 38) = 7.05$ ,  $p = .012$ ,  $\eta_p^2 = .16$ , *observed power* = .74. However, during the one-second presentation rate, there was no significant difference in the proportion of words recalled in serial position between young ( $M = .70$ ,  $SD = .14$ ) and older adults ( $M = .64$ ,  $SD = .19$ ),  $F(1, 38) = 1.17$ ,  $p = .286$ ,  $\eta_p^2 = .03$ , *observed power* = .18.

Young adults recalled a significantly higher proportion of words in serial position during the two-second presentation rate ( $M = .79$ ,  $SD = .13$ ) compared with the one-second presentation rate ( $M = .70$ ,  $SD = .14$ ),  $F(1, 38) = 38.05$ ,  $p < .001$ ,  $\eta_p^2 = .50$ , *observed power* = 1.00. However, there was no significant difference in the proportion of words older adults recalled in serial position during the two-second ( $M = .66$ ,  $SD = .17$ ) and one-second presentation rates ( $M = .64$ ,  $SD = .19$ ),  $F(1, 38) = 1.89$ ,  $p = .178$ ,  $\eta_p^2 = .05$ , *observed power* = .27.

A significant 2-way interaction was also evident between word relatedness and recall interval,  $F(1, 38) = 9.29$ ,  $MSE = 0.21$ ,  $p = .004$ ,  $\eta_p^2 = .20$ , *observed power* = .84. Participants recalled a significantly higher proportion of related words in serial position during immediate conditions ( $M = .86$ ,  $SD = .14$ ) compared with after a delayed interval ( $M = .65$ ,  $SD = .17$ ),  $F(1, 38) = 190.20$ ,  $p < .001$ ,  $\eta_p^2 = .83$ , *observed power* = 1.00. Similarly, participants recalled

a significantly higher proportion of unrelated words in serial position during immediate conditions ( $M = .77$ ,  $SD = .18$ ) compared with after a delayed interval ( $M = .51$ ,  $SD = .21$ ),  $F(1, 38) = 180.73$ ,  $p < .001$ ,  $\eta_p^2 = .83$ , *observed power* = 1.00.

Participants, under immediate conditions, recalled a significantly higher proportion of related words ( $M = .86$ ,  $SD = .14$ ) in serial position compared with unrelated words ( $M = .77$ ,  $SD = .18$ ),  $F(1, 38) = 33.94$ ,  $p < .001$ ,  $\eta_p^2 = .47$ , *observed power* = 1.00. Similarly, participants, under delayed conditions, recalled a significantly higher proportion of related words ( $M = .65$ ,  $SD = .17$ ) in serial position compared with unrelated words ( $M = .51$ ,  $SD = .21$ ),  $F(1, 38) = 81.89$ ,  $p < .001$ ,  $\eta_p^2 = .68$ , *observed power* = 1.00.

There was a significant 2-way interaction between recall interval and study condition,  $F(1, 38) = 14.96$ ,  $MSE = 0.17$ ,  $p < .001$ ,  $\eta_p^2 = .28$ , *observed power* = .97. In immediate conditions, participants recalled a significantly higher proportion of words in serial position during the silence conditions ( $M = .84$ ,  $SD = .16$ ) compared with the irrelevant speech conditions ( $M = .79$ ,  $SD = .16$ ),  $F(1, 38) = 19.08$ ,  $p < .001$ ,  $\eta_p^2 = .33$ , *observed power* = .99. In delayed conditions, there was no significant difference in the proportion of words recalled in serial position during silence ( $M = .57$ ,  $SD = .18$ ) and irrelevant speech ( $M = .59$ ,  $SD = .19$ ),  $F(1, 38) = 1.46$ ,  $p = .235$ ,  $\eta_p^2 = .04$ , *observed power* = .22.

In silence, participants recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .84$ ,  $SD = .16$ ) than after a delayed interval ( $M = .57$ ,  $SD = .18$ ),  $F(1, 38) = 253.32$ ,  $p < .001$ ,  $\eta_p^2 = .87$ , *observed power* = 1.00. In irrelevant speech, participants recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .79$ ,  $SD = .16$ ) than after a delayed interval ( $M = .59$ ,  $SD = .19$ ),  $F(1, 38) = 135.54$ ,  $p < .001$ ,  $\eta_p^2 = .78$ , *observed power* = 1.00.

There was a significant 2-way interaction between recall interval and presentation rate,  $F(1, 38) = 23.65$ ,  $MSE = 0.23$ ,  $p < .001$ ,  $\eta_p^2 = .38$ , *observed power* = 1.00. In immediate conditions, there was no significant difference in the proportion of words recalled in serial position during the two-second ( $M = .82$ ,  $SD = .16$ ) and one-second presentation rates ( $M = .80$ ,  $SD = .16$ ),  $F(1, 38) = 2.28$ ,  $p = .140$ ,  $\eta_p^2 = .06$ , *observed power* = .31. In delayed conditions, participants recalled a significantly higher proportion of words in serial position during the two-second presentation rate ( $M = .62$ ,  $SD = .19$ ) compared with the one-second presentation rate ( $M = .53$ ,  $SD = .19$ ),  $F(1, 38) = 45.97$ ,  $p < .001$ ,  $\eta_p^2 = .55$ , *observed power* = 1.00.

During the two-second presentation rate, participants recalled a significantly higher proportion of words in serial position in immediate conditions ( $M = .82$ ,  $SD = .16$ ) compared with after a delayed interval ( $M = .62$ ,  $SD = .19$ ),  $F(1, 38) = 150.88$ ,  $p < .001$ ,  $\eta_p^2 = .80$ , *observed power* = 1.00. During the one-second presentation rate, participants recalled a significantly higher proportion of words in serial position in immediate conditions ( $M = .80$ ,  $SD = .16$ ) compared with after a delayed interval ( $M = .53$ ,  $SD = .19$ ),  $F(1, 38) = 239.85$ ,  $p < .001$ ,  $\eta_p^2 = .86$ , *observed power* = 1.00.

**Significant 3-way interactions.** There was a significant 3-way interaction between recall interval, presentation rate, and age,  $F(1, 38) = 8.64$ ,  $MSE = 0.09$ ,  $p = .006$ ,  $\eta_p^2 = .19$ , *observed power* = .82. In immediate conditions, under the two-second presentation rate, young adults ( $M = .88$ ,  $SD = .13$ ) recalled a significantly higher proportion of words in serial position compared with older adults ( $M = .77$ ,  $SD = .16$ ),  $F(1, 38) = 5.63$ ,  $p = .023$ ,  $\eta_p^2 = .13$ , *observed power* = .64. In immediate conditions, under the one-second presentation rate, there was no significant difference between young ( $M = .85$ ,  $SD = .13$ ) and older adults ( $M = .76$ ,  $SD = .18$ )



in the proportion of words they recalled in serial position,  $F(1, 38) = 2.80, p = .102, \eta_p^2 = .07$ , *observed power* = .37. In delayed conditions, under the two-second presentation rate, young adults ( $M = .70, SD = .15$ ) recalled a significantly higher proportion of words in serial position relative to older adults ( $M = .55, SD = .20$ ),  $F(1, 38) = 7.10, p = .011, \eta_p^2 = .16$ , *observed power* = .74. In delayed conditions, under the one-second presentation rate, there was no significant difference between young ( $M = .55, SD = .17$ ) and older adults ( $M = .51, SD = .21$ ) in the proportion of words they recalled in serial position,  $F(1, 38) = 0.25, p = .618, \eta_p^2 = .01$ , *observed power* = .08.

Young adults, under the two-second presentation rate, recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .88, SD = .13$ ) compared with after a delayed interval ( $M = .70, SD = .15$ ),  $F(1, 38) = 61.28, p < .001, \eta_p^2 = .62$ , *observed power* = 1.00. Young adults, under the one-second presentation rate, recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .85, SD = .13$ ) compared with after a delayed interval ( $M = .55, SD = .17$ ),  $F(1, 38) = 144.24, p < .001, \eta_p^2 = .79$ , *observed power* = 1.00. Older adults, under the two-second presentation rate, recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .77, SD = .16$ ) compared with after a delayed interval ( $M = .55, SD = .20$ ),  $F(1, 38) = 91.08, p < .001, \eta_p^2 = .71$ , *observed power* = 1.00. Older adults, under the one-second presentation rate, recalled a significantly higher proportion of words during immediate conditions ( $M = .76, SD = .18$ ) compared with after a delayed interval ( $M = .51, SD = .21$ ),  $F(1, 38) = 97.85, p < .001, \eta_p^2 = .72$ , *observed power* = 1.00.

There was no significant difference in the proportion of words young adults recalled in serial position, under immediate conditions, during the two-second ( $M = .88, SD = .13$ ) and

one-second presentation rates ( $M = .85$ ,  $SD = .13$ ),  $F(1, 38) = 3.29$ ,  $p = .078$ ,  $\eta_p^2 = .08$ , *observed power* = .42. However, young adults, under delayed conditions, produced a significantly higher proportion of words in serial position during the two-second presentation rate ( $M = .70$ ,  $SD = .15$ ) than the one-second presentation rate ( $M = .55$ ,  $SD = .17$ ),  $F(1, 38) = 60.56$ ,  $p < .001$ ,  $\eta_p^2 = .61$ , *observed power* = 1.00. There was no significant difference in the proportion of words older adults produced in serial position, under immediate conditions, during the two-second ( $M = .77$ ,  $SD = .16$ ) and one-second presentation rates ( $M = .76$ ,  $SD = .18$ ),  $F(1, 38) = 0.10$ ,  $p = .751$ ,  $\eta_p^2 = .00$ , *observed power* = .06. Finally, there was no significant difference in the proportion of words older adults recalled in serial position, under delayed conditions, during the two-second ( $M = .55$ ,  $SD = .20$ ) and one-second presentation rates ( $M = .51$ ,  $SD = .21$ ),  $F(1, 38) = 3.26$ ,  $p = .079$ ,  $\eta_p^2 = .08$ , *observed power* = .42.

There was also a 3-way interaction between word relatedness, study condition, and age,  $F(1, 38) = 5.89$ ,  $MSE = 0.08$ ,  $p = .020$ ,  $\eta_p^2 = .13$ , *observed power* = .66. Young adults recalled a significantly higher proportion of related words in serial position under silence conditions ( $M = .82$ ,  $SD = .11$ ) compared with irrelevant speech conditions ( $M = .78$ ,  $SD = .13$ ),  $F(1, 38) = 5.46$ ,  $p = .025$ ,  $\eta_p^2 = .13$ , *observed power* = .62. However, young adults did not significantly differ in recalling unrelated words in serial position under silence ( $M = .68$ ,  $SD = .16$ ) and irrelevant speech ( $M = .69$ ,  $SD = .17$ ),  $F(1, 38) = 0.04$ ,  $p = .837$ ,  $\eta_p^2 = .00$ , *observed power* = .06. Older adults did not significantly differ in recall in related words in serial position under silence ( $M = .70$ ,  $SD = .17$ ) and irrelevant speech ( $M = .71$ ,  $SD = .17$ ),  $F(1, 38) = 0.24$ ,  $p = .627$ ,  $\eta_p^2 = .01$ , *observed power* = .08. Similarly, older adults did not significantly differ in recalling unrelated words in serial position under silence ( $M = .61$ ,  $SD = .20$ ) and irrelevant speech ( $M = .58$ ,  $SD = .20$ ),  $F(1, 38) = 3.09$ ,  $p = .087$ ,  $\eta_p^2 = .076$ , *observed power* = .40.

Young adults, under silence, recalled a significantly higher proportion of related words in serial position ( $M = .82$ ,  $SD = .11$ ) compared with unrelated words ( $M = .68$ ,  $SD = .16$ ),  $F(1, 38) = 37.92$ ,  $p < .001$ ,  $\eta_p^2 = .50$ , *observed power* = 1.00. Young adults, under irrelevant speech, recalled a significantly higher proportion of related words in serial position ( $M = .78$ ,  $SD = .13$ ) compared with unrelated words ( $M = .69$ ,  $SD = .17$ ),  $F(1, 38) = 20.62$ ,  $p < .001$ ,  $\eta_p^2 = .35$ , *observed power* = .99. Older adults, under silence, recalled a significantly higher proportion of related words in serial position ( $M = .70$ ,  $SD = .17$ ) compared with unrelated words ( $M = .61$ ,  $SD = .20$ ),  $F(1, 38) = 15.88$ ,  $p < .001$ ,  $\eta_p^2 = .30$ , *observed power* = .97. Older adults, under irrelevant speech, recalled a significantly higher proportion of related words in serial position ( $M = .71$ ,  $SD = .17$ ) compared with unrelated words ( $M = .58$ ,  $SD = .20$ ),  $F(1, 38) = 42.07$ ,  $p < .001$ ,  $\eta_p^2 = .53$ , *observed power* = 1.00.

For related words, under silence conditions, young adults ( $M = .82$ ,  $SD = .11$ ) recalled a significantly higher proportion of words in serial position compared with older adults ( $M = .70$ ,  $SD = .17$ ),  $F(1, 38) = 7.27$ ,  $p = .010$ ,  $\eta_p^2 = .16$ , *observed power* = .75. For related words, under irrelevant speech conditions, there was no significant difference between young ( $M = .78$ ,  $SD = .13$ ) and older adults ( $M = .71$ ,  $SD = .17$ ) in the proportion of words they recalled in serial position,  $F(1, 38) = 2.12$ ,  $p = .153$ ,  $\eta_p^2 = .05$ , *observed power* = .30. For unrelated words, under silence conditions, there was no significant difference between young ( $M = .68$ ,  $SD = .16$ ) and older adults ( $M = .61$ ,  $SD = .20$ ) in the proportion of words they recalled in serial position,  $F(1, 38) = 1.57$ ,  $p = .217$ ,  $\eta_p^2 = .04$ , *observed power* = .23. For related words, under irrelevant speech conditions, there was no significant difference between young ( $M = .69$ ,  $SD = .17$ ) and older adults ( $M = .58$ ,  $SD = .20$ ) in the proportion of words they recalled in serial position,  $F(1, 38) = 3.44$ ,  $p = .071$ ,  $\eta_p^2 = .08$ , *observed power* = .44.

There was a significant 3-way interaction between word relatedness, recall interval, and study condition,  $F(1, 38) = 4.66$ ,  $MSE = 0.06$ ,  $p = .037$ ,  $\eta_p^2 = .11$ , *observed power* = .56. In immediate conditions, under silence, participants recalled a significantly higher proportion of related words ( $M = .87$ ,  $SD = .15$ ) in serial position than unrelated words ( $M = .80$ ,  $SD = .18$ ),  $F(1, 38) = 14.04$ ,  $p = .001$ ,  $\eta_p^2 = .27$ , *observed power* = .96. In immediate conditions, under irrelevant speech, participants recalled a significantly higher proportion of related words ( $M = .84$ ,  $SD = .14$ ) in serial position compared with unrelated words ( $M = .74$ ,  $SD = .19$ ),  $F(1, 38) = 35.06$ ,  $p < .001$ ,  $\eta_p^2 = .48$ , *observed power* = 1.00. In delayed conditions, under silence, participants recalled a significantly higher proportion of related words ( $M = .65$ ,  $SD = .18$ ) in serial position compared with unrelated words ( $M = .49$ ,  $SD = .22$ ),  $F(1, 38) = 50.51$ ,  $p < .001$ ,  $\eta_p^2 = .57$ , *observed power* = 1.00. In delayed conditions, under irrelevant speech, participants recalled a significantly higher proportion of related words ( $M = .65$ ,  $SD = .18$ ) in serial position compared with unrelated words ( $M = .53$ ,  $SD = .22$ ),  $F(1, 38) = 34.92$ ,  $p < .001$ ,  $\eta_p^2 = .48$ , *observed power* = 1.00.

Participants recalled a significantly higher proportion of related words in serial position, under silence, during immediate conditions ( $M = .87$ ,  $SD = .15$ ) compared with after a delayed interval ( $M = .65$ ,  $SD = .18$ ),  $F(1, 38) = 156.90$ ,  $p < .001$ ,  $\eta_p^2 = .81$ , *observed power* = 1.00. Participants also recalled a significantly higher proportion of related words in serial position, under irrelevant speech, during immediate conditions ( $M = .84$ ,  $SD = .14$ ) compared with after a delayed interval ( $M = .65$ ,  $SD = .18$ ),  $F(1, 38) = 104.49$ ,  $p < .001$ ,  $\eta_p^2 = .73$ , *observed power* = 1.00. Participants recalled a significantly higher proportion of unrelated words in serial position, under silence, during immediate conditions ( $M = .80$ ,  $SD = .18$ ) compared with after a delayed interval ( $M = .49$ ,  $SD = .22$ ),  $F(1, 38) = 168.70$ ,  $p < .001$ ,  $\eta_p^2 = .82$ , *observed power*

= 1.00. Participants also recalled a significantly higher proportion of unrelated words in serial position, under irrelevant speech, during immediate conditions ( $M = .74$ ,  $SD = .19$ ) compared with after a delayed interval ( $M = .53$ ,  $SD = .22$ ),  $F(1, 38) = 81.45$ ,  $p < .001$ ,  $\eta_p^2 = .68$ , *observed power* = 1.00.

Participants recalled a significantly higher proportion of related words, under immediate conditions, during silence ( $M = .87$ ,  $SD = .15$ ) compared with irrelevant speech ( $M = .84$ ,  $SD = .14$ ),  $F(1, 38) = 4.87$ ,  $p = .034$ ,  $\eta_p^2 = .11$ , *observed power* = .58. However, there was no significant difference in the proportion of related words participants recalled in serial position, under delayed conditions, during silence ( $M = .65$ ,  $SD = .18$ ) and irrelevant speech ( $M = .65$ ,  $SD = .18$ ),  $F(1, 38) = 0.04$ ,  $p = .840$ ,  $\eta_p^2 = .00$ , *observed power* = .06. Participants recalled a significantly higher proportion of unrelated words, under immediate conditions, during silence ( $M = .80$ ,  $SD = .18$ ) compared with the irrelevant speech conditions ( $M = .74$ ,  $SD = .19$ ),  $F(1, 38) = 17.13$ ,  $p < .001$ ,  $\eta_p^2 = .31$ , *observed power* = .98. However, there was no significant difference in the proportion of related words participants recalled in serial position, under delayed conditions, during silence ( $M = .49$ ,  $SD = .22$ ) and irrelevant speech ( $M = .53$ ,  $SD = .22$ ),  $F(1, 38) = 3.12$ ,  $p = .085$ ,  $\eta_p^2 = .08$ , *observed power* = .41.

Finally, there was a significant 3-way interaction between recall interval, study condition, and presentation rate,  $F(1, 38) = 8.46$ ,  $MSE = 0.14$ ,  $p = .006$ ,  $\eta_p^2 = .18$ , *observed power* = .81. In immediate conditions, under silence, there was no significant difference in the proportion of words participants recalled in serial position during the two-second ( $M = .84$ ,  $SD = .17$ ) and one-second presentation rates ( $M = .83$ ,  $SD = .16$ ),  $F(1, 38) = 0.35$ ,  $p = .555$ ,  $\eta_p^2 = .01$ , *observed power* = .09. In immediate conditions, under irrelevant speech, there was no significant difference in the proportion of words participants recalled in serial position during

the two-second ( $M = .80$ ,  $SD = .16$ ) and one-second presentation rates ( $M = .78$ ,  $SD = .18$ ),  $F(1, 38) = 1.41$ ,  $p = .243$ ,  $\eta_p^2 = .04$ , *observed power* = .21. In delayed conditions, under silence, participants recalled a significantly higher proportion of words in serial position during the two-second presentation rate ( $M = .64$ ,  $SD = .20$ ) compared with the one-second presentation rate ( $M = .50$ ,  $SD = .20$ ),  $F(1, 38) = 50.60$ ,  $p < .001$ ,  $\eta_p^2 = .57$ , *observed power* = 1.00. In delayed conditions, under irrelevant speech, there was no significant difference in the proportion of words participants recalled in serial position during the two-second ( $M = .61$ ,  $SD = .20$ ) and one-second presentation rates ( $M = .56$ ,  $SD = .21$ ),  $F(1, 38) = 0.03$ ,  $p = .860$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

In silence conditions, under the two-second presentation rate, participants recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .84$ ,  $SD = .17$ ) compared with after a delayed interval ( $M = .64$ ,  $SD = .20$ ),  $F(1, 38) = 96.41$ ,  $p < .001$ ,  $\eta_p^2 = .72$ , *observed power* = 1.00. In silence conditions, under the one-second presentation rate, participants recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .83$ ,  $SD = .16$ ) compared with after a delayed interval ( $M = .50$ ,  $SD = .20$ ),  $F(1, 38) = 246.88$ ,  $p < .001$ ,  $\eta_p^2 = .87$ , *observed power* = 1.00. In irrelevant speech conditions, under the two-second presentation rate, participants produced a significantly higher proportion of words in serial position during immediate conditions ( $M = .80$ ,  $SD = .16$ ) compared with after a delayed interval ( $M = .61$ ,  $SD = .20$ ),  $F(1, 38) = 83.43$ ,  $p < .001$ ,  $\eta_p^2 = .69$ , *observed power* = 1.00. In irrelevant speech conditions, under the one-second presentation rate, participants recalled a significantly higher proportion of words in serial position during immediate conditions ( $M = .78$ ,  $SD = .18$ ) compared with after a delayed interval ( $M = .56$ ,  $SD = .21$ ),  $F(1, 38) = 88.06$ ,  $p < .001$ ,  $\eta_p^2 = .70$ , *observed power* = 1.00.

