

**Sensory and motor interventions
for very early school-age children:
A cluster pragmatic randomised controlled trial
examining effect on
development, behaviour and academic
learning outcomes.**

Submitted by

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Declaration

This thesis contains no material that has been extracted in whole or in part from a thesis that I have submitted towards the award of any other degree or diploma in any other tertiary institution.

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

All research procedures reported in the thesis received the approval of the relevant Ethics/Safety Committees.

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List of Publications

Chapter Six

Miles, S.J., Fulbrook, P. & Mainwaring-Mägi, D. (2016). Evaluating suitability, technical adequacy and usability of standardized instruments for use in universal screening of very early school-age children. *Journal of Psychoeducational Assessment*, 1-21 (online first version). Doi: 10.1177/0734282916669246

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Abstract

Sensory and motor interventions are implemented in schools with the aim to improve children's development, behaviour and academic learning outcomes, albeit with limited research evidence of effect. These are particularly used as an early intervention with very early school-age children in an effort to ease the transition to formal schooling and enhance school readiness. This thesis presents a six-phase study undertaken to examine the effect of one such intervention. The aim of this study was to determine any effect from a mixed sensorimotor and sensory integration group intervention, on early academic skills and cognitive, behavioural and socioemotional development of very early school-age children in the school setting, by using a two-year, un-blinded, cluster randomized controlled trial.

A scoping exercise undertaken in Phase 1 determined the nature and extent of intervention use within schools in the study setting. A literature review, undertaken as Phase 2, identified a variety of intervention types and approaches, narrowing the focus to those using an impairment-orientation approach to intervention, with particular focus on those using a sensory integration frame of reference or mixed sensorimotor approach. A scoping review of published and unpublished research trials of interventions, undertaken in Phase 3, identified a suitable intervention to use in a research trial. The *Learning Connections School Program* is classifiable as a mixed *sensorimotor* and *sensory integration* group intervention using an impairment-orientation approach, where some type of learning, behavioural or developmental impairment is assumed for many children within the general school population.

In Phase 4, an evaluative literature review determined suitable measurement instruments to use in a trial. The *Astronaut Invented Spelling Test* (2nd ed.) and the *Sutherland Phonological Awareness Test – Revised* were selected for their Australian norms, low cost and high usability to measure early language skills. The *Draw a Person test* met suitability requirements to measure cognition, with universal norms, use in international research, high usability and low cost. The *Behavior Assessment System for Children* (2nd ed.) - *Teacher Rating Scales* was selected for its high technical adequacy, excellent computerised scoring and familiarity to members of the research team. Two sets of brief, multiple-proficiency mathematics measures, *Early Mathematics Concepts A* and *B* (EMCA, EMCB), were specifically developed for this study. These included mathematical computation concepts suitable to the two age-groups in the trial. A pilot study undertaken in Phase 5 enabled pilot-testing of the selected instruments and intervention in the study setting, to confirm the suitability and feasibility of their use within the study setting for a research trial.

In Phase 6, a two-year cluster pragmatic un-blinded randomised controlled trial was conducted in 2012 and 2013. Schools (n = 116) in one large Catholic Church Archdiocese in Brisbane, Queensland with at least one Prep class, the first year of formal schooling, were eligible to participate in the research trial, with recruitment via email invitation to School Principals. Ethical approval was obtained from the Australian Catholic University Human Research Ethics Committee and further approval for a research trial was obtained from Brisbane Catholic Education. School principals, teachers and parents provided consent to participate, while assent from children was also sought as a form of respect and engagement. Following consent, 480 children across ten schools participated. The intervention, *The Learning Connections School Program*, was implemented for 20 minutes daily in the classroom by the trained class teacher for the intervention arm (n = 286), while children in the control arm (n = 194) attended schooling as usual (no intervention).

Multivariable analysis using the Generalized Estimating Equations modelling approach and accounting for the effects of clustering and time, showed a positive effect for intervention on two mathematics skills measures (EMCA, EMCB). Children in the intervention arm were significantly more likely to have higher scores in mathematics compared to those in the control arm ($p < 0.05$). Despite a relatively large incidence-rate ratio for EMCA (3.9, 95%CI 1.45-11.02), the crude effect of the intervention on math scores was small (Cohen's $d=0.21$). No effect was seen for gender, location, school socioeconomic/educational advantage score, or on measures of early language development, drawing or developmental and behavioural outcomes, despite anecdotal teacher reports of enhanced school-readiness. This study adds Level 1.c evidence in regard to such interventions in school settings. The practical significance of small absolute differences in test scores needs to be considered with regard to intervention funding in each school setting. Despite being a group, low-cost, easy-to-implement early intervention, it is difficult to recommend sensorimotor interventions based on such limited evidence of effect. Further research should focus on visuospatial integration, which may influence mathematical achievement, and specific school-readiness intervention effects.