In immediate conditions, under the two-second presentation rate, participants recalled a significantly higher proportion of words in serial position during the silence conditions ( $M = .84$ ,  $SD = .17$ ) compared with the irrelevant speech conditions ( $M = .80$ ,  $SD = .16$ ),  $F(1, 38) = 4.66$ ,  $p = .037$ ,  $\eta_p^2 = .11$ , *observed power* = .56. In immediate conditions, under the one-second presentation rate, participants recalled a significantly higher proportion of words in serial position during the silence conditions ( $M = .83$ ,  $SD = .16$ ) compared with the irrelevant speech conditions ( $M = .78$ ,  $SD = .18$ ),  $F(1, 38) = 7.49$ ,  $p = .009$ ,  $\eta_p^2 = .17$ , *observed power* = .76. In delayed conditions, under the two-second presentation rate, there was no significant difference in the proportion of words participants recalled in serial position during silence ( $M = .64$ ,  $SD = .20$ ) and irrelevant speech ( $M = .61$ ,  $SD = .20$ ),  $F(1, 38) = 1.06$ ,  $p = .051$ ,  $\eta_p^2 = .10$ , *observed power* = .50. In delayed conditions, under the one-second presentation rate, participants recalled a significantly higher proportion of words in serial position during the silence conditions ( $M = .56$ ,  $SD = .21$ ) compared with the irrelevant speech conditions ( $M = .50$ ,  $SD = .20$ ),  $F(1, 38) = 10.49$ ,  $p = .002$ ,  $\eta_p^2 = .22$ , *observed power* = .88.

### ***Item recall***

***Significant 2-way interactions.*** There was a significant 2-way interaction between presentation rate and age,  $F(1, 38) = 6.48$ ,  $MSE = 0.07$ ,  $p = .015$ ,  $\eta_p^2 = .15$ , *observed power* = .70. During the two-second presentation rate, there was no significant difference between young ( $M = .85$ ,  $SD = .10$ ) and older adults ( $M = .78$ ,  $SD = .11$ ) in the proportion of words recalled,  $F(1, 38) = 3.68$ ,  $p = .063$ ,  $\eta_p^2 = .09$ , *observed power* = .46. Similarly, during the one-second presentation rate, there was no significant difference between young ( $M = .79$ ,  $SD = .11$ ) and older adults ( $M = .77$ ,  $SD = .11$ ) in the proportion of words recalled,  $F(1, 38) = 0.35$ ,  $p = .558$ ,  $\eta_p^2 = .01$ , *observed power* = .09.

Young adults recalled a significantly higher proportion of words during the two-second presentation rate ( $M = .85$ ,  $SD = .10$ ) compared with the one-second presentation rate ( $M = .79$ ,  $SD = .11$ ),  $F(1, 38) = 20.70$ ,  $p < .001$ ,  $\eta_p^2 = .36$ , *observed power* = .99. However, for older adults, there was no significant difference in the proportion of words recalled during the two-second ( $M = .78$ ,  $SD = .11$ ) and one-second presentation rates ( $M = .77$ ,  $SD = .11$ ),  $F(1, 38) = 0.91$ ,  $p = .348$ ,  $\eta_p^2 = .02$ , *observed power* = .15.

There was a significant 2-way interaction between word relatedness and recall interval,  $F(1, 38) = 43.13$ ,  $MSE = 0.37$ ,  $p < .001$ ,  $\eta_p^2 = .53$ , *observed power* = 1.00. Participants recalled a significantly higher proportion of related words in immediate conditions ( $M = .93$ ,  $SD = .06$ ) compared with after a delayed interval ( $M = .79$ ,  $SD = .10$ ),  $F(1, 38) = 186.64$ ,  $p < .001$ ,  $\eta_p^2 = .83$ , *observed power* = 1.00. Participants recalled a significantly higher proportion of unrelated words in immediate conditions ( $M = .85$ ,  $SD = .13$ ) compared with after a delayed interval ( $M = .61$ ,  $SD = .17$ ),  $F(1, 38) = 180.01$ ,  $p < .001$ ,  $\eta_p^2 = .83$ , *observed power* = 1.00.

In immediate conditions, participants recalled a significantly higher proportion of related words ( $M = .93$ ,  $SD = .06$ ) compared with unrelated words ( $M = .85$ ,  $SD = .13$ ),  $F(1, 38) = 48.25$ ,  $p < .001$ ,  $\eta_p^2 = .56$ , *observed power* = 1.00. In delayed conditions, participants recalled a significantly higher proportion of related words ( $M = .79$ ,  $SD = .10$ ) compared with unrelated words ( $M = .61$ ,  $SD = .17$ ),  $F(1, 38) = 135.14$ ,  $p < .001$ ,  $\eta_p^2 = .78$ , *observed power* = 1.00.

There was also a significant 2-way interaction between recall interval and study condition,  $F(1, 38) = 5.28$ ,  $MSE = 0.04$ ,  $p = .027$ ,  $\eta_p^2 = .12$ , *observed power* = .61. In immediate conditions, participants recalled a significantly higher proportion of words during the silence conditions ( $M = .90$ ,  $SD = .10$ ) compared with the irrelevant speech conditions ( $M$



$= .88$ ,  $SD = .10$ ),  $F(1, 38) = 8.03$ ,  $p = .007$ ,  $\eta_p^2 = .18$ , *observed power* = .79. In delayed conditions, there was no significant difference in the proportion of words participants recalled during silence ( $M = .70$ ,  $SD = .13$ ) and irrelevant speech ( $M = .71$ ,  $SD = .14$ ),  $F(1, 38) = 0.81$ ,  $p = .373$ ,  $\eta_p^2 = .02$ , *observed power* = .14.

During silence, participants recalled a significantly higher proportion of words in immediate conditions ( $M = .90$ ,  $SD = .10$ ) than after a delayed interval ( $M = .70$ ,  $SD = .13$ ),  $F(1, 38) = 190.17$ ,  $p < .001$ ,  $\eta_p^2 = .84$ , *observed power* = 1.00. During irrelevant speech, participants recalled a significantly higher proportion of words in immediate conditions ( $M = .88$ ,  $SD = .10$ ) than after a delayed interval ( $M = .71$ ,  $SD = .14$ ),  $F(1, 38) = 156.93$ ,  $p < .001$ ,  $\eta_p^2 = .81$ , *observed power* = 1.00.

There was a significant 2-way interaction between recall interval and presentation rate,  $F(1, 38) = 17.98$ ,  $MSE = 0.15$ ,  $p < .001$ ,  $\eta_p^2 = .32$ , *observed power* = .99. In immediate conditions, there was no significant difference in the proportion of words participants recalled during the two-second ( $M = .89$ ,  $SD = .10$ ) and one-second presentation rates ( $M = .89$ ,  $SD = .09$ ),  $F(1, 38) = 0.09$ ,  $p = .768$ ,  $\eta_p^2 = .00$ , *observed power* = .06. In delayed conditions, participants recalled a significantly higher proportion of words during the one-second presentation rate ( $M = .74$ ,  $SD = .13$ ) compared with the two-second presentation rate ( $M = .67$ ,  $SD = .14$ ),  $F(1, 38) = 22.59$ ,  $p < .001$ ,  $\eta_p^2 = .38$ , *observed power* = 1.00.

During the two-second presentation rate, participants produced a higher proportion of words in immediate conditions ( $M = .89$ ,  $SD = .10$ ) compared with after a delayed interval ( $M = .74$ ,  $SD = .13$ ),  $F(1, 38) = 132.59$ ,  $p < .001$ ,  $\eta_p^2 = .78$ , *observed power* = 1.00. During the one-second presentation rate, participants produced a significantly higher proportion of words

in immediate conditions ( $M = .89$ ,  $SD = .09$ ) compared with after a delayed interval ( $M = .67$ ,  $SD = .14$ ),  $F(1, 38) = 210.07$ ,  $p < .001$ ,  $\eta_p^2 = .85$ , *observed power* = 1.00.

There was a significant 2-way interaction between study condition and presentation rate,  $F(1, 38) = 8.74$ ,  $MSE = 0.07$ ,  $p = .005$ ,  $\eta_p^2 = .19$ , *observed power* = .82. In the silence conditions, participants recalled a significantly higher proportion of words during the two-second presentation rate ( $M = .83$ ,  $SD = .11$ ) compared with the one-second presentation rate ( $M = .77$ ,  $SD = .11$ ),  $F(1, 38) = 20.33$ ,  $p < .001$ ,  $\eta_p^2 = .35$ , *observed power* = .99. In the irrelevant speech conditions, there was no significant difference in the proportion of words participants recalled during the two-second ( $M = .80$ ,  $SD = .12$ ) and one-second presentation rates ( $M = .79$ ,  $SD = .12$ ),  $F(1, 38) = 1.43$ ,  $p = .210$ ,  $\eta_p^2 = .04$ , *observed power* = .21.

During the two-second presentation rate, participants recalled a significantly higher proportion of words in the silence conditions ( $M = .83$ ,  $SD = .11$ ) compared with the irrelevant speech conditions ( $M = .80$ ,  $SD = .12$ ),  $F(1, 38) = 11.43$ ,  $p = .002$ ,  $\eta_p^2 = .23$ , *observed power* = .91. During the one-second presentation rate, there was no significant difference in the proportion of words participants recalled in silence ( $M = .77$ ,  $SD = .11$ ) and irrelevant speech ( $M = .79$ ,  $SD = .12$ ),  $F(1, 38) = 1.90$ ,  $p = .176$ ,  $\eta_p^2 = .05$ , *observed power* = .27.

**Significant 3-way interactions.** The 3-way interaction between recall interval, presentation rate, and age was significant,  $F(1, 38) = 4.23$ ,  $MSE = 0.04$ ,  $p = .047$ ,  $\eta_p^2 = .10$ , *observed power* = .52. In immediate conditions, during the two-second presentation rate, there was no significant difference between young adults ( $M = .91$ ,  $SD = .10$ ) and older adults ( $M = .87$ ,  $SD = .09$ ) in the proportion of words recalled,  $F(1, 38) = 2.16$ ,  $p = .150$ ,  $\eta_p^2 = .05$ , *observed power* = .30. In immediate conditions, during the one-second presentation rate, there was no significant difference between young ( $M = .90$ ,  $SD = .10$ ) and older adults ( $M = .87$ ,

$SD = .09$ ) in the proportion of words recalled,  $F(1, 38) = 1.10, p = .300, \eta_p^2 = .03, \text{observed power} = .18$ . In delayed conditions, during the two-second presentation rate, young adults ( $M = .78, SD = .11$ ) recalled a significantly higher proportion of words compared with older adults ( $M = .69, SD = .14$ ),  $F(1, 38) = 4.21, p = .047, \eta_p^2 = .10, \text{observed power} = .52$ . In delayed conditions, during the one-second presentation rate, there was no significant difference between young ( $M = .68, SD = .14$ ) and older adults ( $M = .67, SD = .14$ ) in the proportion of words recalled,  $F(1, 38) = 0.05, p = .824, \eta_p^2 = .00, \text{observed power} = .06$ .

Young adults, during the two-second presentation rate, recalled a significantly higher proportion of words in immediate conditions ( $M = .91, SD = .10$ ) than after a delayed interval ( $M = .78, SD = .11$ ),  $F(1, 38) = 50.52, p < .001, \eta_p^2 = .57, \text{observed power} = 1.00$ . Young adults, during the one-second presentation rate, recalled a significantly higher proportion of words in immediate conditions ( $M = .90, SD = .10$ ) than after a delayed interval ( $M = .68, SD = .14$ ),  $F(1, 38) = 115.71, p < .001, \eta_p^2 = .75, \text{observed power} = 1.00$ . Older adults, during the two-second presentation rate, recalled a significantly higher proportion of words in immediate conditions ( $M = .87, SD = .09$ ) than after a delayed interval ( $M = .69, SD = .14$ ),  $F(1, 38) = 84.21, p < .001, \eta_p^2 = .69, \text{observed power} = 1.00$ . Older adults, during the one-second presentation rate, recalled a significantly higher proportion of words in immediate conditions ( $M = .87, SD = .09$ ) than after a delayed interval ( $M = .67, SD = .14$ ),  $F(1, 38) = 94.88, p < .001, \eta_p^2 = .71, \text{observed power} = 1.00$ .

There was no significant difference for young adults, under immediate conditions, in the proportion of words recalled during the two-second ( $M = .91, SD = .10$ ) and one-second presentation rates ( $M = .90, SD = .10$ ),  $F(1, 38) = 0.62, p = .436, \eta_p^2 = .02, \text{observed power} = .12$ . However, young adults, under delayed conditions, recalled a significantly higher

proportion of words during the two-second presentation rate ( $M = .87$ ,  $SD = .09$ ) compared with the one-second presentation rate ( $M = .68$ ,  $SD = .14$ ),  $F(1, 38) = 27.94$ ,  $p < .001$ ,  $\eta_p^2 = .43$ , *observed power* = 1.00. Although, there was no significant difference for older adults, under immediate conditions, in the proportion of words recalled during the two-second ( $M = .87$ ,  $SD = .09$ ) and one-second presentation rates ( $M = .87$ ,  $SD = .09$ ),  $F(1, 38) = 0.14$ ,  $p = .715$ ,  $\eta_p^2 = .00$ , *observed power* = .07. Finally, there was no significant difference for older adults, under delayed conditions, in the proportion of words recalled during the two-second ( $M = .69$ ,  $SD = .14$ ) and the one-second presentation rates ( $M = .67$ ,  $SD = .14$ ),  $F(1, 38) = 2.06$ ,  $p = .159$ ,  $\eta_p^2 = .05$ , *observed power* = .29.

There was a significant 3-way interaction between word relatedness, study condition, and age,  $F(1, 38) = 5.41$ ,  $MSE = 0.04$ ,  $p = .025$ ,  $\eta_p^2 = .13$ , *observed power* = .62. When related words were presented during the silence conditions, there was no significant difference in the proportion of related words young ( $M = .89$ ,  $SD = .08$ ) and older adults ( $M = .84$ ,  $SD = .08$ ) recalled,  $F(1, 38) = 3.78$ ,  $p = .059$ ,  $\eta_p^2 = .09$ , *observed power* = .47. When related words were presented during the irrelevant speech conditions, there was no significant difference in the proportion of words young ( $M = .87$ ,  $SD = .08$ ) and older adults ( $M = .84$ ,  $SD = .08$ ) recalled,  $F(1, 38) = 0.84$ ,  $p = .364$ ,  $\eta_p^2 = .02$ , *observed power* = .15. Similarly, when unrelated words were presented during the silence conditions, young ( $M = .75$ ,  $SD = .14$ ) and older adults ( $M = .72$ ,  $SD = .14$ ) did not significantly differ in the proportion of words recalled,  $F(1, 38) = 0.46$ ,  $p = .501$ ,  $\eta_p^2 = .01$ , *observed power* = .10. When unrelated words were presented during the irrelevant speech conditions, young ( $M = .76$ ,  $SD = .14$ ) and older adults ( $M = .70$ ,  $SD = .14$ ) did not significantly differ in the proportion of words recalled,  $F(1, 38) = 2.32$ ,  $p = .136$ ,  $\eta_p^2 = .06$ , *observed power* = .32.

Young adults, during silence, recalled a significantly higher proportion of related words ( $M = .89$ ,  $SD = .08$ ) compared with unrelated words ( $M = .75$ ,  $SD = .14$ ),  $F(1, 38) = 55.26$ ,  $p < .001$ ,  $\eta_p^2 = .59$ , *observed power* = 1.00. Young adults, during irrelevant speech, recalled a significantly higher proportion of related words ( $M = .87$ ,  $SD = .08$ ) compared with unrelated words ( $M = .76$ ,  $SD = .14$ ),  $F(1, 38) = 30.50$ ,  $p < .001$ ,  $\eta_p^2 = .45$ , *observed power* = 1.00. Older adults, during silence, recalled a significantly higher proportion of related words ( $M = .84$ ,  $SD = .08$ ) compared with unrelated words ( $M = .72$ ,  $SD = .14$ ),  $F(1, 38) = 43.19$ ,  $p < .001$ ,  $\eta_p^2 = .53$ , *observed power* = 1.00. Older adults, during irrelevant speech, recalled a significantly higher proportion of related words ( $M = .84$ ,  $SD = .08$ ) compared with unrelated words ( $M = .70$ ,  $SD = .14$ ),  $F(1, 38) = 63.69$ ,  $p < .001$ ,  $\eta_p^2 = .62$ , *observed power* = 1.00.

Young adults recalled a significantly higher proportion of related words during silence conditions ( $M = .89$ ,  $SD = .08$ ) than irrelevant speech conditions ( $M = .87$ ,  $SD = .08$ ),  $F(1, 38) = 4.81$ ,  $p = .034$ ,  $\eta_p^2 = .11$ , *observed power* = .57. However, there was no significant difference for young adults in the proportion of unrelated words recalled during silence ( $M = .75$ ,  $SD = .14$ ) and irrelevant speech ( $M = .76$ ,  $SD = .14$ ),  $F(1, 38) = 1.71$ ,  $p = .199$ ,  $\eta_p^2 = .04$ , *observed power* = .25. There was no significant difference for older adults in the proportion of related words recalled during silence ( $M = .84$ ,  $SD = .08$ ) and irrelevant speech ( $M = .84$ ,  $SD = .08$ ),  $F(1, 38) = 0.01$ ,  $p = .911$ ,  $\eta_p^2 = .00$ , *observed power* = .05. There was no significant difference for older adults in the proportion of unrelated words recalled during silence ( $M = .72$ ,  $SD = .14$ ) and irrelevant speech ( $M = .70$ ,  $SD = .14$ ),  $F(1, 38) = 2.07$ ,  $p = .159$ ,  $\eta_p^2 = .05$ , *observed power* = .29.

Finally, there was a significant 3-way interaction between word relatedness, study condition, and presentation rate,  $F(1, 38) = 8.66$ ,  $MSE = 0.09$ ,  $p = .006$ ,  $\eta_p^2 = .19$ , *observed*

$power = .82$ . There was no significant difference in the proportion of related words participants recalled, under silence, during the two-second ( $M = .88$ ,  $SD = .10$ ) and one second presentation rates ( $M = .86$ ,  $SD = .08$ ),  $F(1, 38) = 1.49$ ,  $p = .230$ ,  $\eta_p^2 = .04$ , *observed power* = .22. There was no significant difference in the proportion of related words recalled, under irrelevant speech, during the two-second ( $M = .87$ ,  $SD = .09$ ) and one-second presentation rates ( $M = .84$ ,  $SD = .10$ ),  $F(1, 38) = 2.10$ ,  $p = .155$ ,  $\eta_p^2 = .05$ , *observed power* = .29. Participants recalled a significantly higher proportion of unrelated words, under silence, during the two-second presentation rate ( $M = .78$ ,  $SD = .14$ ) as opposed to the one-second presentation rate ( $M = .68$ ,  $SD = .16$ ),  $F(1, 38) = 29.81$ ,  $p < .001$ ,  $\eta_p^2 = .44$ , *observed power* = 1.00. There was no significant difference in the proportion of unrelated words recalled, under irrelevant speech, during the two-second ( $M = .73$ ,  $SD = .16$ ) and one-second presentation rates ( $M = .73$ ,  $SD = .16$ ),  $F(1, 38) = 0.03$ ,  $p = .876$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

There was no significant difference in the proportion of related words recalled, under the two-second presentation rate, during silence ( $M = .88$ ,  $SD = .10$ ) and irrelevant speech ( $M = .87$ ,  $SD = .09$ ),  $F(1, 38) = 0.73$ ,  $p = .400$ ,  $\eta_p^2 = .02$ , *observed power* = .13. There was also no significant difference in the proportion of related words recalled, under the one-second presentation rate, during silence ( $M = .86$ ,  $SD = .08$ ) and irrelevant speech ( $M = .84$ ,  $SD = .10$ ),  $F(1, 38) = 1.23$ ,  $p = .275$ ,  $\eta_p^2 = .03$ , *observed power* = .19. However, participants recalled a significantly higher proportion of unrelated words, under the two-second presentation rate, during silence conditions ( $M = .78$ ,  $SD = .14$ ) compared with irrelevant speech conditions ( $M = .73$ ,  $SD = .16$ ),  $F(1, 38) = 10.65$ ,  $p = .002$ ,  $\eta_p^2 = .22$ , *observed power* = .89. Similarly, participants recalled a significantly higher proportion of unrelated words, under the one-second presentation rate, during irrelevant speech conditions ( $M = .73$ ,  $SD = .16$ ) compared

with silence conditions ( $M = .68$ ,  $SD = .16$ ),  $F(1, 38) = 7.41$ ,  $p = .010$ ,  $\eta_p^2 = .16$ , *observed power* = .76.

In silence conditions, under the two-second presentation rate, participants recalled a significantly higher proportion of related words ( $M = .88$ ,  $SD = .10$ ) compared with unrelated words ( $M = .78$ ,  $SD = .14$ ),  $F(1, 38) = 39.44$ ,  $p < .001$ ,  $\eta_p^2 = .51$ , *observed power* = 1.00. In silence conditions, under the one-second presentation rate, participants recalled a significantly higher proportion of related words ( $M = .86$ ,  $SD = .08$ ) compared with unrelated words ( $M = .68$ ,  $SD = .16$ ),  $F(1, 38) = 102.05$ ,  $p < .001$ ,  $\eta_p^2 = .73$ , *observed power* = 1.00. In irrelevant speech conditions, under the two-second presentation rate, participants recalled a significantly higher proportion of related words ( $M = .87$ ,  $SD = .09$ ) compared with unrelated words ( $M = .73$ ,  $SD = .16$ ),  $F(1, 38) = 55.56$ ,  $p < .001$ ,  $\eta_p^2 = .59$ , *observed power* = 1.00. In irrelevant speech conditions, under the one-second presentation rate, participants recalled a significantly higher proportion of related words ( $M = .84$ ,  $SD = .10$ ) compared with unrelated words ( $M = .73$ ,  $SD = .16$ ),  $F(1, 38) = 31.83$ ,  $p < .001$ ,  $\eta_p^2 = .46$ , *observed power* = 1.00.

### ***Order accuracy***

***Significant 2-way interactions.*** There was a significant 2-way interaction between recall interval and study condition,  $F(1, 38) = 11.58$ ,  $MSE = 0.12$ ,  $p = .002$ ,  $\eta_p^2 = .23$ , *observed power* = .91. In immediate conditions, order accuracy was significantly higher when words were presented during the silence conditions ( $M = .92$ ,  $SD = .11$ ) compared with the irrelevant speech conditions ( $M = .89$ ,  $SD = .11$ ),  $F(1, 38) = 21.12$ ,  $p < .001$ ,  $\eta_p^2 = .36$ , *observed power* = .99. In delayed conditions, order accuracy did not significantly differ when words were presented during silence ( $M = .79$ ,  $SD = .15$ ) and irrelevant speech ( $M = .81$ ,  $SD = .15$ ),  $F(1, 38) = 2.10$ ,  $p = .156$ ,  $\eta_p^2 = .05$ , *observed power* = .29.

In silence conditions, order accuracy was significantly higher during immediate recall ( $M = .92$ ,  $SD = .11$ ) compared with after a delayed interval ( $M = .79$ ,  $SD = .15$ ),  $F(1, 38) = 93.57$ ,  $p < .001$ ,  $\eta_p^2 = .71$ , *observed power* = 1.00. In irrelevant speech conditions, order accuracy was significantly higher during immediate recall ( $M = .89$ ,  $SD = .11$ ) compared with after a delayed interval ( $M = .81$ ,  $SD = .15$ ),  $F(1, 38) = 27.94$ ,  $p < .001$ ,  $\eta_p^2 = .42$ , *observed power* = 1.00.

**Significant 3-way interactions.** There was a significant 3-way interaction between recall interval, study condition, and presentation rate,  $F(1, 38) = 8.66$ ,  $MSE = 0.13$ ,  $p = .006$ ,  $\eta_p^2 = .19$ , *observed power* = .82. In immediate conditions, under silence, there was no significant difference in order accuracy during the two-second ( $M = .92$ ,  $SD = .11$ ) and one-second presentation rates ( $M = .92$ ,  $SD = .11$ ),  $F(1, 38) = 0.00$ ,  $p = .988$ ,  $\eta_p^2 = .00$ , *observed power* = .05. In immediate conditions, under irrelevant speech, order accuracy was significantly higher during the two-second presentation rate ( $M = .91$ ,  $SD = .10$ ) compared with the one-second presentation rate ( $M = .87$ ,  $SD = .14$ ),  $F(1, 38) = 4.47$ ,  $p = .041$ ,  $\eta_p^2 = .11$ , *observed power* = .54. In delayed conditions, under silence, order accuracy was significantly higher during the two-second presentation rate ( $M = .84$ ,  $SD = .15$ ) compared with the one-second presentation rate ( $M = .73$ ,  $SD = .20$ ),  $F(1, 38) = 18.30$ ,  $p < .001$ ,  $\eta_p^2 = .33$ , *observed power* = .99. In delayed conditions, under irrelevant speech, there was no significant difference in order accuracy during the one-second ( $M = .79$ ,  $SD = .17$ ) and two-second presentation rates ( $M = .77$ ,  $SD = .14$ ),  $F(1, 38) = 1.86$ ,  $p = .181$ ,  $\eta_p^2 = .05$ , *observed power* = .26.

In silence conditions, under the two-second presentation rate, order accuracy was significantly higher in immediate conditions ( $M = .92$ ,  $SD = .11$ ) compared with after a delayed interval ( $M = .84$ ,  $SD = .15$ ),  $F(1, 38) = 40.51$ ,  $p < .001$ ,  $\eta_p^2 = .52$ , *observed power* =



1.00. In silence conditions, under the one-second presentation rate, order accuracy was significantly higher in immediate conditions ( $M = .92$ ,  $SD = .11$ ) compared with after a delayed interval ( $M = .73$ ,  $SD = .20$ ),  $F(1, 38) = 68.96$ ,  $p < .001$ ,  $\eta_p^2 = .65$ , *observed power* = 1.00. In irrelevant speech conditions, under the two-second presentation rate, order accuracy was significantly higher for immediate conditions ( $M = .91$ ,  $SD = .10$ ) compared with after a delayed interval ( $M = .82$ ,  $SD = .15$ ),  $F(1, 38) = 22.22$ ,  $p < .001$ ,  $\eta_p^2 = .37$ , *observed power* = 1.00. In irrelevant speech conditions, under the one-second presentation rate, order accuracy was significantly higher in immediate conditions ( $M = .87$ ,  $SD = .14$ ) compared with after a delayed interval ( $M = .79$ ,  $SD = .17$ ),  $F(1, 38) = 12.83$ ,  $p = .001$ ,  $\eta_p^2 = .25$ , *observed power* = .94.

In immediate conditions, under the two-second presentation rate, there was no significant difference in order accuracy during the silence ( $M = .92$ ,  $SD = .11$ ) and irrelevant speech conditions ( $M = .91$ ,  $SD = .10$ ),  $F(1, 38) = 0.95$ ,  $p = .336$ ,  $\eta_p^2 = .02$ , *observed power* = .16. In immediate conditions, under the one-second presentation rate, order accuracy was significantly higher during the silence ( $M = .92$ ,  $SD = .11$ ) than irrelevant speech conditions ( $M = .87$ ,  $SD = .14$ ),  $F(1, 38) = 11.44$ ,  $p = .002$ ,  $\eta_p^2 = .23$ , *observed power* = .91. In delayed conditions, under the two-second presentation rate, there was no significant difference in order accuracy during the silence ( $M = .84$ ,  $SD = .15$ ) and irrelevant speech conditions ( $M = .82$ ,  $SD = .15$ ),  $F(1, 38) = 0.87$ ,  $p = .358$ ,  $\eta_p^2 = .22$ , *observed power* = .15. However, in delayed conditions, under the one-second presentation rate, order accuracy was significantly higher during irrelevant speech ( $M = .79$ ,  $SD = .17$ ) than silence conditions ( $M = .73$ ,  $SD = .20$ ),  $F(1, 38) = 5.62$ ,  $p = .023$ ,  $\eta_p^2 = .13$ , *observed power* = .64.

### ***Transposition errors***

***Significant 2-way interaction.*** A significant 2-way interaction emerged between word relatedness and recall interval,  $F(1, 38) = 5.48$ ,  $MSE = 0.02$ ,  $p = .025$ ,  $\eta_p^2 = .13$ , *observed power* = .63. Participants produced a significantly higher proportion of transposition errors when related words were recalled after a delayed interval ( $M = .05$ ,  $SD = .03$ ) compared with immediate recall ( $M = .02$ ,  $SD = .03$ ),  $F(1, 38) = 14.99$ ,  $p < .001$ ,  $\eta_p^2 = .28$ , *observed power* = .97. However, there was no significant difference in the proportion of transposition errors participants produced when unrelated words were recalled immediately ( $M = .03$ ,  $SD = .03$ ) and after a delayed interval ( $M = .02$ ,  $SD = .03$ ),  $F(1, 38) = 0.31$ ,  $p = .581$ ,  $\eta_p^2 = .01$ , *observed power* = .08.

During immediate recall conditions, there was no significant difference in the proportion of transposition errors produced for related ( $M = .02$ ,  $SD = .03$ ) and unrelated words ( $M = .02$ ,  $SD = .03$ ),  $F(1, 38) = 0.08$ ,  $p = .782$ ,  $\eta_p^2 = .00$ , *observed power* = .06. During delayed recall conditions, however, participants produced a significantly higher proportion of transposition errors for related words ( $M = .05$ ,  $SD = .03$ ) compared with unrelated words ( $M = .03$ ,  $SD = .03$ ),  $F(1, 38) = 13.95$ ,  $p = .001$ ,  $\eta_p^2 = .27$ , *observed power* = .95.

***Significant 3-way interactions.*** There was a significant 3-way interaction between word relatedness, presentation rate, and age,  $F(1, 38) = 5.38$ ,  $MSE = 0.01$ ,  $p = .026$ ,  $\eta_p^2 = .12$ , *observed power* = .62. When related words were presented during the two-second rate, older adults ( $M = .05$ ,  $SD = .04$ ) produced a significantly higher proportion of transposition errors compared with young adults ( $M = .03$ ,  $SD = .02$ ),  $F(1, 38) = 4.91$ ,  $p = .033$ ,  $\eta_p^2 = .11$ , *observed power* = .58. However, when related words were presented during the one-second rate, there was no significant difference in the proportion of transposition errors young ( $M = .04$ ,  $SD =$

.03) and older adults produced during recall ( $M = .04$ ,  $SD = .03$ ),  $F(1, 38) = 0.00$ ,  $p = .949$ ,  $\eta_p^2 = .00$ , *observed power* = .05. When unrelated words were presented during the two-second rate, there was no significant difference in the proportion of transposition errors young ( $M = .02$ ,  $SD = .02$ ) and older adults ( $M = .02$ ,  $SD = .04$ ) produced during recall,  $F(1, 38) = 0.39$ ,  $p = .537$ ,  $\eta_p^2 = .01$ , *observed power* = .09. When unrelated words were presented during the one-second rate, older adults ( $M = .04$ ,  $SD = .02$ ) produced a significantly higher proportion of transposition errors during recall compared with young adults ( $M = .02$ ,  $SD = .02$ ),  $F(1, 38) = 5.99$ ,  $p = .019$ ,  $\eta_p^2 = .14$ , *observed power* = .66.

There was no significant difference in the proportion of transposition errors young adults produced, under the two-second presentation rate, for related ( $M = .03$ ,  $SD = .02$ ) and unrelated words ( $M = .02$ ,  $SD = .02$ ),  $F(1, 38) = 0.66$ ,  $p = .423$ ,  $\eta_p^2 = .02$ , *observed power* = .12. However, young adults, under the one-second presentation rate, produced a significantly higher proportion of transposition errors for related words ( $M = .04$ ,  $SD = .03$ ) compared with unrelated words ( $M = .02$ ,  $SD = .02$ ),  $F(1, 38) = 9.21$ ,  $p = .004$ ,  $\eta_p^2 = .20$ , *observed power* = .84. Older adults, under the two-second presentation rate, produced a significantly higher proportion of transposition errors for related words ( $M = .05$ ,  $SD = .04$ ) compared with unrelated words ( $M = .02$ ,  $SD = .04$ ),  $F(1, 38) = 5.59$ ,  $p = .023$ ,  $\eta_p^2 = .13$ , *observed power* = .64. However, there was no significant difference in the proportion of transposition errors older adults produced, under the one-second presentation rate, for related ( $M = .04$ ,  $SD = .03$ ) and unrelated words ( $M = .04$ ,  $SD = .02$ ),  $F(1, 38) = 0.03$ ,  $p = .871$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

There was no significant difference in the proportion of transposition errors young adults produced for related words during the two-second ( $M = .03$ ,  $SD = .02$ ) and one-second

presentation rates ( $M = .04$ ,  $SD = .03$ ),  $F(1, 38) = 3.42$ ,  $p = .072$ ,  $\eta_p^2 = .08$ , *observed power* = .44. There was also no significant difference in the proportion of transposition errors young adults produced for unrelated words during the two-second ( $M = .02$ ,  $SD = .02$ ) and one-second presentation rates ( $M = .02$ ,  $SD = .02$ ),  $F(1, 38) = 0.01$ ,  $p = .943$ ,  $\eta_p^2 = .00$ , *observed power* = .05. There was no significant difference in the proportion of transposition errors older adults produced for related words during the two-second ( $M = .05$ ,  $SD = .04$ ) and one-second presentation rates ( $M = .04$ ,  $SD = .03$ ),  $F(1, 38) = 0.59$ ,  $p = .446$ ,  $\eta_p^2 = .02$ , *observed power* = .12. There was no significant difference in the proportion of transposition errors older adults produced for unrelated words during the two-second ( $M = .02$ ,  $SD = .02$ ) and one-second presentation rates ( $M = .04$ ,  $SD = .02$ ),  $F(1, 38) = 2.71$ ,  $p = .108$ ,  $\eta_p^2 = .07$ , *observed power* = .36.

Finally, there was a significant 3-way interaction between recall interval, study condition, and presentation rate,  $F(1, 38) = 12.05$ ,  $MSE = 0.02$ ,  $p = .001$ ,  $\eta_p^2 = .24$ , *observed power* = .93. In immediate conditions, under silence, there was no significant difference in the proportion of transposition errors participants produced during the one-second ( $M = .02$ ,  $SD = .03$ ) and two-second presentation rates ( $M = .02$ ,  $SD = .03$ ),  $F(1, 38) = 0.17$ ,  $p = .687$ ,  $\eta_p^2 = .00$ , *observed power* = .07. In immediate conditions, under irrelevant speech, there was no significant difference in the proportion of transposition errors participants produced during the one-second ( $M = .04$ ,  $SD = .05$ ) and two-second presentation rates ( $M = .02$ ,  $SD = .03$ ),  $F(1, 38) = 2.86$ ,  $p = .099$ ,  $\eta_p^2 = .07$ , *observed power* = .38. In delayed conditions, under silence, participants produced a significantly higher proportion of transposition errors during the one-second presentation rate ( $M = .05$ ,  $SD = .04$ ) compared with the two-second presentation rate ( $M = .03$ ,  $SD = .04$ ),  $F(1, 38) = 4.51$ ,  $p = .040$ ,  $\eta_p^2 = .11$ , *observed power* = .54. In delayed

conditions, under irrelevant speech, there was no significant difference in the proportion of transposition errors participants produced during the one-second ( $M = .03$ ,  $SD = .03$ ) and two-second presentation rates ( $M = .04$ ,  $SD = .04$ ),  $F(1, 38) = 2.07$ ,  $p = .159$ ,  $\eta_p^2 = .05$ , *observed power* = .29.

In silence conditions, during the two-second presentation rate, participants produced a significantly higher proportion of transposition errors when recall was required after a delayed interval ( $M = .03$ ,  $SD = .04$ ) compared with immediate recall ( $M = .02$ ,  $SD = .03$ ),  $F(1, 38) = 4.47$ ,  $p = .041$ ,  $\eta_p^2 = .11$ , *observed power* = .54. In silence conditions, during the one-second presentation rate, participants produced a significantly higher proportion of transposition errors when recall was required after a delayed interval ( $M = .05$ ,  $SD = .04$ ) compared with immediate recall ( $M = .02$ ,  $SD = .03$ ),  $F(1, 38) = 11.39$ ,  $p = .002$ ,  $\eta_p^2 = .23$ , *observed power* = .91. In irrelevant speech conditions, during the two-second presentation rate, participants produced a significantly higher proportion of transposition errors when recall was required after a delayed interval ( $M = .04$ ,  $SD = .04$ ) compared with immediate recall ( $M = .02$ ,  $SD = .03$ ),  $F(1, 38) = 14.12$ ,  $p = .001$ ,  $\eta_p^2 = .27$ , *observed power* = .96. In irrelevant speech conditions, under the one-second presentation rate, however, there was no significant difference in the proportion of transposition errors produced in immediate recall conditions ( $M = .04$ ,  $SD = .05$ ) and when recall was required after a delayed interval ( $M = .03$ ,  $SD = .03$ ),  $F(1, 38) = 0.39$ ,  $p = .535$ ,  $\eta_p^2 = .01$ , *observed power* = .09.

In immediate recall conditions, during the two-second presentation rate, there was no significant difference in the proportion of transposition errors produced in the silence ( $M = .02$ ,  $SD = .03$ ) and irrelevant speech conditions ( $M = .02$ ,  $SD = .03$ ),  $F(1, 38) = 0.12$ ,  $p = .734$ ,  $\eta_p^2 = .00$ , *observed power* = .06. Similarly, in immediate recall conditions, during the one-

second presentation rate, there was no significant difference in the proportion of transposition errors produced in the silence ( $M = .02$ ,  $SD = .03$ ) and irrelevant speech conditions ( $M = .04$ ,  $SD = .05$ ),  $F(1, 38) = 3.46$ ,  $p = .071$ ,  $\eta_p^2 = .08$ , *observed power* = .44. In delayed recall conditions, during the two-second presentation rate, there was no significant difference in the proportion of transposition errors produced under silence ( $M = .03$ ,  $SD = .03$ ) and irrelevant speech ( $M = .04$ ,  $SD = .04$ ),  $F(1, 38) = 2.45$ ,  $p = .126$ ,  $\eta_p^2 = .06$ , *observed power* = .33. In delayed recall conditions, during the one-second presentation rate, participants produced a significantly higher proportion of transposition errors in the silence conditions ( $M = .05$ ,  $SD = .04$ ) compared with the irrelevant speech conditions ( $M = .03$ ,  $SD = .03$ ),  $F(1, 38) = 4.15$ ,  $p = .049$ ,  $\eta_p^2 = .10$ , *observed power* = .51.

### ***Omission errors***

***Significant 2-way interactions.*** A significant 2-way interaction emerged between word relatedness and recall interval,  $F(1, 38) = 44.40$ ,  $MSE = 0.37$ ,  $p < .001$ ,  $\eta_p^2 = .54$ , *observed power* = 1.00. Participants omitted a significantly higher proportion of related words when recall was required after a delayed interval ( $M = .16$ ,  $SD = .09$ ) compared with immediate recall ( $M = .05$ ,  $SD = .06$ ),  $F(1, 38) = 116.06$ ,  $p < .001$ ,  $\eta_p^2 = .75$ , *observed power* = 1.00. Similarly, participants omitted a significantly higher proportion of unrelated words when recall was required after a delayed interval ( $M = .32$ ,  $SD = .17$ ) compared with immediate recall ( $M = .12$ ,  $SD = .11$ ),  $F(1, 38) = 127.80$ ,  $p < .001$ ,  $\eta_p^2 = .77$ , *observed power* = 1.00.

In immediate recall conditions, participants omitted a significantly higher proportion of unrelated words ( $M = .12$ ,  $SD = .11$ ) compared with related words ( $M = .05$ ,  $SD = .06$ ),  $F(1, 38) = 27.47$ ,  $p < .001$ ,  $\eta_p^2 = .42$ , *observed power* = 1.00. In delayed recall conditions, participants also omitted a significantly higher proportion of unrelated words ( $M = .32$ ,  $SD =$

.17) compared with related words ( $M = .16$ ,  $SD = .09$ ),  $F(1, 38) = 90.73$ ,  $p < .001$ ,  $\eta_p^2 = .71$ , *observed power* = 1.00.

A significant 2-way interaction also emerged between presentation rate and age,  $F(1, 38) = 4.73$ ,  $MSE = 0.05$ ,  $p = .036$ ,  $\eta_p^2 = .11$ , *observed power* = .56. During the two-second presentation rate, there was no significant difference in the proportion of words young ( $M = .13$ ,  $SD = .10$ ) and older adults ( $M = .18$ ,  $SD = .10$ ) omitted during recall,  $F(1, 38) = 1.86$ ,  $p = .180$ ,  $\eta_p^2 = .05$ , *observed power* = .27. Similarly, during the one-second presentation rate, there was no significant difference in the proportion of words young ( $M = .18$ ,  $SD = .11$ ) and older adults ( $M = .18$ ,  $SD = .10$ ) omitted during recall,  $F(1, 38) = 0.02$ ,  $p = .880$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

Young adults omitted a significantly higher proportion of words during the one-second presentation rate ( $M = .18$ ,  $SD = .11$ ) compared with the two-second presentation rate ( $M = .13$ ,  $SD = .10$ ),  $F(1, 38) = 14.44$ ,  $p < .001$ ,  $\eta_p^2 = .28$ , *observed power* = .96. For older adults, however, there was no significant difference in the proportion of words omitted during the two-second ( $M = .18$ ,  $SD = .10$ ) and one-second presentation rates ( $M = .18$ ,  $SD = .10$ ),  $F(1, 38) = 0.52$ ,  $p = .440$ ,  $\eta_p^2 = .02$ , *observed power* = .12.

There was a significant 2-way interaction between recall interval and study condition,  $F(1, 38) = 7.37$ ,  $MSE = 0.05$ ,  $p = .010$ ,  $\eta_p^2 = .16$ , *observed power* = .75. In immediate recall conditions, participants omitted a significantly higher proportion words during the irrelevant speech conditions ( $M = .10$ ,  $SD = .08$ ) compared with the silence conditions ( $M = .08$ ,  $SD = .08$ ),  $F(1, 38) = 6.03$ ,  $p = .019$ ,  $\eta_p^2 = .14$ , *observed power* = .67. In delayed recall conditions, there was no significant difference in the proportion of words omitted during the silence ( $M =$

.25,  $SD = .12$ ) and irrelevant speech conditions ( $M = .23$ ,  $SD = .13$ ),  $F(1, 38) = 2.33$ ,  $p = .135$ ,  $\eta_p^2 = .06$ , *observed power* = .32.

In silence conditions, participants omitted a significantly higher proportion of words after a delayed interval ( $M = .25$ ,  $SD = .12$ ) compared with immediate recall ( $M = .08$ ,  $SD = .08$ ),  $F(1, 38) = 138.98$ ,  $p < .001$ ,  $\eta_p^2 = .79$ , *observed power* = 1.00. In irrelevant speech conditions, participants omitted a significantly higher proportion of words after a delayed interval ( $M = .23$ ,  $SD = .13$ ) compared with immediate recall ( $M = .10$ ,  $SD = .08$ ),  $F(1, 38) = 100.26$ ,  $p < .001$ ,  $\eta_p^2 = .73$ , *observed power* = 1.00.

There was a significant 2-way interaction between recall interval and presentation rate,  $F(1, 38) = 30.10$ ,  $MSE = 0.17$ ,  $p < .001$ ,  $\eta_p^2 = .44$ , *observed power* = 1.00. In immediate recall conditions, there was no significant difference in the proportion of words omitted during the one-second ( $M = .08$ ,  $SD = .08$ ) and two-second presentation rates ( $M = .09$ ,  $SD = .09$ ),  $F(1, 38) = 0.37$ ,  $p = .549$ ,  $\eta_p^2 = .01$ , *observed power* = .09. In delayed recall conditions, participants omitted a significantly higher proportion of words during the one-second presentation rate ( $M = .27$ ,  $SD = .14$ ) compared with the two-second presentation rate ( $M = .21$ ,  $SD = .13$ ),  $F(1, 38) = 27.63$ ,  $p < .001$ ,  $\eta_p^2 = .42$ , *observed power* = 1.00.