Glossary of Key Terms

Term	Definition
Developmental terms	
Sensory motor integration	Interaction of the sensory and motor systems in the body which enhances developmental maturation (Santrock, 2005)
Perceptual-Motor development	A step further from sensory motor integration where a meaning is attached to a sensation (perception) and that meaning is then relayed into a motor movement (motor) to enhance developmental maturation (Mauer, 1999)
Intervention approaches	
Impairment-oriented	Intervention approaches which aim to improve activity performance and participation by correcting, reducing, or remediating underlying impairments in body function or structure (Polatakjo & Cantin, 2010)
Performance-oriented	Intervention approaches which aim to improve performance of a specific skill, task or activity to enhance participation and socialisation (Polatakjo & Cantin, 2010)
Intervention types	
Sensory and motor interventions	A collective term for interventions which use sensory-based and/or motor-based activities as intervention to enhance sensory motor integration (Baranek, 2002)
Ayres® sensory integration (aka) Classic sensory integration	An individualised trademarked treatment by an occupational therapist to address a dysfunction in sensory processing by aiming to enhance sensory (motor) integration (Roley, Mailloux, Miller-Kuhaneck, & Glennon, 2007)
Mixed approach	Use of activities from one or more intervention types with individuals or groups (Polatakjo & Cantin, 2010)
Neurodevelopmental Training	Mimicking of movements made by infants and toddlers to enhance neurological maturation (Chapparo, 2005)
Perceptual-Motor Training	Intentional use of movements similar to primary infant reflexes to replace retained reflexes with purposeful movement (Callcott, 2008)
Sensorimotor	Intervention providing a variety of sensory stimuli and motor activities, not necessarily individualised (Polatakjo & Cantin, 2010)
Sensory-based	Activities focused specifically on how an individual responds to sensory

stimuli (Polatakjo & Cantin, 2010)

Sensory integration Intervention aimed to enhance the process of sensory motor integration (Ayres, 2005)

Using a sensory integration frame of reference Interventions guided by the theory of sensory integration with variations on the original premise of sensory integration treatment (Kimball & May-Benson, 2013)

Education Terms

Early intervention An intervention undertaken in early childhood (up to 8 years of age) (Bailey, Bruer, Symons, & Lichtman, 2001)

Prep Year The first year of formal schooling in Queensland (Queensland Government, Department of Education and Training, 2016)

Year 1 The second year of formal schooling in Queensland (Queensland Government, Department of Education and Training, 2016)

Very early school-age children Children in the first two years of formal schooling and in the transition from preschool to formal schooling (4 – 7 years of age) (van Hartingsveldt, de Groot, Aarts, & Nijhuis-van der Sanden, 2011; Willis, Dumont, & Kaufman, 2013)

Research Terms

Cluster Randomized Controlled Trial A study where clusters of individuals (e.g. a school class or school), instead of individuals, are randomly allocated to receive or not receive an intervention, under controlled conditions (Campbell, Piaggio, Elbourne, & Altman, 2012)

Generalized Estimating Equations (GEE) An approach to data analysis for clusters – a marginal model in which the effect of the covariates on the outcome is averaged over individuals at a point in time and compared over time (Ghisletta & Spini, 2004; Hardin, 2005)

Pragmatic Randomized Controlled Trial A study where an intervention is compared to ‘usual practice (e.g. usual schooling) under flexible conditions (Thorpe et al., 2009)

Randomized Controlled Trial A study where participants are randomly allocated to receive or not receive an intervention, under controlled conditions (Campbell, Elbourne, & Altman, 2004)

Un-blinded A study where participants are not blinded to whether they are in an intervention or control group, or to which intervention they are receiving (Campbell, Elbourne, & Altman, 2004)

Chapter One Introduction and Background

Introduction

Children develop in a sequential process, albeit at varied rates. This discrepancy in rate of development leads to concern for each child's future success, with parents, teachers and school principals, as well as health care professionals, being involved in promoting child development and learning. While physical education programs are a mainstay of schooling, there is also widespread implementation of other interventions designed to promote development and address potential and actual developmental delay. Notably, these interventions aim to also address potential and actual behavioural problems and promote accomplishment of academic learning outcomes. Such interventions are collectively known as sensory and motor interventions, and examination of the effect of one of these interventions is the focus of study in the program of research presented in this thesis.

This introductory chapter presents an overview of sensory and motor interventions and their theoretical underpinnings, to situate these interventions within the broader health care and education literature. A typology of interventions is situated within an international framework of intervention approach, which helps to clarify the intervention approach of various health and education professionals. Classification sharpens the focus of this study on interventions using an impairment-oriented approach to intervention and sets the context for the research problem being addressed. Further chapters will address the research aims developed to answer the research question formulated in this chapter.

Background

Overview of Sensory and Motor Interventions

While most children progress along a typically sequential pattern of development at a similar rate, some children experience early or late difficulties with aspects of development or coordination. Others experience behavioural and academic problems in the transition to formal schooling from kindergarten or day care, or in later schooling. Inclusive education policies and disability standards introduced in previous decades (e.g. Australian Government, Department of Education and Training, 2005; Ministerial Council on Education, Employment, Training and Youth Affairs, 2008) ensure equity and access to formal schooling for all children. Mainstream schooling thus accommodates children with a diverse array of conditions and developmental problems or delays, along with typically developing children. This means some early school-age children will have not yet reached their full

potential for development relative to their age (Sugden, 2007), which may manifest later in an academic or behavioural problem (Kettler, Glover, Albers, & Feeney-Kettler, 2014; Wilson, 2005). There is evidence in Australia that not all children are developmentally ready for formal schooling (Australian Government, 2016; Williams, 2015). Hence, there is impetus for education professionals, parents and other professionals to seek easy-to-implement early intervention programs (Kettler et al., 2014) with a view to addressing and/or redressing such problems and/or easing the transition of children into formal schooling. More detail about this transition and impetus is provided later in this chapter.

One type of early intervention program targets *sensory motor integration*, an aspect of sensory motor development, as a key aspect of development and precursor to academic learning. Thus, various programs providing a set of sensory and/or motor activities are implemented widely in the school setting (Stephenson, Carter & Wheldall, 2007), as a way of addressing any developmental or behavioural problems and for enhancing school readiness for all children (Kettler et al., 2014). These are collectively known as sensory and motor interventions (Baranek, 2002), meaning that interventions are sensory activity-based, or motor activity-based, or both; though there is varied terminology used and several theoretical approaches followed within this area of literature, research and practice. For example, the terms *sensory integration*, *sensory motor integration*, *sensorimotor*, *sensory-based*, *perceptual motor*, and *motor-based*, are used to delineate or label particular types of interventions implemented by particular practitioners, who may include occupational therapists, physiotherapists, nurses, exercise scientists, education professionals and lay people. Further detail of intervention types and approaches is provided shortly within this chapter.

For the most part, there is an assumption by practitioners and/or intervention program operators that many children need some type of intervention to promote or enhance successful development (Leong, Carter, & Stephenson, 2015a). There is a long history of intervention use for children with recognised conditions, such as *autism*, *developmental coordination disorder*, and learning difficulties (Baranek, 2002; Watling, Dietz, Kanny, & McLaughlin, 1999; Wilson, 2005), and also with other less well-recognised conditions, such as *sensory processing problems* and *sensory integration disorder* (Polatjako & Cantin, 2010; Watling & Hauer, 2015). The scientific basis for the use of sensory and motor interventions includes aspects of neurodevelopmental theory, among other theories, to explain sensory motor development (Wilson, 2005), which is also referred to as *sensorimotor* development (Ball & Bindler, 2010). However, it is also argued that there is no scientific basis for these interventions and/or that the theories and assumptions used are older and outdated (e.g. Baranek, 2002; Hoehn & Baumeister, 1994; Leong, Carter, & Stephenson, 2015a; Polenick & Flora, 2012; Wilson, 2005). A brief overview of the basic theoretical underpinnings and understanding

forming the basis of sensory and motor interventions is now presented to provide some background to the planning of this research project and situate the project within the broader literature.

Theoretical Underpinnings (Basic Theory)

Sensory motor integration

Children are born with the ability to move and respond to sensations with reflex actions (Santrock, 2005). During infancy, these reflexes are replaced with specific motor actions as the child grows and learns to achieve motor and sensory developmental milestones; regarded as 'normal growth and development' (Ball & Bindler, 2010). The Royal Society (2011) reports that the brain is constantly changing in a process whereby "connections between neurons are strengthened when they are simultaneously activated" (p. 2), colloquially known as 'neurons that fire together wire together' (Hebb, 1949, cited by The Royal Society, 2011, p. 2). Research has progressed the understanding of how this necessary interaction of the motor and sensory systems in the body enhances neuronal networks in the brain and nervous system (Marieb & Hoehn, 2010; Santrock, 2005; The Royal Society, 2011). Interaction of these systems is known as sensory motor integration, while the progression in capability of children is known as *development* or *maturation* (Ball & Bindler, 2010). Developmental maturation occurs naturally for most children, though provision of both stimulus and opportunity is required to promote optimal development for each child (Ball & Bindler, 2010; Santrock, 2005), and performance can be further enhanced with the provision of specific stimuli and opportunities for practice (Bailey et al., 2001; Bee, 1997).

Current understanding of the integration of the sensory and motor systems in infants is significantly influenced by the work of Piaget (Santrock, 2005), who recognised that the infant's random motor movements and reflexes resulted in sensations that the infant found pleasurable or painful, which then further influenced motor movement. For example, providing a mobile toy in front of or above an infant will influence sensory motor integration. The infant's interest is piqued on sighting [sensation] the mobile and, if sufficiently interested and not tired or hungry, the infant will attempt to reach out [motor movement] and touch the mobile. The touch [sensation] stimulates a feeling or sensation, which relays further information back to the sensory system, providing the infant with information on which to base their next motor movement; for example, to reach further, to reflexively or purposefully grasp the toy, or to bring the toy to their mouth for further [sensory] exploration regarding texture, size, shape and taste. Thus, the infant uses sensation to guide motor movement and learning; developing concepts of themselves and their world, leading to increasing cognition over time (Ball & Bindler, 2010; Santrock 2005). Piaget therefore concluded that sensory

motor integration is critical to the development of intelligence (Santrock, 2005), with the early phase of this integration labelled as *sensorimotor development* (Ball & Bindler, 2010).