During the two-second presentation rate, participants omitted a significantly higher proportion of words after a delayed interval ( $M = .21$ ,  $SD = .13$ ) than in immediate recall conditions ( $M = .09$ ,  $SD = .09$ ),  $F(1, 38) = 78.60$ ,  $p < .001$ ,  $\eta_p^2 = .67$ , *observed power* = 1.00. During the one-second presentation rate, participants omitted a significantly higher proportion of words after a delayed interval ( $M = .27$ ,  $SD = .14$ ) than in immediate recall conditions ( $M = .08$ ,  $SD = .08$ ),  $F(1, 38) = 177.61$ ,  $p < .001$ ,  $\eta_p^2 = .82$ , *observed power* = 1.00.



Finally, there was a significant 2-way interaction between study condition and presentation rate,  $F(1, 38) = 5.69$ ,  $MSE = 0.05$ ,  $p = .022$ ,  $\eta_p^2 = .13$ , *observed power* = .64. In the silence conditions, participants omitted a significantly higher proportion of words during the one-second presentation rate ( $M = .19$ ,  $SD = .11$ ) compared with the two-second presentation rate ( $M = .14$ ,  $SD = .10$ ),  $F(1, 38) = 14.29$ ,  $p = .001$ ,  $\eta_p^2 = .27$ , *observed power* = .96. In the irrelevant speech conditions, there was no significant difference in the proportion of words participants omitted during the one-second ( $M = .17$ ,  $SD = .11$ ) and the two-second presentation rates ( $M = .16$ ,  $SD = .11$ ),  $F(1, 38) = 1.04$ ,  $p = .314$ ,  $\eta_p^2 = .03$ , *observed power* = .17.

During the two-second presentation rate, participants omitted a significantly higher proportion of words in the silence conditions ( $M = .16$ ,  $SD = .11$ ) compared with the irrelevant speech conditions ( $M = .14$ ,  $SD = .10$ ),  $F(1, 38) = 5.39$ ,  $p = .026$ ,  $\eta_p^2 = .12$ , *observed power* = .62. During the one-second presentation rate, there was no significant difference in the proportion of words participants omitted under silence ( $M = .19$ ,  $SD = .11$ ) and irrelevant speech ( $M = .17$ ,  $SD = .11$ ),  $F(1, 38) = 1.80$ ,  $p = .187$ ,  $\eta_p^2 = .05$ , *observed power* = .26.

**Significant 3-way interaction.** A significant 3-way interaction emerged between word relatedness, study condition, and presentation rate,  $F(1, 38) = 8.22$ ,  $MSE = 0.06$ ,  $p = .007$ ,  $\eta_p^2 = .18$ , *observed power* = .80. For related words presented in the silence conditions, there was no significant difference in the proportion of words participants omitted during the one-second ( $M = .11$ ,  $SD = .07$ ) and two-second presentation rates ( $M = .10$ ,  $SD = .09$ ),  $F(1, 38) = 1.74$ ,  $p = .195$ ,  $\eta_p^2 = .04$ , *observed power* = .25. When related words were presented in the irrelevant speech conditions, there was no significant difference in the proportion of words participants omitted during the one-second ( $M = .12$ ,  $SD = .09$ ) and two-second presentation rates ( $M =$

.10,  $SD = .09$ ),  $F(1, 38) = 2.76$ ,  $p = .105$ ,  $\eta_p^2 = .07$ , *observed power* = .37. For unrelated words presented in the silence conditions, participants omitted a significantly higher proportion of words during the one-second presentation rate ( $M = .26$ ,  $SD = .15$ ) compared with the two-second presentation rate ( $M = .19$ ,  $SD = .13$ ),  $F(1, 38) = 17.58$ ,  $p < .001$ ,  $\eta_p^2 = .32$ , *observed power* = .98. When unrelated words were presented in the irrelevant speech conditions, there was no significant difference in the proportion of words participants omitted during the one-second ( $M = .22$ ,  $SD = .15$ ) and two-second presentation rates ( $M = .22$ ,  $SD = .14$ ),  $F(1, 38) = 0.00$ ,  $p = .971$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

For related words presented during the two-second rate, there was no significant difference in the proportion of omissions participants made during the silence ( $M = .10$ ,  $SD = .09$ ) and irrelevant speech conditions ( $M = .10$ ,  $SD = .09$ ),  $F(1, 38) = 0.12$ ,  $p = .735$ ,  $\eta_p^2 = .00$ , *observed power* = .06. Similarly, for related words presented during the one-second rate, there was no significant difference in the proportion of omissions participants made during the silence ( $M = .11$ ,  $SD = .07$ ) and irrelevant speech conditions ( $M = .12$ ,  $SD = .09$ ),  $F(1, 38) = 0.56$ ,  $p = .457$ ,  $\eta_p^2 = .02$ , *observed power* = .11. For unrelated words presented during the two-second rate, participants made a significantly higher proportion of omissions during the irrelevant speech conditions ( $M = .22$ ,  $SD = .14$ ) compared with the silence conditions ( $M = .19$ ,  $SD = .13$ ),  $F(1, 38) = 6.92$ ,  $p = .012$ ,  $\eta_p^2 = .15$ , *observed power* = .73. For unrelated words presented during the one-second rate, participants made a significantly higher proportion of omissions errors during the irrelevant speech conditions ( $M = .26$ ,  $SD = .15$ ) compared with the silence conditions ( $M = .22$ ,  $SD = .15$ ),  $F(1, 38) = 5.96$ ,  $p = .019$ ,  $\eta_p^2 = .14$ , *observed power* = .66.

In silence conditions, during the two-second presentation rate, participants omitted a significantly higher proportion of unrelated words ( $M = .19$ ,  $SD = .13$ ) compared with related words ( $M = .10$ ,  $SD = .09$ ),  $F(1, 38) = 26.74$ ,  $p < .001$ ,  $\eta_p^2 = .41$ , *observed power* = 1.00.

Similarly, in silence conditions, during the one-second presentation rate, participants omitted a significantly higher proportion of unrelated words ( $M = .26$ ,  $SD = .15$ ) compared with related words ( $M = .11$ ,  $SD = .07$ ),  $F(1, 38) = 64.36$ ,  $p < .001$ ,  $\eta_p^2 = .63$ , *observed power* = 1.00. In

irrelevant speech conditions, during the two-second presentation rate, participants omitted a significantly higher proportion of unrelated words ( $M = .22$ ,  $SD = .14$ ) compared with related words ( $M = .12$ ,  $SD = .09$ ),  $F(1, 38) = 52.26$ ,  $p < .001$ ,  $\eta_p^2 = .58$ , *observed power* = 1.00. In

irrelevant speech conditions, during the one-second presentation rate, participants omitted a significantly higher proportion of unrelated words ( $M = .22$ ,  $SD = .15$ ) compared with related words ( $M = .11$ ,  $SD = .07$ ),  $F(1, 38) = 27.15$ ,  $p < .001$ ,  $\eta_p^2 = .42$ , *observed power* = 1.00.

## **Appendix C – 4.2: Non-significant interactions**

### **Correct-in-position recall**

**Non-significant main effect.** The remaining main effects were not significant: study condition,  $F(1, 38) = 2.83$ ,  $MSE = 0.40$ ,  $p = .101$ ,  $\eta_p^2 = .07$ , *observed power* = .38; and age,  $F(1, 38) = 3.53$ ,  $MSE = 1.40$ ,  $p = .068$ ,  $\eta_p^2 = .09$ , *observed power* = .45.

**Non-significant 2-way interactions.** The remaining 2-way interactions were not significant: word relatedness and age,  $F(1, 38) = 0.41$ ,  $MSE = 0.00$ ,  $p = .841$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval and age,  $F(1, 38) = 0.05$ ,  $MSE = 0.00$ ,  $p = .818$ ,  $\eta_p^2 = .00$ , *observed power* = .06; study condition and age,  $F(1, 38) = 0.22$ ,  $MSE = 0.00$ ,  $p = .645$ ,  $\eta_p^2 = .01$ , *observed power* = .07; word relatedness and age,  $F(1, 38) = 0.86$ ,  $MSE = 0.01$ ,  $p = .360$ ,  $\eta_p^2 = .02$ , *observed power* = .15; word relatedness and study condition,  $F(1, 38) = 0.03$ ,  $MSE = 0.00$ ,  $p = .860$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word relatedness and presentation rate,  $F(1, 38) = 2.62$ ,  $MSE = 0.04$ ,  $p = .114$ ,  $\eta_p^2 = .07$ , *observed power* = .35; and between study condition and presentation rate,  $F(1, 38) = 4.10$ ,  $MSE = 0.08$ ,  $p = .050$ ,  $\eta_p^2 = .10$ , *observed power* = .51.

**Non-significant 3-way interactions.** The remaining 3-way interactions were not significant: word relatedness, recall interval, and age,  $F(1, 38) = 1.90$ ,  $MSE = 0.03$ ,  $p = .176$ ,  $\eta_p^2 = .05$ , *observed power* = .27; word relatedness, study condition, and age,  $F(1, 38) = 3.64$ ,  $MSE = 0.05$ ,  $p = .064$ ,  $\eta_p^2 = .09$ , *observed power* = .46; recall interval, study condition, and age,  $F(1, 38) = 1.99$ ,  $MSE = 0.02$ ,  $p = .167$ ,  $\eta_p^2 = .05$ , *observed power* = .28; word relatedness, presentation rate, and age,  $F(1, 38) = 1.33$ ,  $MSE = 0.02$ ,  $p = .255$ ,  $\eta_p^2 = .03$ , *observed power* = .20; word relatedness, recall interval, and presentation rate,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .930$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between study condition, presentation rate, and age,

$F(1, 38) = 2.42$ ,  $MSE = 0.04$ ,  $p = .128$ ,  $\eta_p^2 = .06$ , *observed power* = .33; and between word relatedness, study condition, and presentation rate,  $F(1, 38) = 3.79$ ,  $MSE = 0.07$ ,  $p = .059$ ,  $\eta_p^2 = .10$ , *observed power* = .48.

***Non-significant 4-way interactions.*** All 4-way interactions were not significant: word relatedness, recall interval, study condition, and age,  $F(1, 38) = 1.34$ ,  $MSE = 0.02$ ,  $p = .254$ ,  $\eta_p^2 = .03$ , *observed power* = .20; word relatedness, recall interval, presentation rate, and age,  $F(1, 38) = 0.34$ ,  $MSE = 0.01$ ,  $p = .562$ ,  $\eta_p^2 = .01$ , *observed power* = .09; word relatedness, study condition, presentation rate, and age,  $F(1, 38) = 0.80$ ,  $MSE = 0.01$ ,  $p = .378$ ,  $\eta_p^2 = .02$ , *observed power* = .14; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 0.89$ ,  $MSE = 0.02$ ,  $p = .352$ ,  $\eta_p^2 = .02$ , *observed power* = .15; and between word relatedness, recall interval, study condition, and presentation rate,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .943$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

***Non-significant 5-way interaction.*** The 5-way interaction between word relatedness, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.03$ ,  $MSE = 0.00$ ,  $p = .871$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

### ***Item recall***

***Non-significant main effects.*** The remaining main effects were not significant: study condition,  $F(1, 38) = 1.27$ ,  $MSE = 0.01$ ,  $p = .267$ ,  $\eta_p^2 = .03$ , *observed power* = .20; and age,  $F(1, 38) = 1.64$ ,  $MSE = 0.02$ ,  $p = .208$ ,  $\eta_p^2 = .04$ , *observed power* = .24.

***Non-significant 2-way interactions.*** The remaining 2-way interactions were not significant: word relatedness and age,  $F(1, 38) = 0.38$ ,  $MSE = 0.01$ ,  $p = .543$ ,  $\eta_p^2 = .01$ , *observed power* = .09; recall interval and age,  $F(1, 38) = 0.13$ ,  $MSE = 0.00$ ,  $p = .717$ ,  $\eta_p^2 = .00$ ,

*observed power* = .07; study condition and age,  $F(1, 38) = 0.44$ ,  $MSE = 0.00$ ,  $p = .510$ ,  $\eta_p^2 = .01$ , *observed power* = .10; word relatedness and study condition,  $F(1, 38) = 0.78$ ,  $MSE = 0.01$ ,  $p = .382$ ,  $\eta_p^2 = .02$ , *observed power* = .14; and between word relatedness and presentation rate,  $F(1, 38) = 2.98$ ,  $MSE = 0.04$ ,  $p = .093$ ,  $\eta_p^2 = .07$ , *observed power* = .39.

***Non-significant 3-way interactions.*** The remaining 3-way interactions were not significant: word relatedness, recall interval, and age,  $F(1, 38) = 0.53$ ,  $MSE = 0.01$ ,  $p = .473$ ,  $\eta_p^2 = .01$ , *observed power* = .11, recall interval, study condition, and age,  $F(1, 38) = 0.70$ ,  $MSE = 0.01$ ,  $p = .407$ ,  $\eta_p^2 = .02$ , *observed power* = .13; word relatedness, recall interval, and study condition,  $F(1, 38) = 2.61$ ,  $MSE = 0.02$ ,  $p = .115$ ,  $\eta_p^2 = .06$ , *observed power* = .35; word relatedness, presentation rate, and age,  $F(1, 38) = 0.22$ ,  $MSE = 0.00$ ,  $p = .643$ ,  $\eta_p^2 = .01$ , *observed power* = .07; word relatedness, recall interval, and presentation rate,  $F(1, 38) = 0.09$ ,  $MSE = 0.00$ ,  $p = .764$ ,  $\eta_p^2 = .00$ , *observed power* = .06; study condition, presentation rate, and age,  $F(1, 38) = 1.38$ ,  $MSE = 0.01$ ,  $p = .248$ ,  $\eta_p^2 = .04$ , *observed power* = .21; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 2.26$ ,  $MSE = 0.02$ ,  $p = .141$ ,  $\eta_p^2 = .06$ , *observed power* = .31.

***Non-significant 4-way interactions.*** All 4-way interactions were not significant: word relatedness, recall interval, study condition, and age,  $F(1, 38) = 1.23$ ,  $MSE = 0.01$ ,  $p = .275$ ,  $\eta_p^2 = .03$ , *observed power* = .19; word relatedness, recall interval, presentation rate, and age,  $F(1, 38) = 0.31$ ,  $MSE = 0.00$ ,  $p = .583$ ,  $\eta_p^2 = .01$ , *observed power* = .08; word relatedness, study condition, presentation rate, and age,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .939$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 1.22$ ,  $MSE = 0.01$ ,  $p = .276$ ,  $\eta_p^2 = .03$ , *observed power* = .19; and between word relatedness,

recall interval, study condition, and presentation rate,  $F(1, 38) = 1.59$ ,  $MSE = 0.01$ ,  $p = .216$ ,  $\eta_p^2 = .04$ , *observed power* = .23.

***Non-significant 5-way interaction.*** The 5-way interaction between word relatedness, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.37$ ,  $MSE = 0.00$ ,  $p = .549$ ,  $\eta_p^2 = .01$ , *observed power* = .09.

### ***Order accuracy***

***Non-significant main effects.*** The remaining main effects were not significant: word relatedness,  $F(1, 38) = 1.18$ ,  $MSE = 0.03$ ,  $p = .285$ ,  $\eta_p^2 = .03$ , *observed power* = .19; study condition,  $F(1, 38) = 0.40$ ,  $MSE = 0.01$ ,  $p = .534$ ,  $\eta_p^2 = .01$ , *observed power* = .09; and age,  $F(1, 38) = 3.95$ ,  $MSE = 0.55$ ,  $p = .054$ ,  $\eta_p^2 = .09$ , *observed power* = .49.

***Non-significant 2-way interactions.*** The remaining 2-way interactions were not significant: word relatedness and age,  $F(1, 38) = 0.23$ ,  $MSE = 0.01$ ,  $p = .638$ ,  $\eta_p^2 = .01$ , *observed power* = .08; recall interval and age,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .945$ ,  $\eta_p^2 = .00$ , *observed power* = .05; study condition and age,  $F(1, 38) = 1.57$ ,  $MSE = 0.02$ ,  $p = .218$ ,  $\eta_p^2 = .04$ , *observed power* = .23; presentation rate and age,  $F(1, 38) = 2.50$ ,  $MSE = 0.06$ ,  $p = .122$ ,  $\eta_p^2 = .06$ , *observed power* = .34; word relatedness and recall interval,  $F(1, 38) = 0.22$ ,  $MSE = 0.00$ ,  $p = .649$ ,  $\eta_p^2 = .01$ , *observed power* = .07; word relatedness and study condition,  $F(1, 38) = 0.02$ ,  $MSE = 0.00$ ,  $p = .882$ ,  $\eta_p^2 = .00$ , *observed power* = .05; word relatedness and presentation rate,  $F(1, 38) = 1.05$ ,  $MSE = 0.01$ ,  $p = .312$ ,  $\eta_p^2 = .03$ , *observed power* = .17; study condition and presentation rate,  $F(1, 38) = 0.79$ ,  $MSE = 0.01$ ,  $p = .381$ ,  $\eta_p^2 = .02$ , *observed power* = .14; and between recall interval and presentation rate,  $F(1, 38) = 0.09$ ,  $MSE = 0.00$ ,  $p = .771$ ,  $\eta_p^2 = .00$ , *observed power* = .06.

**Non-significant 3-way interactions.** The remaining 3-way interactions were not significant: word relatedness, recall interval, and age,  $F(1, 38) = 1.43$ ,  $MSE = 0.02$ ,  $p = .238$ ,  $\eta_p^2 = .04$ , *observed power* = .22; word relatedness, study condition, and age,  $F(1, 38) = 2.30$ ,  $MSE = 0.03$ ,  $p = .138$ ,  $\eta_p^2 = .06$ , *observed power* = .32; recall interval, study condition, and age,  $F(1, 38) = 1.61$ ,  $MSE = 0.02$ ,  $p = .213$ ,  $\eta_p^2 = .04$ , *observed power* = .24; word relatedness, recall interval, and study condition,  $F(1, 38) = 3.35$ ,  $MSE = 0.05$ ,  $p = .075$ ,  $\eta_p^2 = .08$ , *observed power* = .43; word relatedness, presentation rate, and age,  $F(1, 38) = 2.26$ ,  $MSE = 0.02$ ,  $p = .141$ ,  $\eta_p^2 = .06$ , *observed power* = .31; recall interval, presentation rate, and age,  $F(1, 38) = 2.71$ ,  $MSE = 0.03$ ,  $p = .108$ ,  $\eta_p^2 = .07$ , *observed power* = .36; word relatedness, recall interval, and presentation rate,  $F(1, 38) = 0.16$ ,  $MSE = 0.00$ ,  $p = .696$ ,  $\eta_p^2 = .00$ , *observed power* = .07; study condition, presentation rate, and age,  $F(1, 38) = 1.02$ ,  $MSE = 0.02$ ,  $p = .319$ ,  $\eta_p^2 = .03$ , *observed power* = .17; word relatedness, study condition, and presentation rate,  $F(1, 38) = 0.06$ ,  $MSE = 0.00$ ,  $p = .803$ ,  $\eta_p^2 = .00$ , *observed power* = .06.

**Non-significant 4-way interactions.** The remaining 4-way interactions were not significant: word relatedness, recall interval, study condition, and age,  $F(1, 38) = 0.52$ ,  $MSE = 0.01$ ,  $p = .477$ ,  $\eta_p^2 = .01$ , *observed power* = .11; word relatedness, recall interval, presentation rate, and age,  $F(1, 38) = 1.27$ ,  $MSE = 0.02$ ,  $p = .266$ ,  $\eta_p^2 = .03$ , *observed power* = .20; word relatedness, study condition, presentation rate, and age,  $F(1, 38) = 2.49$ ,  $MSE = 0.05$ ,  $p = .123$ ,  $\eta_p^2 = .06$ , *observed power* = .34; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 0.15$ ,  $MSE = 0.00$ ,  $p = .702$ ,  $\eta_p^2 = .00$ , *observed power* = .07; and between word relatedness, recall interval, study condition, and presentation rate,  $F(1, 38) = 0.09$ ,  $MSE = 0.00$ ,  $p = .771$ ,  $\eta_p^2 = .00$ , *observed power* = .06.



**Non-significant 5-way interaction.** The 5-way interaction between word relatedness, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.18$ ,  $MSE = 0.00$ ,  $p = .673$ ,  $\eta_p^2 = .01$ , *observed power* = .07.

### ***Transposition errors***

**Non-significant main effects.** The remaining main effects were not significant: study condition,  $F(1, 38) = 0.47$ ,  $MSE = 0.00$ ,  $p = .499$ ,  $\eta_p^2 = .01$ , *observed power* = .10; presentation rate,  $F(1, 38) = 1.56$ ,  $MSE = 0.01$ ,  $p = .219$ ,  $\eta_p^2 = .04$ , *observed power* = .23.