It is understood that sensory motor integration is a process whereby the brain uses information from all five senses, as well as from movement, gravity and position (Ayres, 2005; Santrock, 2005). From the information received, the brain must decide on what to focus upon in order to give meaning to these sensations and what is experienced. The brain is then able to allow actions or responses to these sensations and experiences in a purposeful manner, enabling the formation of perceptions, learning and behaviour (Ayres, 2005). Sensory integration by the brain forms the basis of understanding of the importance of the interaction of the sensory and motor systems in the body, in order to lead to enhanced learning and development (Ayres, 1972; 2005). Early childhood (under eight years) is a critical period for development (Bailey et al., 2001), so it is important that each child is provided with the opportunity to maximise sensory motor integration to promote optimal learning and development (Ayres, 2005; Williams, 2007).

What is clearly understood, then, is that specific sensory input enhances motor development and motor activity from an early age. Enhancing development is also well understood in terms of parents' or caregivers' provision of a rich, sensory stimulating environment for their infant and child in the early years of life (Ball & Bindler, 2010; Bee, 1997; Williams, 2007), as well as in terms of the specific practice of a skill, for example grasping a toy, resulting in enhanced performance of that skill, such as grasp/hand grip (Ball & Bindler, 2010; Bee, 1997). While it is apparent that this theory of sensory motor integration has importance for explaining some early aspects of development for *infants*, it is less clear whether specific, directed sensory and motor activities promote *ongoing* learning and development, especially cognitive learning and academic achievement, as has been claimed for many sensory and motor interventions. There is a contention within the broader literature that this theory is overly emphasised (e.g. Leong, Carter, & Stephenson, 2015a) in promoting and justifying some sensory and motor interventions for children of all ages; well beyond the period of *sensorimotor development* described by Piaget. Therefore, a discussion of various developmental theoretical perspectives is relevant and presented next, followed by how these perspectives guide various professional groups and focus their favoured sensory and motor interventions. To guide the reader, Table 1 (p. 5) provides a map of the developmental theories to be discussed in the following section, while the corresponding frameworks, classifications and intervention types and approaches in this table will be referred to later in this chapter.

Table 1. Classification of theoretical perspective and intervention approach

Framework	Theory, Classification, Focus		Reference Source/s
<i>International Classification of Functioning, Disability and Health [ICF]</i> (World Health Organization, 2001)	Body function and structure ↓	Activity and participation ↓	Polatjako & Cantin, 2010
Developmental perspective	Neurodevelopmental theory (medical model)	Cognitive psychology (information from sensory receptors is processed cognitively then motor movement planned and executed)	Sugden, 2007; Wilson, 2005
	Maturational theory of development (autonomous unfolding of the nervous system)	Behavioural	
	Normative-functional skills	Cognitive neuroscience	
	General abilities	Dynamical systems	
Therapeutic approach	Impairment-oriented: Reduce impairment & restore function: target impaired body structure & function and increase activity participation & performance)	Performance-oriented: Aim to improve performance of a particular skill or activity	Polatjako & Cantin, 2010
	Process or deficit to be addressed	Functional skills training	Sugden, 2007
Intervention type	Sensory integration	Direct skills teaching	Polatjako & Cantin, 2010; Sugden, 2007; Wilson, 2005
	Sensory processing	Cognitive-based, performance-based interventions	
	Sensory-based approach	Cognitive Orientation to daily Occupational Performance (CO-OP)	
	Sensorimotor approach	Ecological Intervention	
	Perceptual-motor	Neuromotor task training	
Professional / specialist Group	Occupational Therapists, School Nurses, Education Professionals/ Class Teachers	Exercise Scientists, Physiotherapists, Psychologists, Physical Education Teachers	
Types of impairments / deficits addressed	Sensory processing disorder, retained primitive reflexes, autism, attention deficit / hyperactivity disorder	Developmental Coordination Disorder, poor performance of activities of daily living and movement skills	Sugden, 2007; Wilson, 2005
School problems addressed	Learning difficulties, Dyslexia, behavioural challenges, attention difficulties	Poor sports / school activity participation or performance, motor / coordination / behavioural difficulties	