**Non-significant 2-way interactions.** The remaining 2-way interactions were not significant: word relatedness and age,  $F(1, 38) = 0.17$ ,  $MSE = 0.00$ ,  $p = .682$ ,  $\eta_p^2 = .00$ , *observed power* = .07; recall interval and age,  $F(1, 38) = 0.44$ ,  $MSE = 0.00$ ,  $p = .513$ ,  $\eta_p^2 = .01$ , *observed power* = .10; study condition and age,  $F(1, 38) = 0.59$ ,  $MSE = 0.00$ ,  $p = .447$ ,  $\eta_p^2 = .02$ , *observed power* = .12; presentation rate and age,  $F(1, 38) = 0.12$ ,  $MSE = 0.00$ ,  $p = .731$ ,  $\eta_p^2 = .00$ , *observed power* = .06; word relatedness and study condition,  $F(1, 38) = 0.25$ ,  $MSE = 0.00$ ,  $p = .623$ ,  $\eta_p^2 = .01$ , *observed power* = .08; recall interval and study condition,  $F(1, 38) = 2.76$ ,  $MSE = 0.01$ ,  $p = .105$ ,  $\eta_p^2 = .07$ , *observed power* = .37; word relatedness and presentation rate,  $F(1, 38) = 0.10$ ,  $MSE = 0.00$ ,  $p = .751$ ,  $\eta_p^2 = .00$ , *observed power* = .06; recall interval and presentation rate,  $F(1, 38) = 0.76$ ,  $MSE = 0.00$ ,  $p = .387$ ,  $\eta_p^2 = .02$ , *observed power* = .14; and between study condition and presentation rate,  $F(1, 38) = 0.82$ ,  $MSE = 0.00$ ,  $p = .370$ ,  $\eta_p^2 = .02$ , *observed power* = .14.

**Non-significant 3-way interactions.** The remaining 3-way interactions were not significant: word relatedness, recall interval, and age,  $F(1, 38) = 1.03$ ,  $MSE = 0.00$ ,  $p = .318$ ,  $\eta_p^2 = .03$ , *observed power* = .17; word relatedness, study condition, and age,  $F(1, 38) = 0.01$ ,

$MSE = 0.00$ ,  $p = .935$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval, study condition, and age,  $F(1, 38) = 0.08$ ,  $MSE = 0.00$ ,  $p = .784$ ,  $\eta_p^2 = .00$ , *observed power* = .06; word relatedness, recall interval, and study condition,  $F(1, 38) = 0.74$ ,  $MSE = 0.00$ ,  $p = .396$ ,  $\eta_p^2 = .02$ , *observed power* = .13; recall interval, presentation rate, and age,  $F(1, 38) = 2.21$ ,  $MSE = 0.01$ ,  $p = .145$ ,  $\eta_p^2 = .06$ , *observed power* = .31; word relatedness, recall interval, and presentation rate,  $F(1, 38) = 1.89$ ,  $MSE = 0.00$ ,  $p = .177$ ,  $\eta_p^2 = .05$ , *observed power* = .27; study condition, presentation rate, and age,  $F(1, 38) = 0.49$ ,  $MSE = 0.00$ ,  $p = .490$ ,  $\eta_p^2 = .01$ , *observed power* = .10; and between word relatedness, study condition, and presentation rate,  $F(1, 38) = 0.32$ ,  $MSE = 0.00$ ,  $p = .576$ ,  $\eta_p^2 = .01$ , *observed power* = .09.

***Non-significant 4-way interactions.*** All 4-way interactions were not significant: word relatedness, recall interval, study condition, and age,  $F(1, 38) = 0.13$ ,  $MSE = 0.00$ ,  $p = .723$ ,  $\eta_p^2 = .00$ , *observed power* = .06; word relatedness, recall interval, presentation rate, and age,  $F(1, 38) = 3.26$ ,  $MSE = 0.01$ ,  $p = .079$ ,  $\eta_p^2 = .08$ , *observed power* = .42; word relatedness, study condition, presentation rate, and age,  $F(1, 38) = 0.65$ ,  $MSE = 0.00$ ,  $p = .425$ ,  $\eta_p^2 = .02$ , *observed power* = .12; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 2.17$ ,  $MSE = 0.00$ ,  $p = .149$ ,  $\eta_p^2 = .05$ , *observed power* = .30; and between word relatedness, recall interval, study condition, and presentation rate,  $F(1, 38) = 2.10$ ,  $MSE = 0.00$ ,  $p = .156$ ,  $\eta_p^2 = .05$ , *observed power* = .29.

***Non-significant 5-way interaction.*** The 5-way interaction between word relatedness, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.93$ ,  $MSE = 0.00$ ,  $p = .340$ ,  $\eta_p^2 = .02$ , *observed power* = .16.

### ***Critical lures***

***Non-significant main effects.*** The remaining main effects were not significant: presentation rate,  $F(1, 38) = 0.81$ ,  $MSE = 0.00$ ,  $p = .374$ ,  $\eta_p^2 = .02$ , *observed power* = .14; and age,  $F(1, 38) = 3.73$ ,  $MSE = 0.01$ ,  $p = .061$ ,  $\eta_p^2 = .09$ , *observed power* = .47.

***Non-significant 2-way interactions.*** All 2-way interactions were not significant: recall interval and age,  $F(1, 38) = 0.90$ ,  $MSE = 0.00$ ,  $p = .348$ ,  $\eta_p^2 = .02$ , *observed power* = .15; study condition and age,  $F(1, 38) = 0.85$ ,  $MSE = 0.00$ ,  $p = .361$ ,  $\eta_p^2 = .02$ , *observed power* = .15; presentation rate and age,  $F(1, 38) = 2.79$ ,  $MSE = 0.00$ ,  $p = .103$ ,  $\eta_p^2 = .07$ , *observed power* = .37; recall interval and study condition,  $F(1, 38) = 0.34$ ,  $MSE = 0.00$ ,  $p = .564$ ,  $\eta_p^2 = .01$ , *observed power* = .09; recall interval and presentation rate,  $F(1, 38) = 0.02$ ,  $MSE = 0.00$ ,  $p = .887$ ,  $\eta_p^2 = .00$ , *observed power* = .05; and between study condition and presentation rate,  $F(1, 38) = 0.22$ ,  $MSE = 0.00$ ,  $p = .640$ ,  $\eta_p^2 = .01$ , *observed power* = .07.

***Non-significant 3-way interactions.*** All 3-way interactions were not significant: recall interval, study condition, and age,  $F(1, 38) = 0.12$ ,  $MSE = 0.00$ ,  $p = .729$ ,  $\eta_p^2 = .00$ , *observed power* = .06; study condition, presentation rate, and age,  $F(1, 38) = 0.18$ ,  $MSE = 0.00$ ,  $p = .671$ ,  $\eta_p^2 = .01$ , *observed power* = .07; study condition, presentation rate, and age,  $F(1, 38) = 0.22$ ,  $MSE = 0.00$ ,  $p = .640$ ,  $\eta_p^2 = .01$ , *observed power* = .07; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 0.02$ ,  $MSE = 0.00$ ,  $p = .877$ ,  $\eta_p^2 = .01$ , *observed power* = .05.

***Non-significant 4-way interaction.*** The 4-way interaction between recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.02$ ,  $MSE = 0.00$ ,  $p = .877$ ,  $\eta_p^2 = .00$ , *observed power* = .05.

### ***Omission errors***

***Non-significant main effects.*** The remaining main effects were not significant: study condition,  $F(1, 38) = 0.23$ ,  $MSE = 0.00$ ,  $p = .638$ ,  $\eta_p^2 = .01$ , *observed power* = .08; and age,  $F(1, 38) = 0.59$ ,  $MSE = 0.09$ ,  $p = .448$ ,  $\eta_p^2 = .02$ , *observed power* = .12.

***Non-significant 2-way interactions.*** The remaining 2-way interactions were not significant: word relatedness and age,  $F(1, 38) = 0.03$ ,  $MSE = 0.00$ ,  $p = .858$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval and age,  $F(1, 38) = 0.11$ ,  $MSE = 0.00$ ,  $p = .738$ ,  $\eta_p^2 = .00$ , *observed power* = .06; study condition and age,  $F(1, 38) = 1.26$ ,  $MSE = 0.01$ ,  $p = .269$ ,  $\eta_p^2 = .03$ , *observed power* = .19; word relatedness and study condition,  $F(1, 38) = 0.35$ ,  $MSE = 0.00$ ,  $p = .556$ ,  $\eta_p^2 = .01$ , *observed power* = .09; and between word relatedness and presentation rate,  $F(1, 38) = 1.30$ ,  $MSE = 0.01$ ,  $p = .261$ ,  $\eta_p^2 = .03$ , *observed power* = .20.

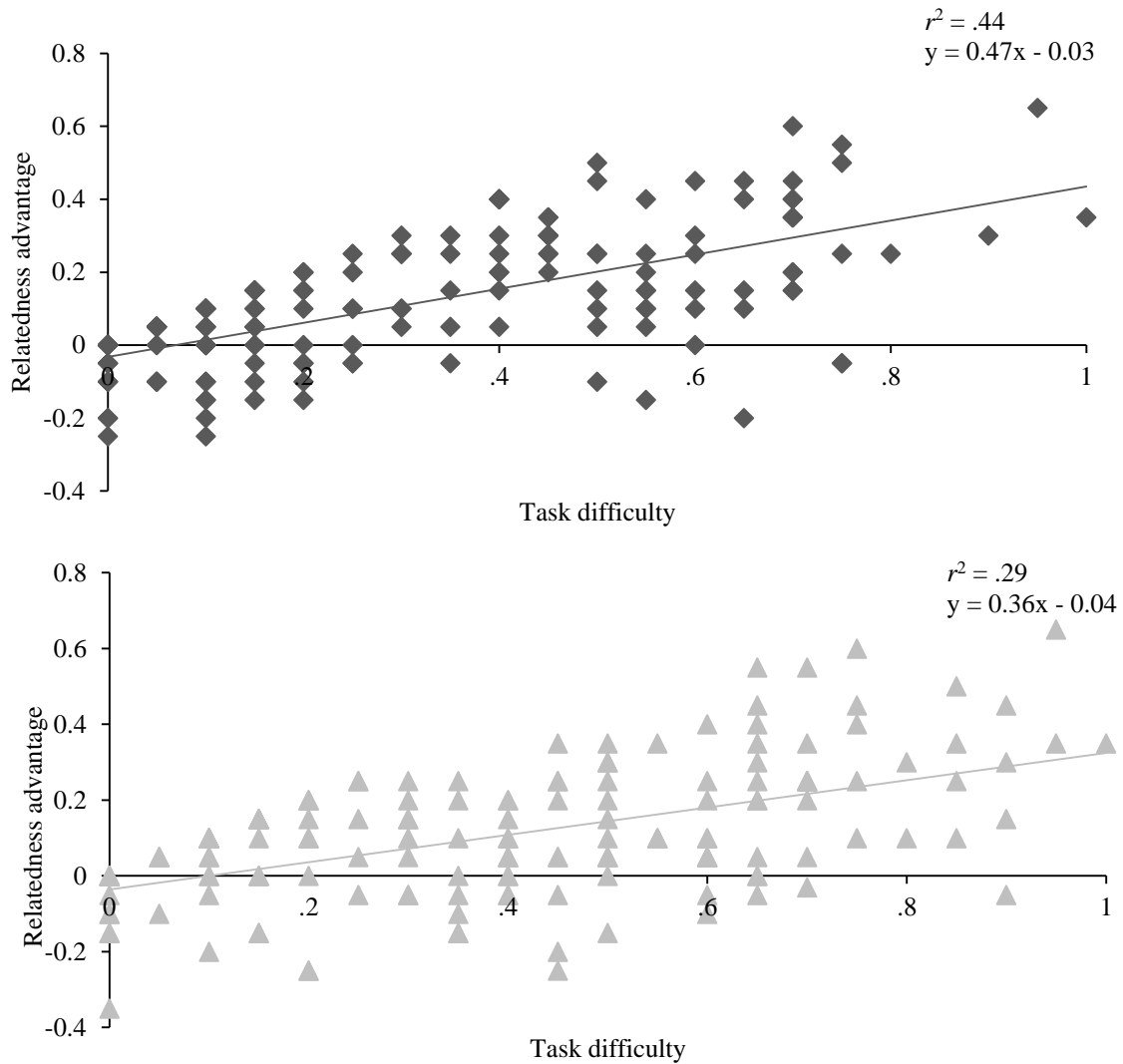
***Non-significant 3-way interactions.*** The remaining 3-way interactions were not significant: word relatedness, recall interval, and age,  $F(1, 38) = 0.39$ ,  $MSE = 0.00$ ,  $p = .535$ ,  $\eta_p^2 = .01$ , *observed power* = .09; word relatedness, study condition, and age,  $F(1, 38) = 3.01$ ,  $MSE = 0.02$ ,  $p = .091$ ,  $\eta_p^2 = .07$ , *observed power* = .39; recall interval, study condition, and age,  $F(1, 38) = 0.31$ ,  $MSE = 0.00$ ,  $p = .584$ ,  $\eta_p^2 = .01$ , *observed power* = .08; word relatedness, recall interval, and study condition,  $F(1, 38) = 1.23$ ,  $MSE = 0.01$ ,  $p = .274$ ,  $\eta_p^2 = .03$ , *observed power* = .19; word relatedness, presentation rate, and age,  $F(1, 38) = 0.47$ ,  $MSE = 0.00$ ,  $p = .498$ ,  $\eta_p^2 = .01$ , *observed power* = .10; recall interval, presentation rate, and age,  $F(1, 38) = 3.80$ ,  $MSE = 0.02$ ,  $p = .059$ ,  $\eta_p^2 = .09$ , *observed power* = .48; word relatedness, recall interval, and presentation rate,  $F(1, 38) = 0.07$ ,  $MSE = 0.00$ ,  $p = .789$ ,  $\eta_p^2 = .00$ , *observed power* = .06; study condition, presentation rate, and age,  $F(1, 38) = 1.01$ ,  $MSE = 0.01$ ,  $p = .322$ ,  $\eta_p^2 = .03$ ,

*observed power* = .17; and between recall interval, study condition, and presentation rate,  $F(1, 38) = 1.43$ ,  $MSE = 0.01$ ,  $p = .239$ ,  $\eta_p^2 = .04$ , *observed power* = .21.

***Non-significant 4-way interactions.*** All 4-way interactions were not significant: word relatedness, recall interval, study condition, and age,  $F(1, 38) = 0.86$ ,  $MSE = 0.01$ ,  $p = .360$ ,  $\eta_p^2 = .02$ , *observed power* = .15; word relatedness, recall interval, presentation rate, and age,  $F(1, 38) = 0.44$ ,  $MSE = 0.00$ ,  $p = .513$ ,  $\eta_p^2 = .01$ , *observed power* = .10; word relatedness, study condition, presentation rate, and age,  $F(1, 38) = 0.01$ ,  $MSE = 0.00$ ,  $p = .982$ ,  $\eta_p^2 = .00$ , *observed power* = .05; recall interval, study condition, presentation rate, and age,  $F(1, 38) = 1.96$ ,  $MSE = 0.01$ ,  $p = .170$ ,  $\eta_p^2 = .05$ , *observed power* = .28; and between word relatedness, recall interval, study condition, and presentation rate,  $F(1, 38) = 0.19$ ,  $MSE = 0.00$ ,  $p = .663$ ,  $\eta_p^2 = .01$ , *observed power* = .07.

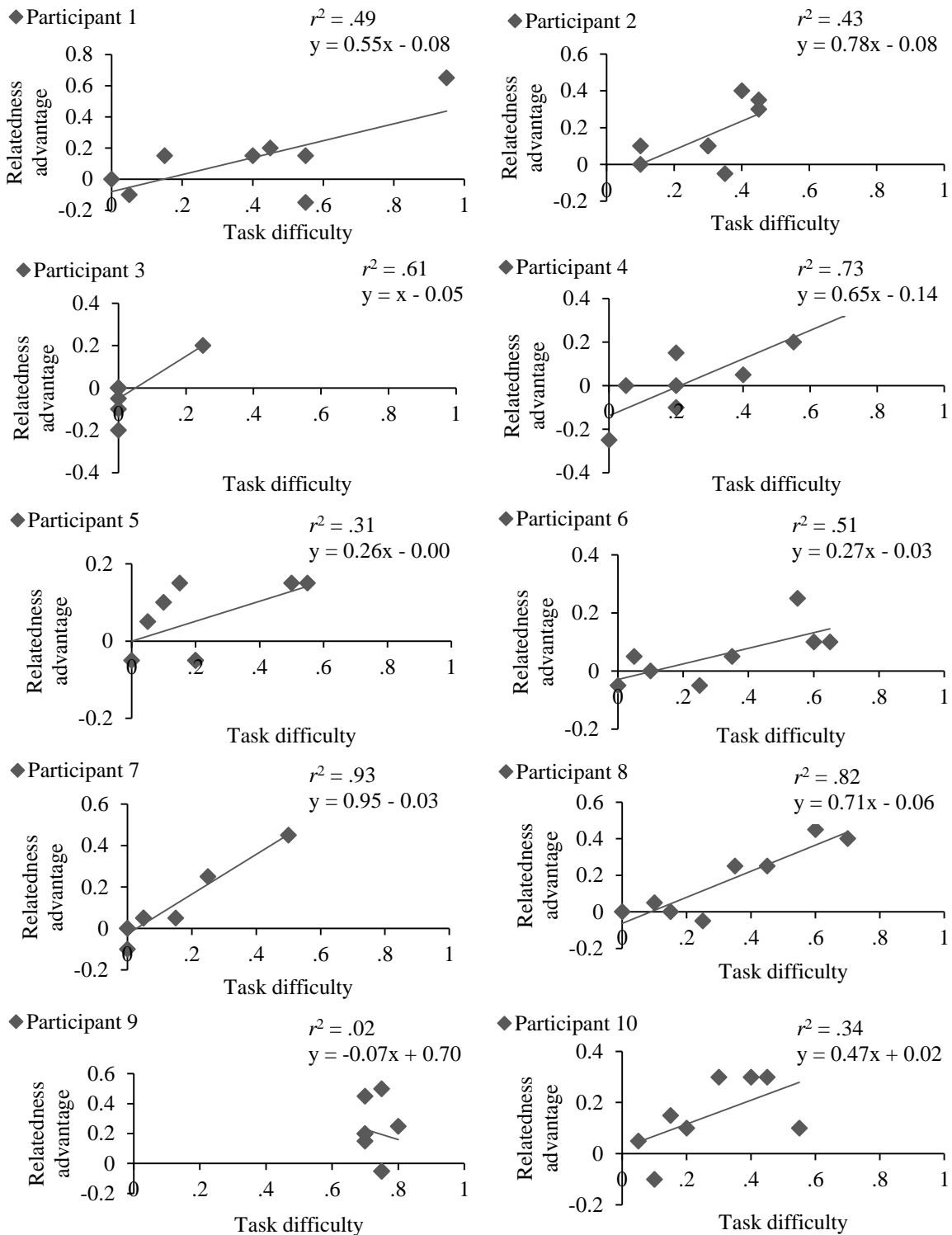
***Non-significant 5-way interaction.*** The 5-way interaction between word relatedness, recall interval, study condition, presentation rate, and age was not significant,  $F(1, 38) = 0.51$ ,  $MSE = 0.00$ ,  $p = .479$ ,  $\eta_p^2 = .01$ , *observed power* = .11.

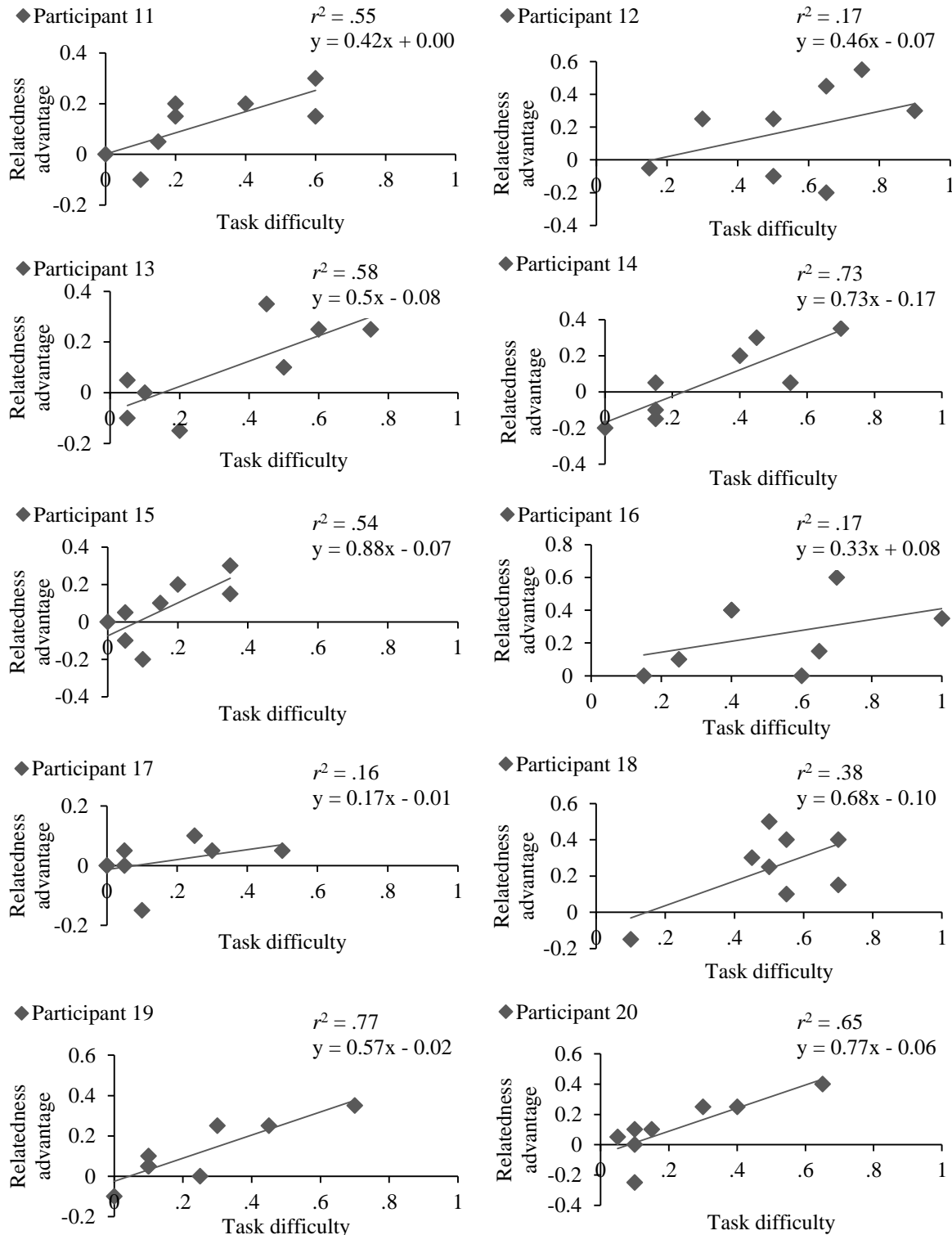
**Appendix C – 4.3: Relatedness advantage as a function of task difficulty for correct-in-position recall for young adults (upper graph) and older adults (lower graph)**



At the group levels, young adults in the upper graph and older adults in the lower graph showed the relatedness advantage increased with task difficulty. This relationship was moderately strong for the young adults and weak for the older adults.

**Appendix C – 4.4: Relatedness advantage as a function of task difficulty for correct-in-position recall for each young adult**





All of the young adults used redintegration, particularly in the difficult task conditions.

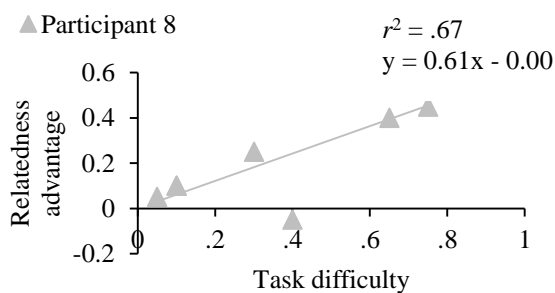
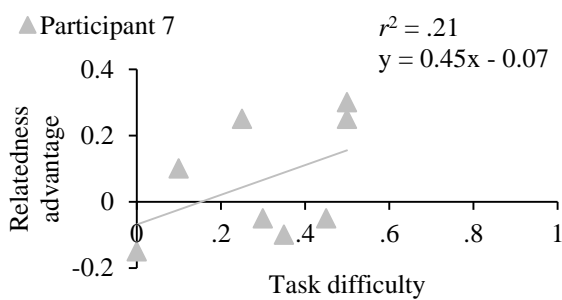
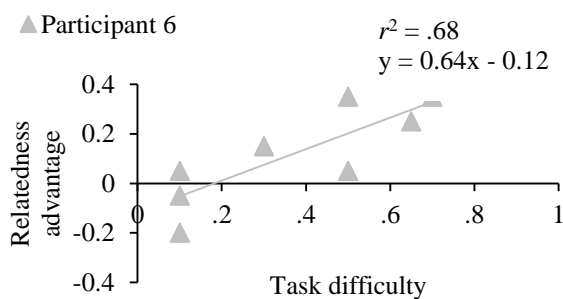
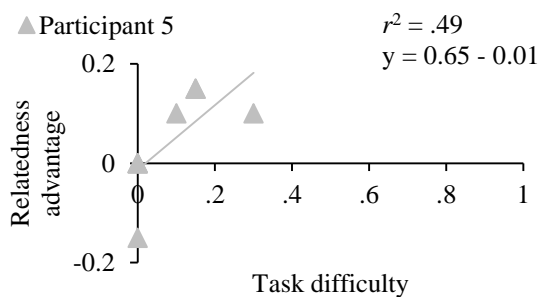
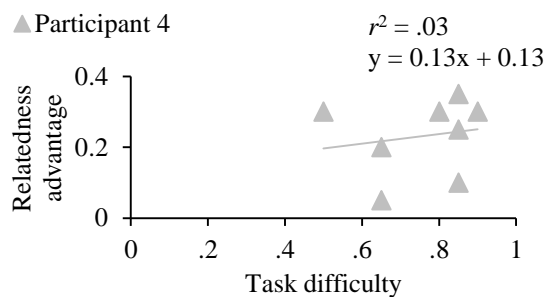
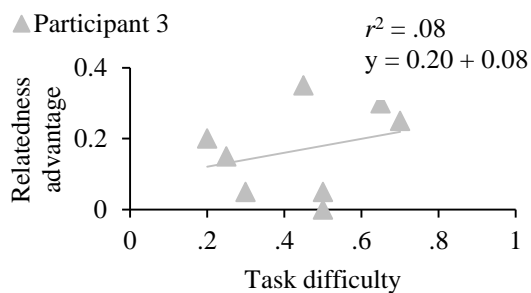
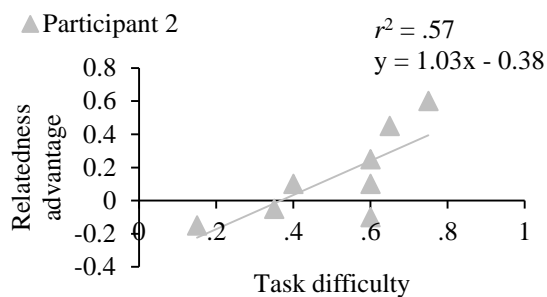
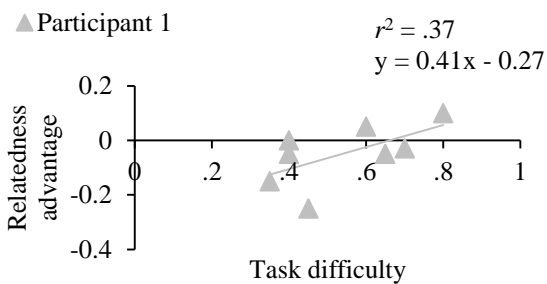
Five participants demonstrated reasonably strong redintegration effects where  $r^2 > .70$

(Participants 4, 7, 8, 14, and 19) and four participants demonstrated weak redintegration

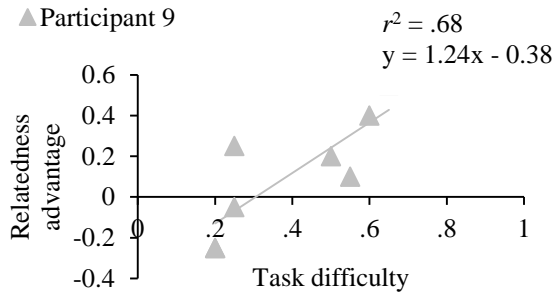


effects where  $r^2 < .30$  (Participants 9, 12, 16, and 17). The remaining 11 participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 1, 2, 3, 5, 6, 10, 11, 13, 15, 18, and 20).

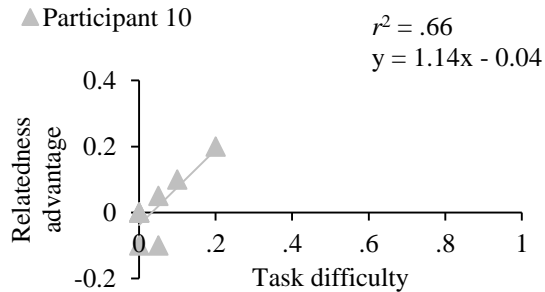
**Appendix C – 4.5: Relatedness advantage as a function of task difficulty for correct-in-position recall for each older adult**



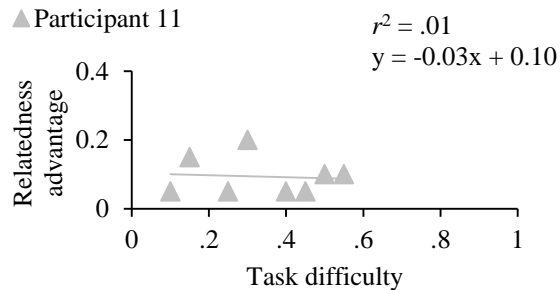
▲ Participant 9



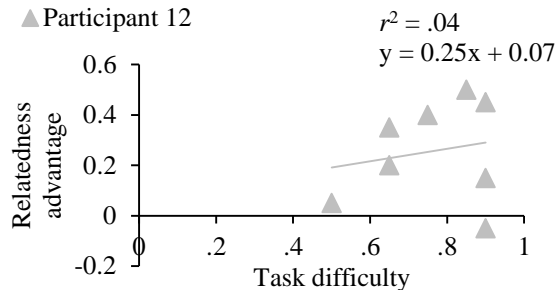
▲ Participant 10



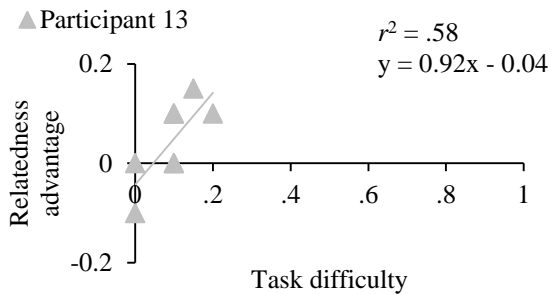
▲ Participant 11



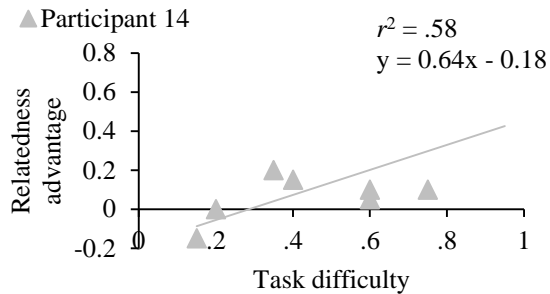
▲ Participant 12



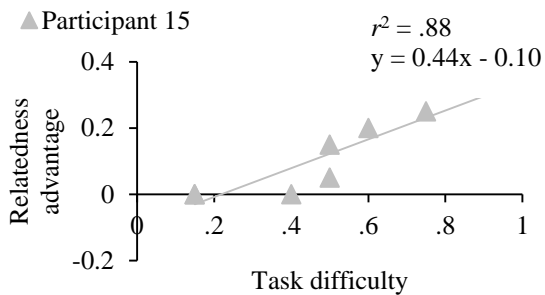
▲ Participant 13



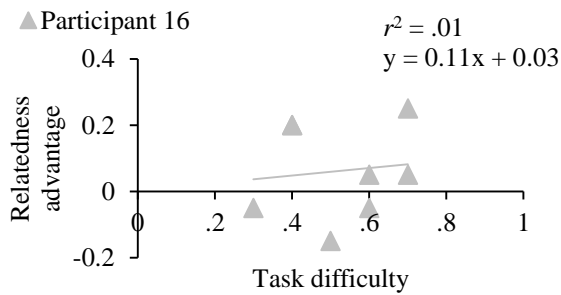
▲ Participant 14

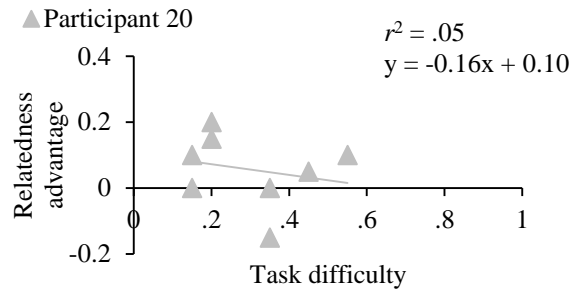
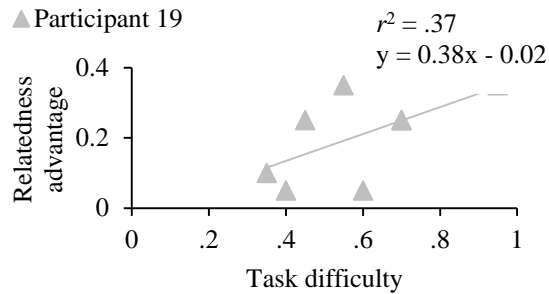
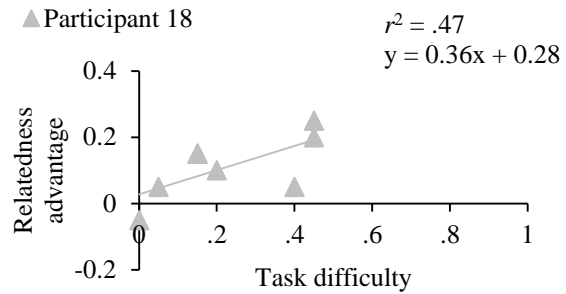
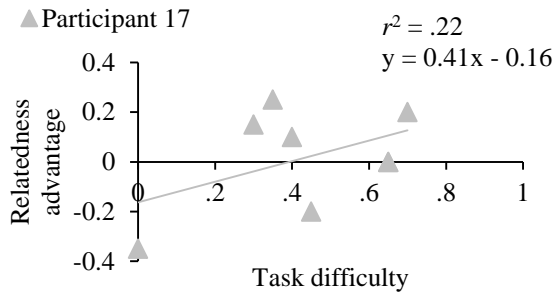


▲ Participant 15



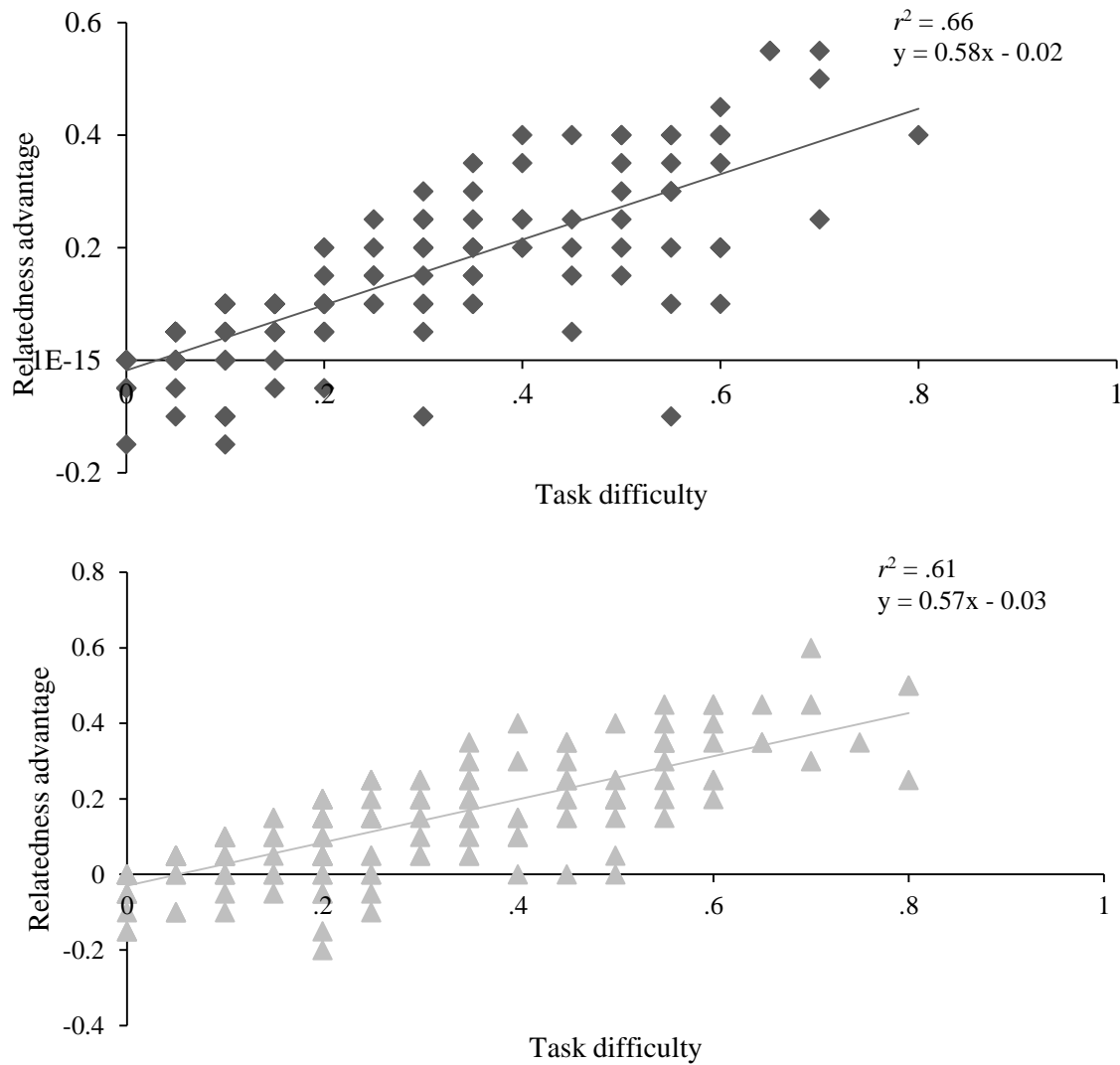
▲ Participant 16





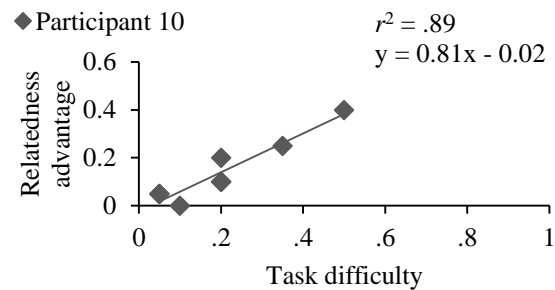
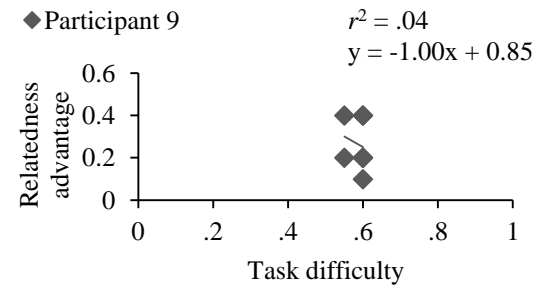
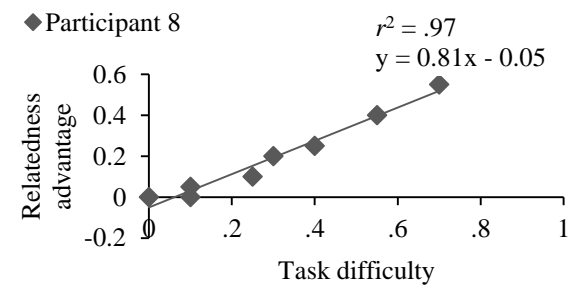
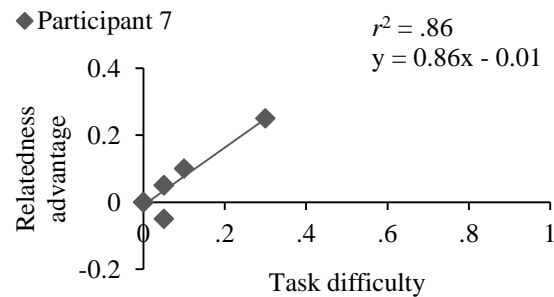
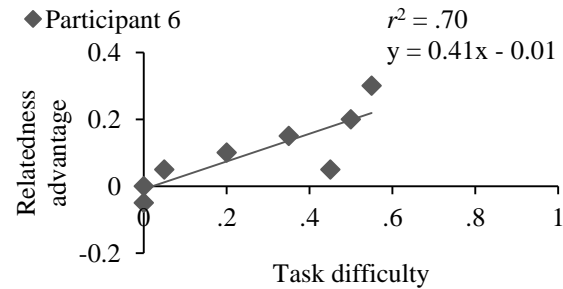
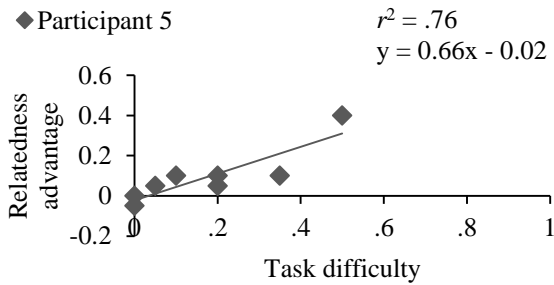
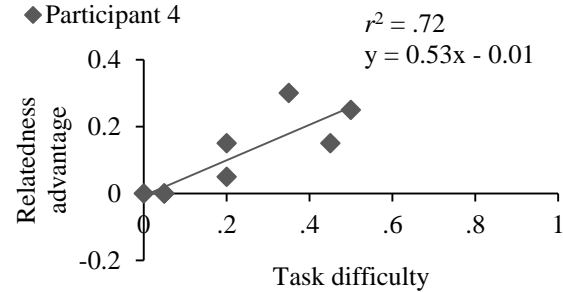
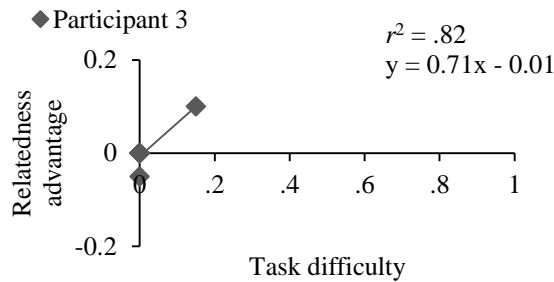
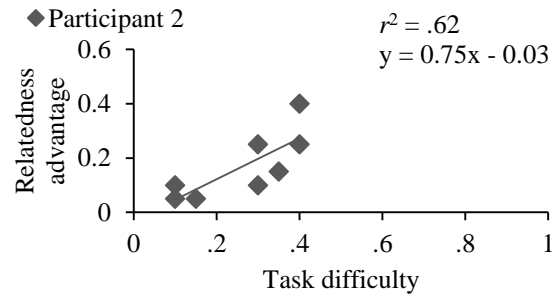
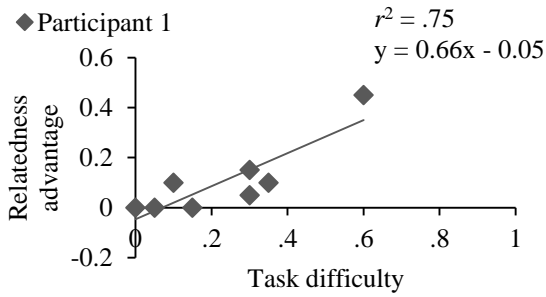
Overall, there was a consistent redintegration effect amongst the older adults. One participant demonstrated strong redintegration effects where  $r^2 > .70$  (Participants 15) and eight participants demonstrated weak redintegration effects, where  $r^2 < .30$  (Participants 3, 4, 7, 11, 12, 16, 17, and 20). The remaining 11 participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 2, 5, 6, 8, 9, 10, 13, 14, 18, and 19).