Theories of Development

The key theory about the process of development is *neurodevelopmental theory*, a neurally oriented understanding, based on an expectation of the autonomous unfolding or maturation of the nervous system (Sugden, 2007). This is certainly the approach studied by health care professionals and teachers as part of the medical model (Wilson, 2005). Wilson (2005) describes this as the *normative functional skills* approach to developmental theory, drawing on the work of Piaget, Illingworth and other early theorists, who observed sensorimotor, physical and cognitive developmental milestones and noted that development occurs naturally in stages, while maturation follows (Santrock, 2005). This type of *maturational theory of development* provides a major explanation of how children develop (Sugden, 2007), but is regarded as observational (Wilson, 2005), self- or child-directed (Mauer, 1999), and simply expectant that maturation will occur over time. It does not explain why some children do not develop naturally, unless a medical model of disease or condition is used to explain those children who do not develop naturally (Wilson, 2005). All problems are seen to arise from some inherent problem or impairment within the nervous system that affects the process and progress of development (Sugden, 2007). This approach does not support any particular treatment or intervention, though screening tests are used to diagnose developmental delay, with an underlying assumption of a neurodevelopmental disorder (Wilson, 2005). It is therefore not helpful when a child's learning or developmental difficulty cannot be identified for a specific diagnosis or treatment (Wilson, 2005).

A related theory that takes more of an action-orientation approach is *developmental theory* (Mauer, 1999). This is most related to the understanding of sensory motor integration as outlined earlier, since it is understood that the sequence of development, the neurological unfolding, is predetermined (Sugden, 2007), but that the rate of development and level of attainment of skills may be influenced (Ball & Bindler, 2010). It is believed that a child will seek out the opportunity to achieve a certain motor movement when they see a need to learn or refine that skill (Sugden, 2007) or when a sensation caused by the movement provides pleasure (Ball & Bindler, 2010). As well, it is understood that provision of opportunities to practice certain skills will enhance development (Bailey et al., 2001) and that skills can also be taught when the child does not attempt to learn themselves or is slow to learn (Mauer, 1999). This theory is based on a conceptual understanding that the sensorimotor process described earlier is the basis for normal development. The environment for development and the opportunities for acquisition and practice of skills are understood to be essential to development occurring (Mauer, 1999). Thus, some sensory and motor interventions are based on *Developmental theory* and mainly provide opportunities for practising specific physical/motor developmental skills to achieve expected developmental milestones.

Although the *neurodevelopmental* and *developmental* theories have served well for a long time, it is now recognised that there is less time for free play in society (Burdette & Whitaker, 2005) and a more sedentary lifestyle for children, including the increased use of computers, television and other technology (Starling, 2011). This interferes with children accessing the types of learning opportunities needed for usual development as associated with the *normative functional* or *maturational* development theory. It is believed that, because of this increased use of technology and lack of opportunity, some children do not experience all the required motor patterns, e.g. crawling, in the sensorimotor phase of development (Williams, 2007; 2015), or that developmental stages are skipped or experienced in an abbreviated form (Brace & Hatch, 2002). This is thought to result in underdevelopment of sensory and motor skills required for later functioning and academic achievement (Brace & Hatch, 2002; Williams, 2007). However, Wilson (2005) claims there is a lack of clarity regarding developmental and age norms for motor movement, i.e. “what are developmentally appropriate tasks?”, which leads to an increase in diagnosis of problems, such as *developmental coordination disorder*, recognised through movement clumsiness. Wilson (2005) states there is confusion regarding whether or not any delay is worthy of follow up or diagnosis. As a recognised expert in this area of research and practice, he argues that recognition and treatment of *developmental coordination disorder* has been controversial and dependent on the particular social-cultural context, underlying assumptions, and allegiance of researchers and practitioners to particular theories and approaches. This may be because age-related developmental expectations for young children have increased over time.

The developmental outcome expectations for the preschool age group, four to five year olds, changed with the advent of a Prep year for all children within the formal school setting in Queensland in 2007, which was compulsory from 2017 (Queensland Government, Department of Education and Training, 2016). Whereas previously, the preschool year was focused soundly on play, this is now the purview of the kindergarten year (three to four year olds) (Hansom, 2015). Meanwhile, outcome expectations for preschool changed to include more focus on readiness for school learning in the Prep year, including an emphasis on cognitive aspects of learning and being able to sit still at a desk, leaving less time for children to continue their sensory motor development in this early school year (Hansom, 2015). National concern over poor national literacy and numeracy (NAPLAN) results; first undertaken in Year 3, point to either a change in expectations or a decrease in development for early school-age children (e.g. Fox & Geddes, 2016; Williams, 2015). So, there is an argument for early intervention to promote, enhance and hasten the normal maturation process (Fox & Geddes, 2016); hence the rise in use of interventions based on alternate theories of development and alternate explanations for delay or difficulty.

A theory related to this increase in developmental expectations is that of *behavioural theory* (Mauer, 1999). This theory views development as a set of behaviours that must be learned, with the child's environment being a major influencer or reinforcement on how such behaviours are acquired and expressed (Bailey et al., 2001; Mauer, 1999). When a child is challenged by their environment, such as entry to school, they may express desirable behaviours and meet the challenge, or they may express undesirable behaviours in response to a challenge that is beyond their current capability (Mauer, 1999; Santrock, 2005). The undesirable behaviour is viewed as a behavioural problem, which can significantly affect a child's ability to fit in with kindergarten and schooling (Fox & Geddes, 2016), while further challenges reinforce the undesirable behaviour (Santrock, 2005). Since it is understood, from this theory, that behaviours can be taught, specific intervention programs target skills useful for behavioural development, such as the sequence of getting dressed, or the rules and activities of a game (Ball & Bindler, 2010; Mauer, 1999). The aim of intervention programs is to improve behaviour, which, in turn, is understood to enhance developmental maturation (Ball & Bindler, 2010; Mauer, 1999). This theory is widely used for the performance-oriented type of sensory and motor interventions which treat school problems to enhance school readiness (Ball & Bindler, 2010; Santrock, 2005). Wilson (2005) argues that the theory used in this approach is one-sided and does not take account of dynamic interaction between the child and their environment.

A further related theory described by Wilson (2005) is the *general abilities approach*. This theory also refers to the organisation or integration of the sensory and motor systems as the basis for later motor and intellectual development. *Neurodevelopmental treatment* and *perceptual motor training* are utilised in this approach (Pless & Carlsson, 2000). Such approaches aim to enhance age-appropriate reflexes, postural reactions and perceptual-motor abilities, as these underlie functional motor skills (Pless & Carlsson, 2000; Callcott, 2008) and, as such, are part of the diagnostic and treatment framework for addressing problems and enhancing development and maturation from this theoretical perspective (Pless & Carlsson, 2000). Proponents of these intervention approaches cite a noted increase in persistence or retention of primary infant reflexes, such as the asymmetrical tonic-neck reflex (ATNR), in young school-age children (e.g. Callcott, 2008; McPhillips, Hepper, & Mulhern, 2000; Reynolds, Nicolson, & Hambly, 2003). The asymmetrical tonic-neck reflex can interfere with normal movement and muscle tone, which causes problems with holding a pencil or pen and writing or drawing (Callcott, 2012; Williams, 2015). As well, visual field problems occur, due to inappropriate or limited head and neck movement (Pless & Carlsson, 2000), which influence the vestibular system and ocular movement (Callcott, 2012). Further, the child's attention is impeded due to the eliciting or automatic firing of the reflex when the child moves their head, resulting in awkwardness (Brace & Hatch, 2002; Callcott, 2008). Callcott (2012) found a higher level of retained asymmetrical tonic-neck reflex in Indigenous children in the Kimberley region of Western Australia,

albeit with a small sample size (n = 40). The ATNR had a significant correlation with lower performance on movement activities important for school readiness (e.g. drawing, cutting and manual dexterity, balance, catching) (Callcott, 2012). Specific movement activities and experiences in this impairment-oriented approach are used to help mature brain function and improve developmental and learning trajectories (Williams, 2015).

Wilson (2005), however, claims the *general abilities* approach is outdated, with an implicit acceptance of the child's behaviour and problems with motor movement as being based on their neurodevelopmental status. He highlights the need to also consider lack of opportunity for practice and low motor confidence as more potentially underlying any awkwardness, motor clumsiness or delay, including diagnosed *developmental coordination disorder*. However, other authors (e.g. Ayres, 1972, 2005; Cermak & Henderson, 1989; Mauer, 1999; Pless & Carlsson, 2000) state that, in this theory, development is regarded as having more of a flexible sequence, requiring exposure to a set of purposeful activities based on the child's adaptive responses to challenges and their environment. In this way, active brain processing is required for the acquisition of developmental skills, rather than this being seen as a passive unfolding of the neurological system (Mauer, 1999).

The theoretical approach favoured by Wilson (2005) is the *dynamical systems approach*, which uses *dynamical systems theory* as a framework for understanding child development. This approach considers the multiple systems within the child that must cooperate and interact with both the task (e.g. writing) and the environmental enablers and constraints (e.g. pencil shape and size, strength of child's grip) in order to master a developmental task. Using *systems theory*, this approach stresses the importance of assessing real world contextual factors related to skill acquisition for a child; though this favours a task-specific approach to assessment and treatment (Wilson, 2005). This might include looking at opportunity, or lack thereof, within the provided environment, to practice a particular skill and how this might impact on overall development and developmental rate and influence mastery of motor skills. From this perspective, approaches to treatment might include implementing performance-oriented interventions that provide a favourable environment for practice of skills (Sugden, 2007).