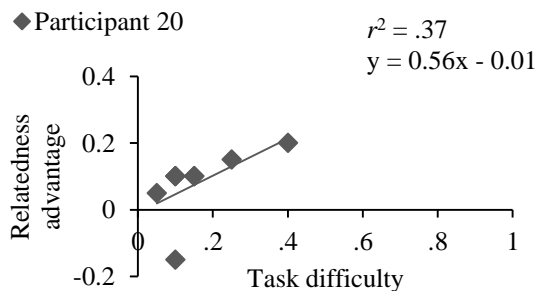
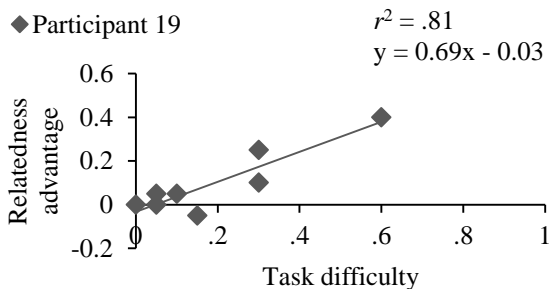
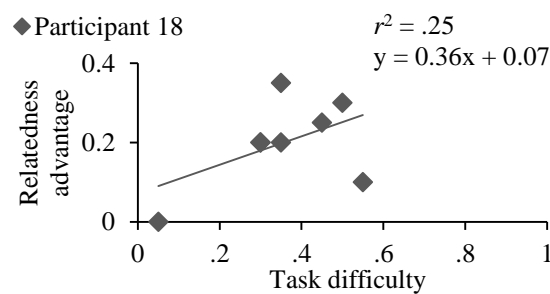
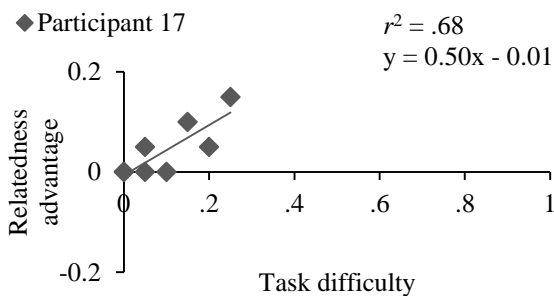
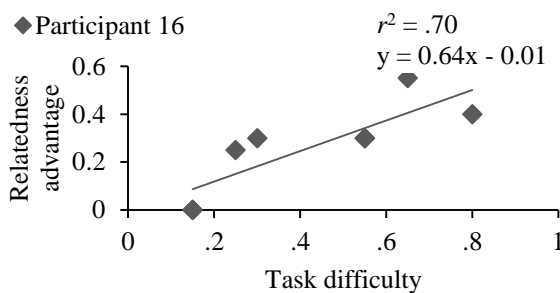
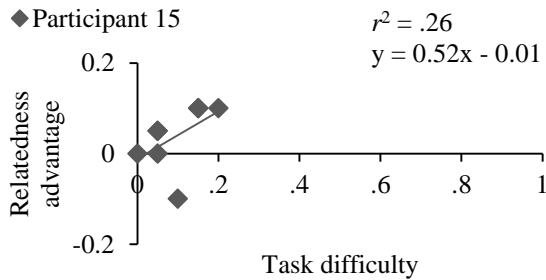
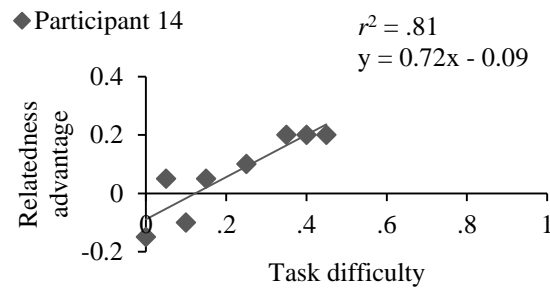
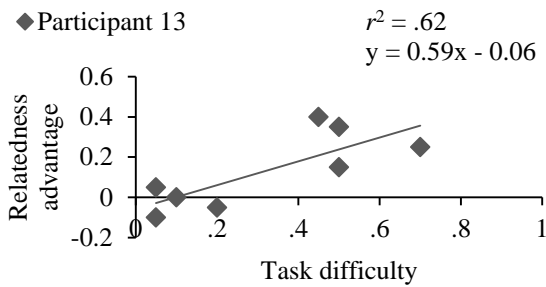
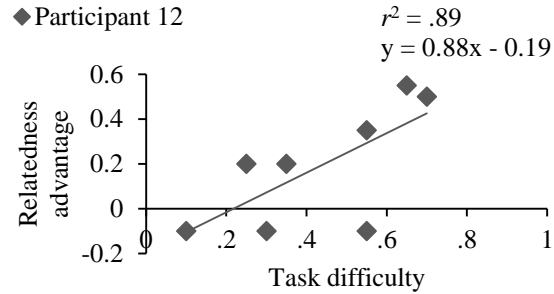
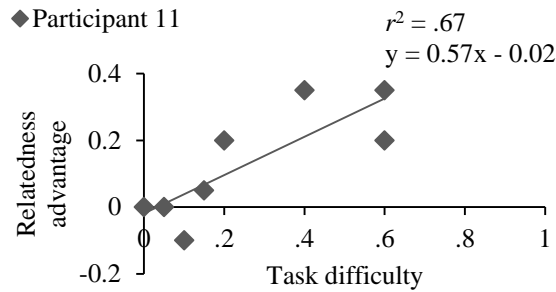
**Appendix C – 4.6: Relatedness advantage as a function of task difficulty for item recall for young adults (upper graph) and older adults (lower graph)**



At the sample level, young adults in the upper graph and older adults in lower graph demonstrated that the relatedness advantage moderately increased with task difficulty.

**Appendix C – 4.7: Relatedness advantage as a function of task difficulty for item recall for each young adult**



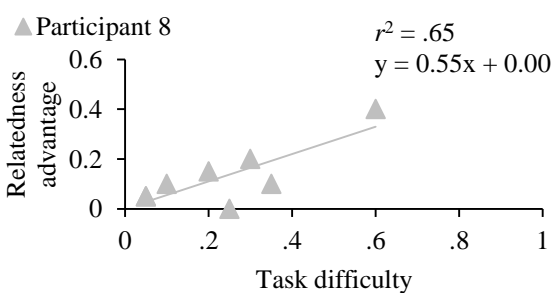
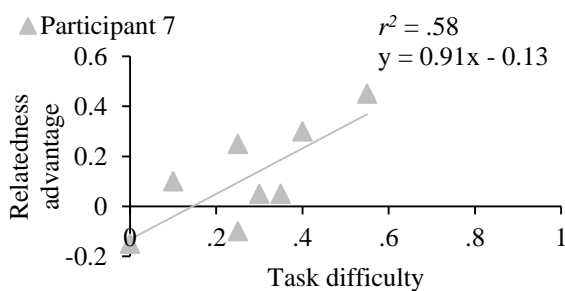
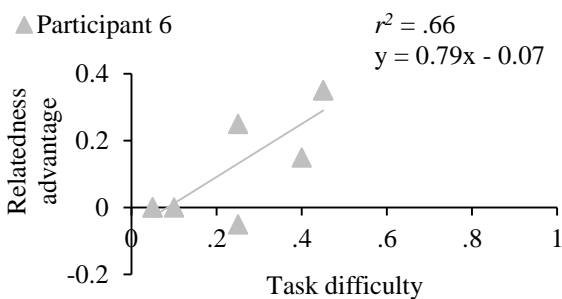
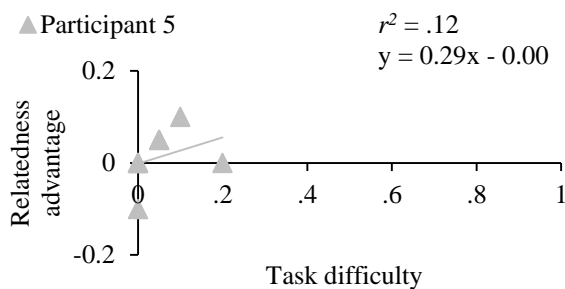
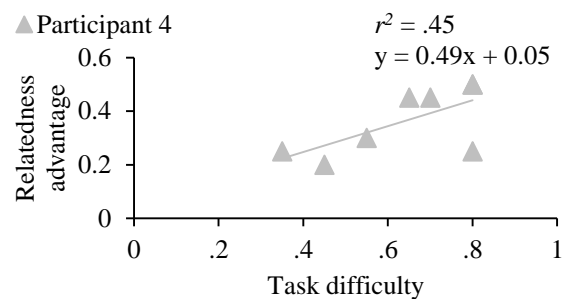
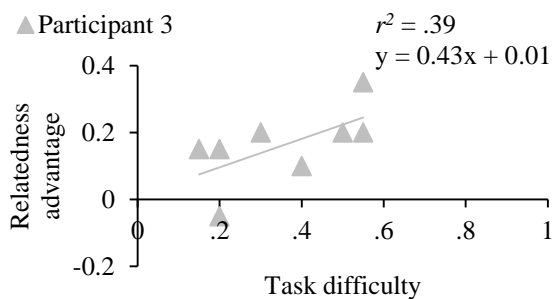
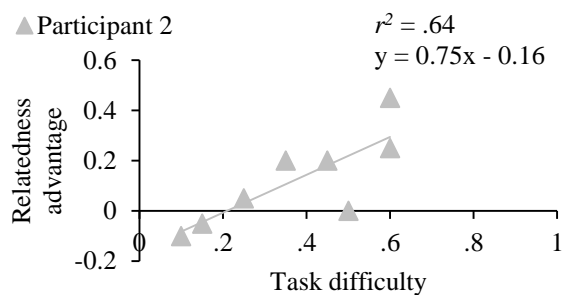
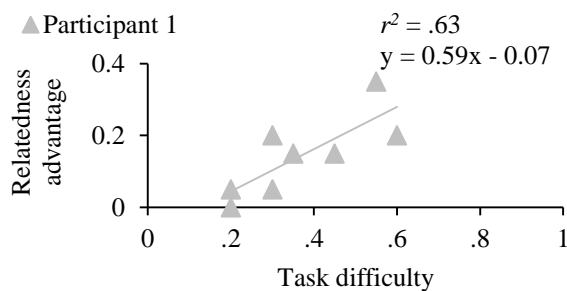


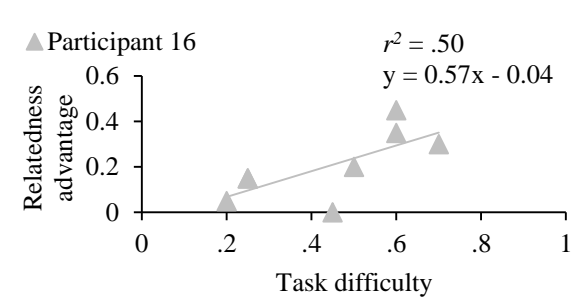
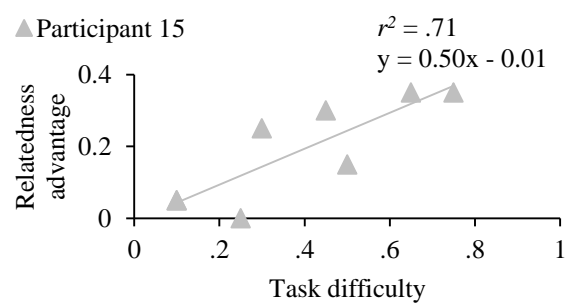
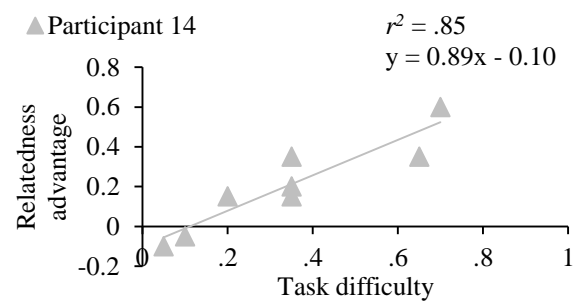
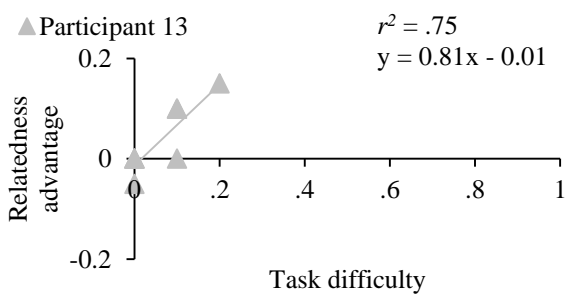
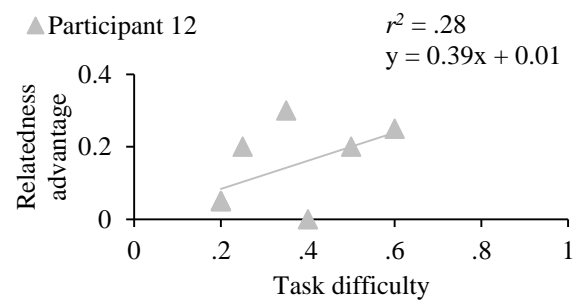
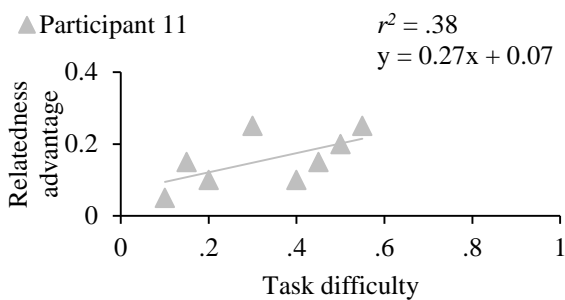
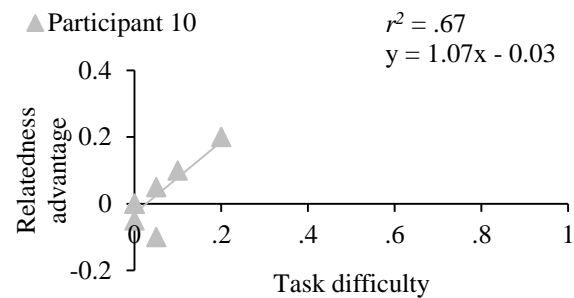
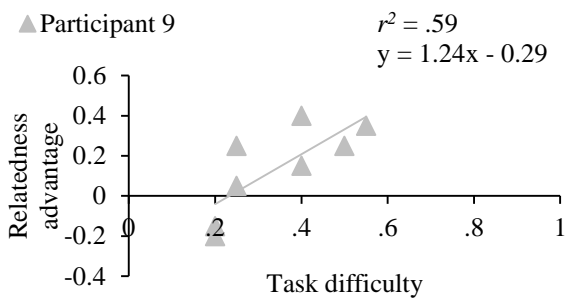
All participants demonstrated redintegrative processing. Twelve participants demonstrated reasonably strong redintegration effects where  $r^2 > .70$  (Participants 1, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16, and 19) and two participants demonstrated weak redintegration effects

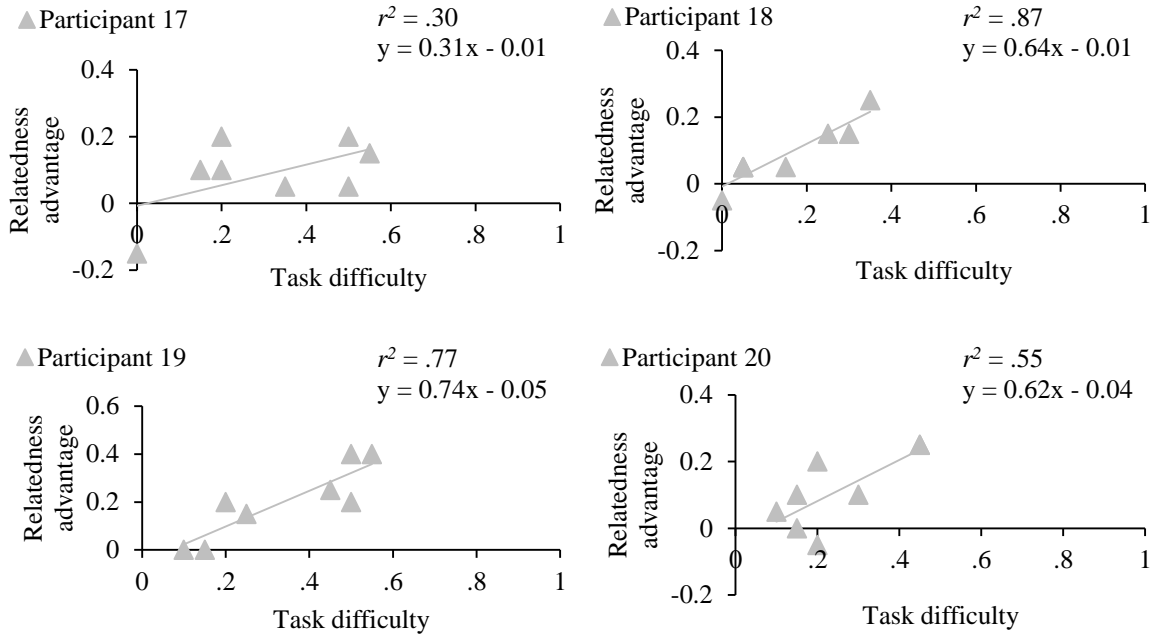
where  $r^2 < .30$  (Participants 9 and 15). The remaining five participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 2, 11, 13, 17, and 18).