Many impairment-oriented sensory and motor interventions are designed to offer opportunity for repetitive practice of developmental skills and may, in fact, offer practice for very early developmental tasks in order to ensure that previous missed learning opportunities are now provided (Ayres, 2005; Hawke, 2011). The *dynamical systems approach* offers a way of assessing through observational analysis; requiring no specific tools or accessories, merely observation of a child's performance of a skill, so that task-specific difficulties may be targeted for performance-

oriented intervention (Wilson, 2005). The key is to select tasks that are contextually relevant to the individual child and environment, while also recognising that the child may achieve the task in a different way to others, as long as they eventually acquire the ability to complete the chosen task (Wilson, 2005). In this way, individual sensory and motor interventions may be successful by replacing missed opportunities at the right time when a child is more biomechanically- or maturation-ready than previously (Ayres, 2005; Wilson, 2005). Nonetheless, many such interventions are implemented in a whole of class manner, rather than by individualised approach.

Cognitive neuroscience is a different theoretical approach that looks at brain-behaviour interaction to achieve developmental goals (Wilson, 2005). This *process-oriented approach* relates to kinaesthetic training, where motor skill development is perceived in terms of key functions that drive the motor system toward higher states of learning and readiness (Wilson, 2005). Intervention includes working with a child to achieve imagery of attaining a specific motor skill, in order to help the child attain an internal model of an intended skill or motor movement to replicate in real life (Crammond, 1997). Again, this is similar to providing the opportunity to practise a skill, though with an in-built schema of how to actually do the skill prior to practice, with drawing being one such way to build up imagery (Crammond, 1997). This performance-oriented approach is highly individualised.

In summary, according to Wilson (2005), the *normative functional skill approach* remains the cornerstone of movement assessment for problems such as *developmental coordination disorder* and the need to provide a sensory and/or motor type of intervention. However, this approach does not take into consideration the internal and environmental context within which development occurs. The *dynamical systems approach* provides a better focus for assessment and intervention for children with *developmental coordination disorder*, and, as such, may be well used to support the need for sensory and motor interventions and justify their use with young children in mainstream settings as a way to provide much needed practice for missed developmental learning opportunities. Whilst Wilson (2005) criticises the premise of *sensory integration* and *perceptual motor* programs, he emphasises the social-emotional benefits of such interventions and of those provided via the *dynamical systems approach*. Facilitating movement confidence and self-efficacy in task achievement cannot be underestimated for children that have not developed at the same rate as their peers (Wilson, 2005).

Given that the benefit of sensory and motor interventions may go beyond motor control and include enhanced socio-emotional development and acceptance by peers, it is understandable that such interventions are highly favoured in the early childhood context. However, considering the diverse theoretical background and approach to interventions, it is important to review the framework for

various intervention approaches to understand their place within the intervention context. This will help to set the scene before a critical examination of the research into such interventions to determine if there is evidence of benefit as ascribed by proponents of the various intervention approaches.

Framework for Intervention Approach

There is great disparity in the terms used to name and describe the various sensory and motor interventions used for children. As well, despite the publication of many meta-analyses and systematic reviews of interventions over five decades, there is a striking diversity of nomenclature, types of interventions and populations that have been studied in trials and compared in reviews (May-Benson & Koomar, 2010; Polatakjo & Cantin, 2010; Watling & Hauer, 2015). Interventions are implemented by varied health care professionals, including occupational therapists, physiotherapists, exercise scientists and psychologists, and/or by education professionals and educational psychologists, as well as by commercial organisations and lay program operators (Table 1). This has led to a variety of intervention types and orientation/foci, as well as varied participant ages and characteristics being studied and compared. Thus, in many previously published systematic reviews and meta-analyses, it is contended that ‘apples’ have been compared to ‘oranges’, which has precluded the formation of any firm conclusions regarding the evidence basis for sensory and motor interventions (Polatakjo & Cantin, 2010).

Given this lack of coherence and clarity, significant work to classify the types of sensory and motor interventions has been undertaken in recent years by the *American Occupational Therapy Association*, as part of its *Evidence-Based Literature Review Project* (e.g. May-Benson & Koomar, 2010; Polatakjo & Cantin, 2010; Watling & Hauer, 2015). Outcomes from the resulting systematic reviews confirm that this area of literature, research and practice has been plagued by lack of clarity, with dissimilar interventions and research being discussed, critiqued and compared. This is partly because published papers do not include sufficient detail of the specific interventions employed (Leong, Carter & Stephenson, 2015a), though nomenclature and classification of interventions across and within different disciplines has also been a significant problem (Polatakjo & Cantin, 2010). Recent use of a framework to re-classify interventions means that interventions can be more readily identified and compared in terms of approach, purpose and outcomes (Polatakjo & Cantin, 2010). Table 1 (p. 5) provides a map of the developmental theories previously discussed, and the corresponding framework, classifications and intervention types and approaches to be discussed now.