**Appendix C – 4.8: Relatedness advantage as a function of task difficulty for item recall for each older adult**

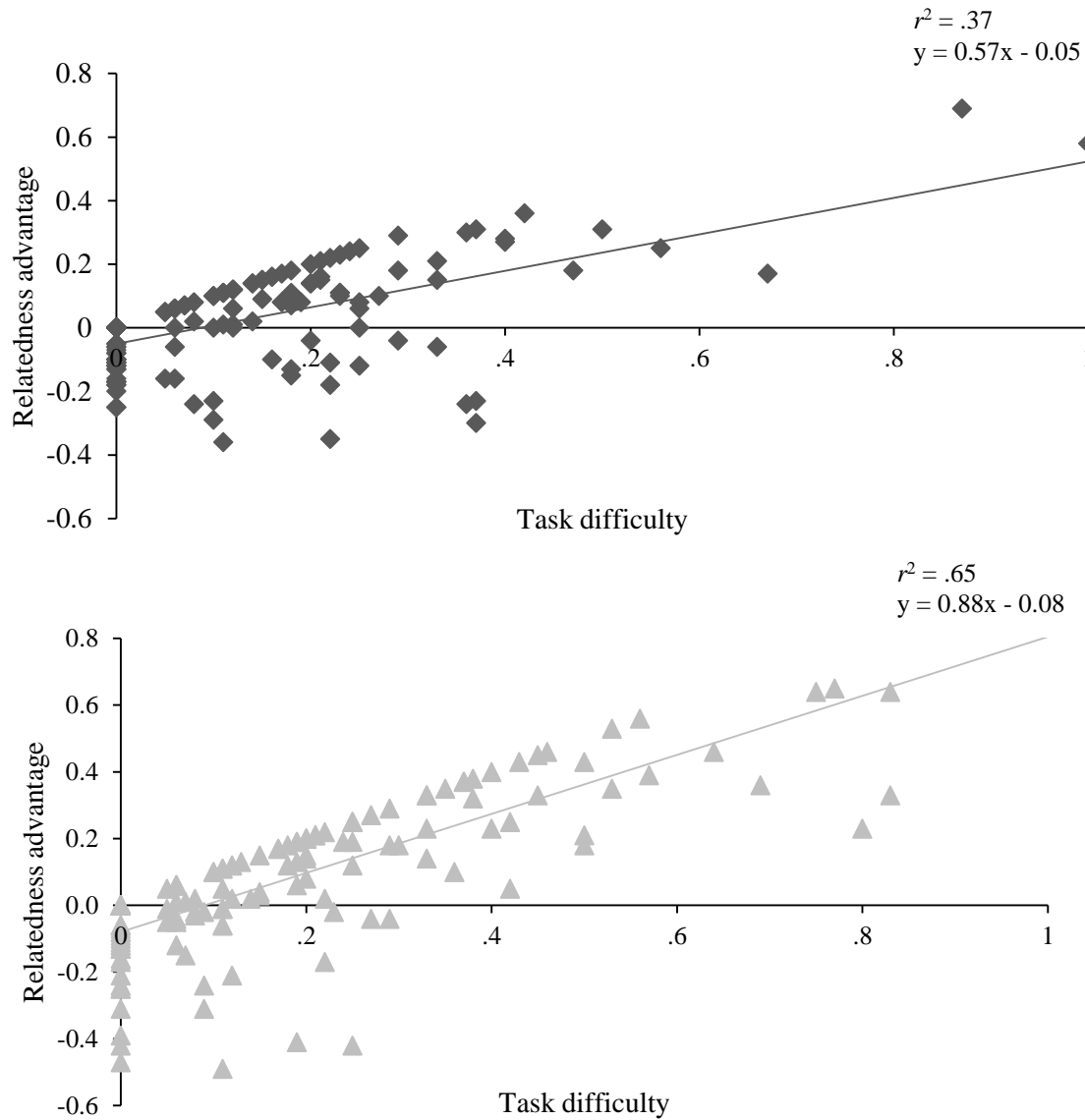






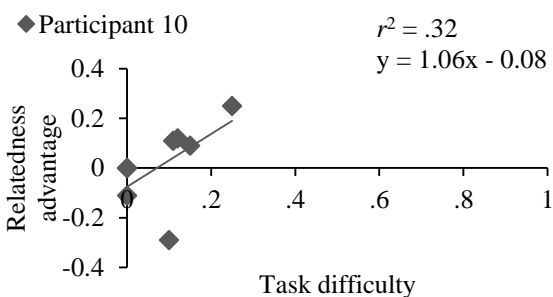
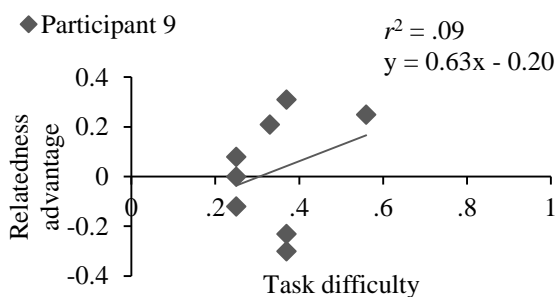
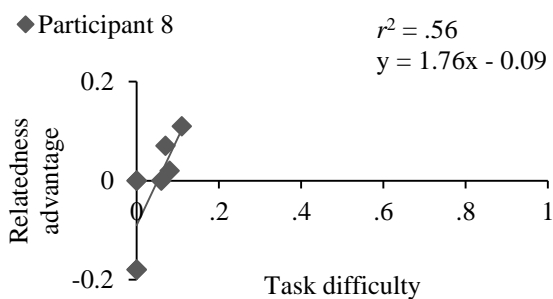
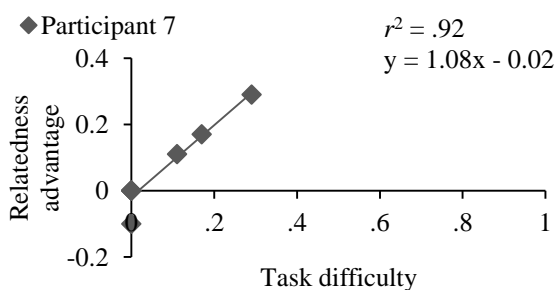
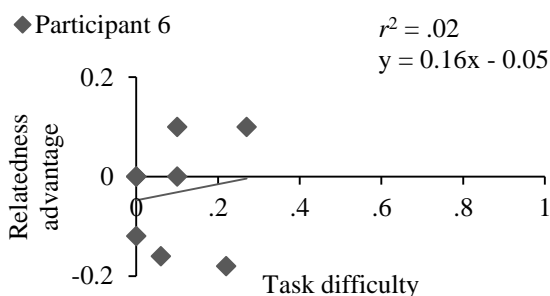
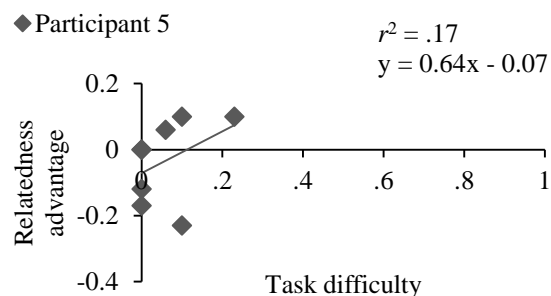
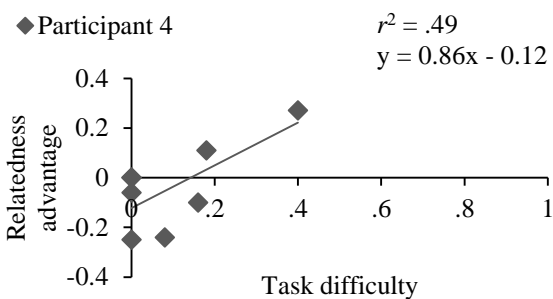
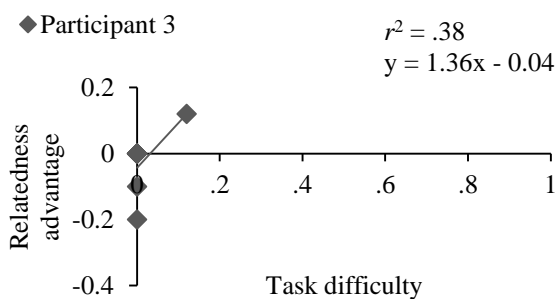
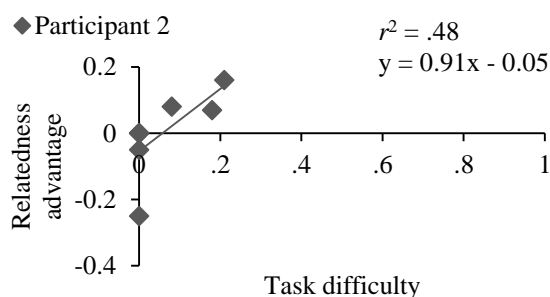
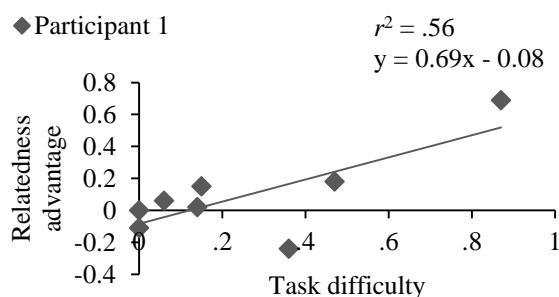
All older adults demonstrated redintegration effects for item recall. Five participants demonstrated strong redintegration effects where  $r^2 > .70$  (Participants 13, 14, 15, 18, and 19) whereas three participants demonstrated weak redintegration effects where  $r^2 < .30$  (Participants 5, 12, and 17). The remaining 12 participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 16, and 20).

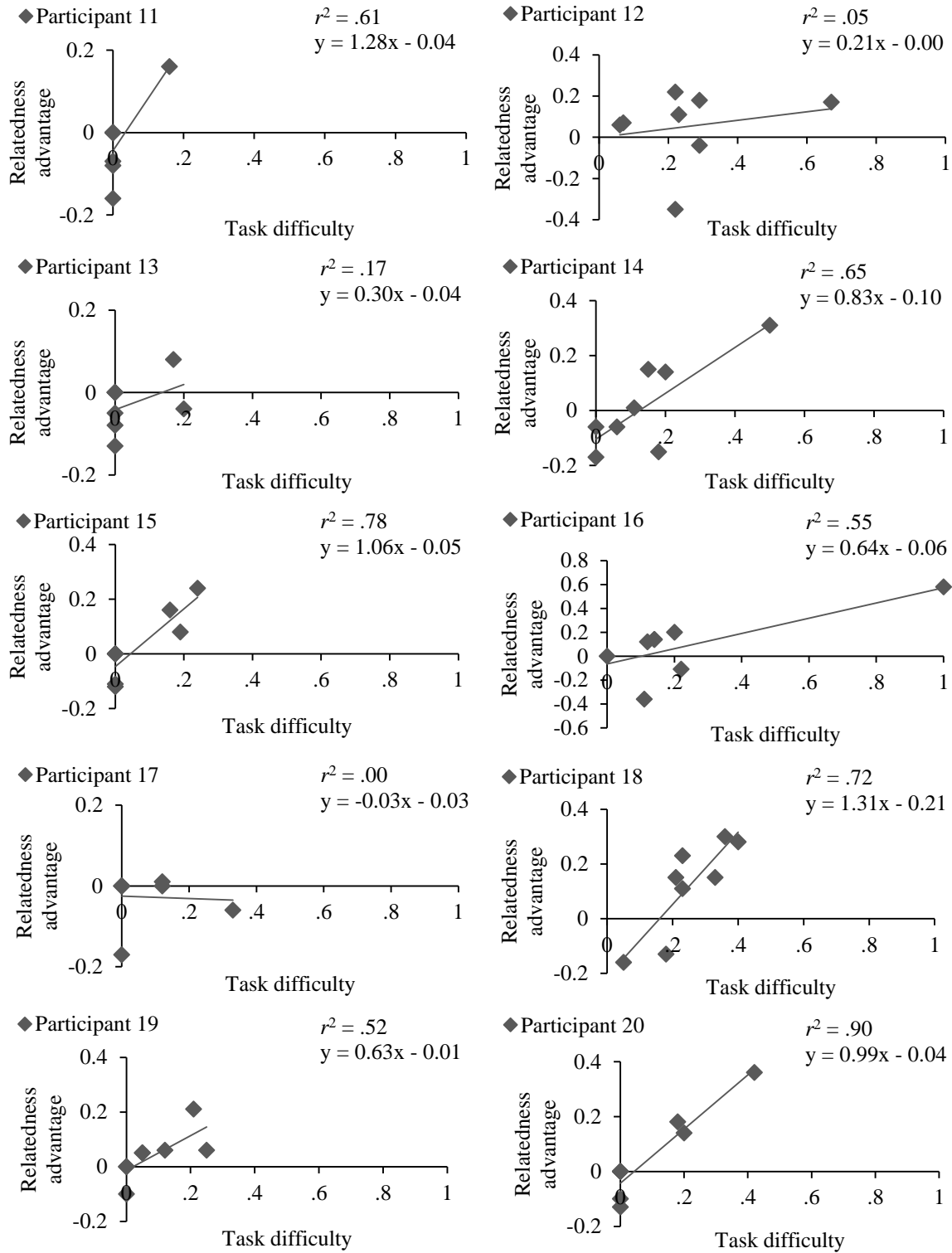
**Appendix C – 4.9: Relatedness advantage as a function of task difficulty for order accuracy for young adults (upper graph) and older adults (lower graph)**



At a sample level, young adults in the upper graph demonstrated that as task difficulty increased, the relatedness advantage increased the order accuracy of the words at output. Older adults in the lower graph also displayed a stronger positive increase in the relatedness advantage to aid order accuracy as task difficulty increased.

**Appendix C – 4.10: Relatedness advantage as a function of task difficulty for order accuracy for each young adult**

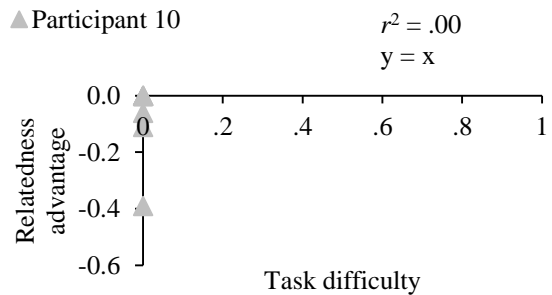
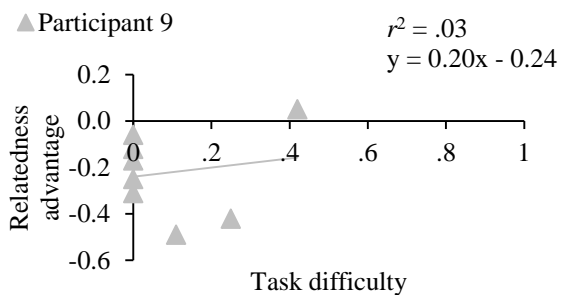
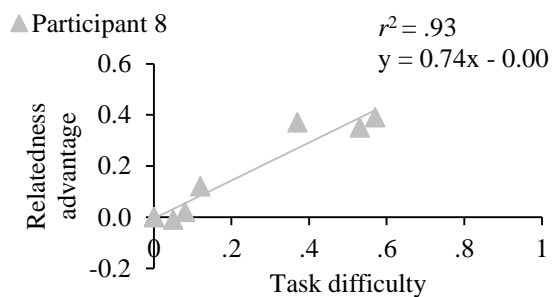
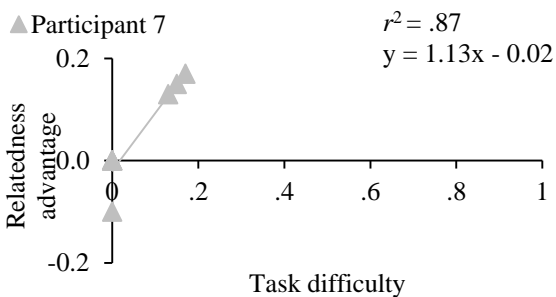
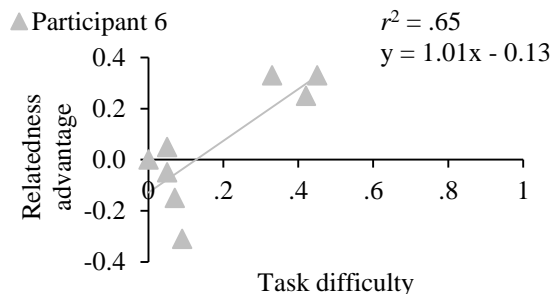
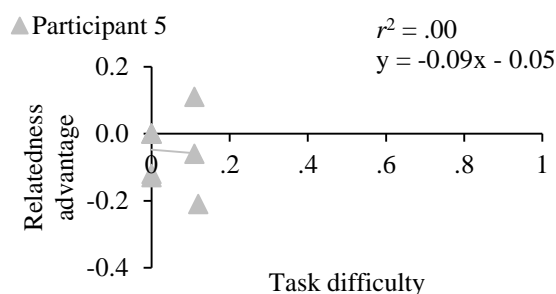
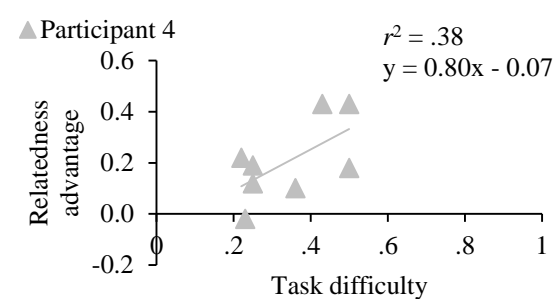
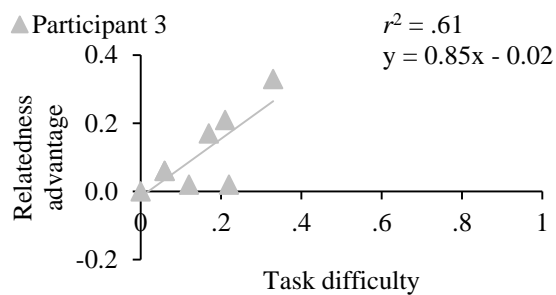
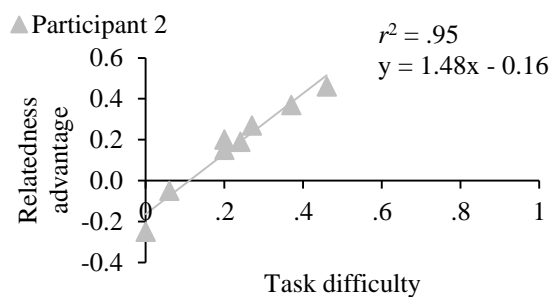
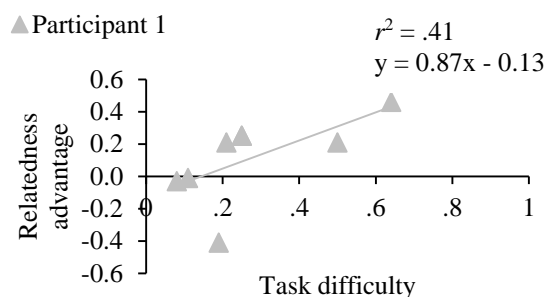




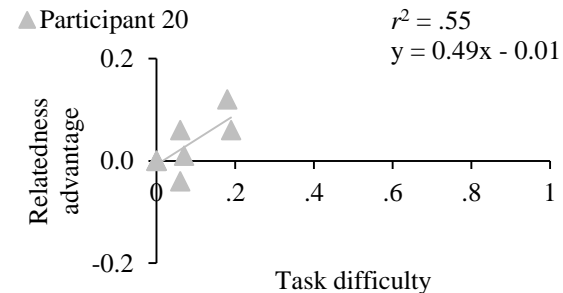
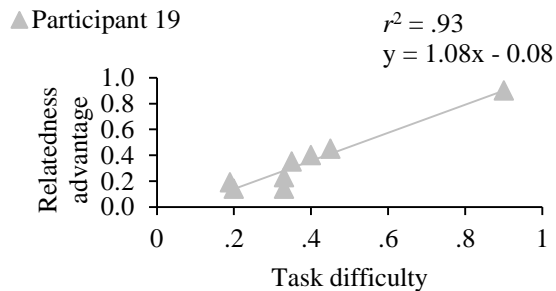
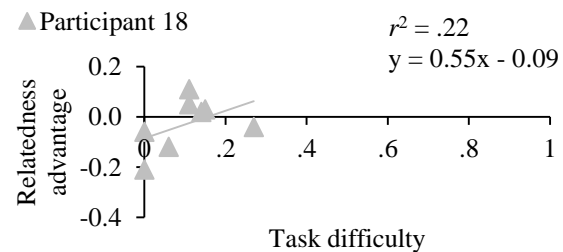
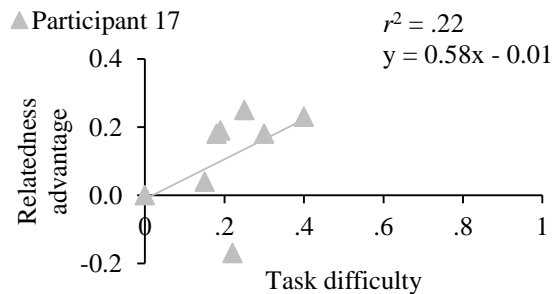
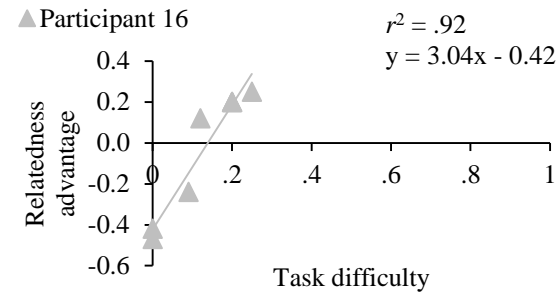
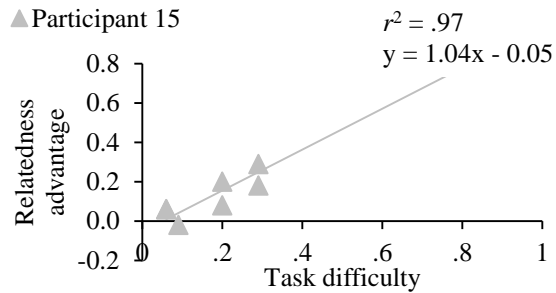
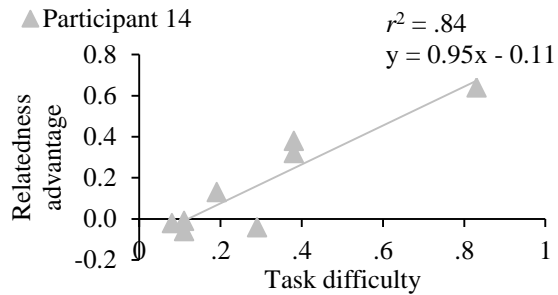
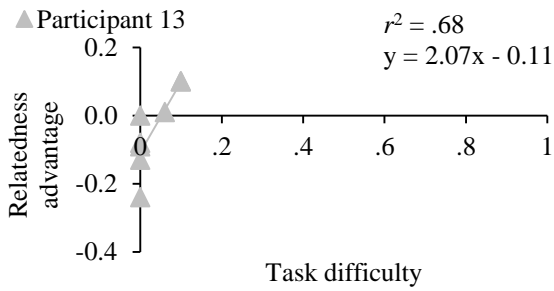
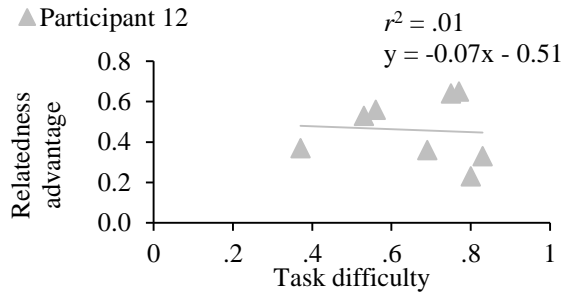
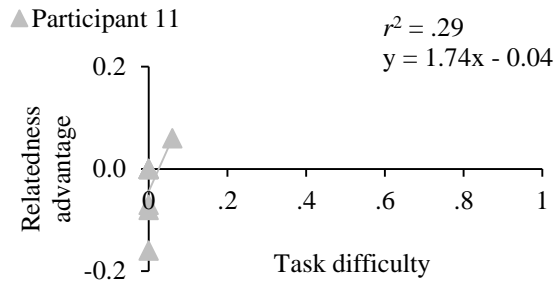
Given the participant initially recalled the words, there was a consistent redintegration effect. Four participants demonstrated strong redintegration effects where  $r^2 > .70$  (Participants 7, 15, 18, and 20), five participants demonstrated weak redintegration effects

where  $r^2 < .30$  (Participants 5, 6, 9, 12, and 13), and one participant demonstrated no redintegration effects where  $r^2 = .00$  (Participant 17). The remaining 10 participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 1, 2, 3, 4, 8, 10, 11, 14, 16, and 19).

**Appendix C – 4.10: Relatedness advantage as a function of task difficulty for order accuracy for each older adult**







Much like the young adults, patterns of order accuracy indicated there was a consistent redintegration effect amongst the older adults. Seven participants demonstrated strong redintegration effects where  $r^2 > .70$  (Participants 2, 7, 8, 14, 15, 16, and 19) whereas five

participants demonstrated weak redintegration effects where  $r^2 < .30$  (Participants 9, 11, 12, 17, and 18). Two participants demonstrated no redintegration effects where  $r^2 = .00$  (Participants 5 and 10) and the remaining six participants demonstrated moderate redintegration effects where  $r^2$  was between .30 and .70 (Participants 1, 3, 4, 6, 13, and 20).