In 2002, Baranek published a typology of sensory and motor interventions suitable for children with *autism*. This typology is useful for clarifying types of interventions and the varied theoretical and practical approaches, therapists and presumed outcomes of these interventions. More recent work by Polatakjo and Cantin (2010) further clarifies intervention type using the *International Classification of Functioning, Disability and Health* [ICF] (World Health Organization, 2001) as a framework for intervention classification. The theories previously discussed in this chapter are also classifiable using this framework, with Table 1 (p. 5) detailing the ICF framework and classifications in relation to the theories. In the ICF, *health and well-being* is classified into two main domains: *body function and structure*; and *activity and participation*. Polatakjo and Cantin (2010) state that practitioners usually give primacy to one domain over the other in terms of approach to intervention, with some interventions targeting real or supposed impairments in *body structure and function* in one type of approach, while others focus on enhancing performance of specific tasks and activities without specifying, acknowledging or addressing any underlying deficits or impairments. Thus two key approaches to interventions are respectively labelled as *impairment-oriented* and *performance-oriented* (Polatakjo & Cantin, 2010).

Impairment-oriented approaches specifically aim to correct or address any underlying impairment, such as: damage to musculoskeletal, sensory or nervous systems; or abnormal or limited development that limits function (Polatakjo & Cantin, 2010). Interventions using this approach are underpinned by the *neurodevelopmental* and *developmental* theories and relate to the *normative-functional* and *general-abilities* theoretical approaches. *Sensory integration disorder* and *sensory processing disorder* are two identified impairments suggested to arise from difficulties in processing and integrating sensory information (Polatakjo & Cantin, 2010). These purportedly lead to poor sensory motor processing, function and integration, which, in turn, may lead to delayed development and academic and behavioural problems (Dunn, 1997). Sugden (2007) refers to the impairment-oriented approach as a *process* or *deficit* approach, where the objective of an intervention is to remedy some underlying process or deficit in a neural structure, such as the cerebellum, or in a function, such as sensory processing or retained primitive reflexes. Again, this highlights how this approach is significantly based on the *neurodevelopmental* or *maturational* theory of development (Sugden, 2007). An impairment or deficit might be recognised by problems with coordination or handwriting, or with difficulty performing activities of daily living, such as getting dressed and feeding (Sugden, 2007). The types of interventions used in the *impairment-oriented* approach include *sensory integration*, *sensorimotor* approach, *sensory-based* approach and *perceptual-motor* interventions. These will shortly be detailed further.

Performance-oriented approaches, on the other hand, focus on the actual performance of a specific skill, activity or function, such as riding a bicycle, where poor performance may limit participation in schooling or socialisation, and with therapy aimed to improve performance (Polatakjo & Cantin, 2010). Sugden (2007) refers to this as a *functional skills* approach, which typically involves the teaching and practice of activities of daily living and schooling. Specific approaches used include *direct skills teaching*, where training for the activity is provided, and *cognitive-based, performance-based* interventions, where cognitive strategies are used to support specific training and enable learning (Polatakjo & Cantin, 2010). Wilson (2005) explains that *Cognitive Neuroscience* theory is the basis of a *process oriented, neurocognitive modelling* approach to training programs. This approach frames the development of motor skills in terms of brain-behaviour interactions, so focuses on using mental stimulation to imagine *the self* actually performing a task, in order to improve performance in that task (Wilson, 2005). These approaches are widely used by exercise science professionals and physical education teachers for skills teaching and coaching purposes. Given that the program of research reported in this thesis is undertaken by nursing and education professionals, for whom an impairment-oriented approach is more familiar and useful, further discussion of interventions using a *performance-oriented* approach are beyond the scope of this thesis. Instead, further discussion of various interventions informed by an *impairment-oriented* approach will now be detailed.

Impairment-oriented approaches to sensory and motor interventions

Various sensory and motor interventions are based on the *impairment-orientation* approach to intervention. This classification is based on the underlying theoretical assumptions of such interventions, or on the perspective of the professional/specialist group offering the intervention. The differing types of impairment-oriented intervention are now described, along with their specific approach to intervention. Table 1 (p. 5) provides a map of the various sensory and motor interventions and their informing classifications and intervention approaches referred to in the next section of this chapter.

Sensory integration

Sensory integration is the most popular and commonly used sensory and motor intervention. It is used by approximately 90% of occupational therapists working in school settings in the USA (May-Benson & Koomar, 2010; Yack, 1989) and by those working with children with conditions such as autism (Baranek, 2002; Watling et al., 1999). Approximately 80% of Australian and Canadian occupational therapists use sensory integration therapy in their practice, including within schools, for conditions such as learning disabilities and developmental delays (Brown et al., 2005). *Sensory integration* is a simplified form of the term, *sensory motor integration*, and refers specifically to the processing of sensory information by the brain to produce some type of integrated activity (Roley,

Mailloux, Miller-Kuhaneck, & Glennon, 2007). *Sensory integration* is a term coined by Ayres (1972), an occupational therapist, to denote a particular type of treatment by an occupational therapist. The key purpose of the intervention is to address a dysfunction in sensory processing, or a disorder resulting from a child's inability to process sensory information, known as a *sensory processing disorder* (Dunn, 1997). Addressing this type of dysfunction with the specific form of sensory integration treatment is proposed to lead to gains in higher order learning (Ayres, 2005).

The theory of how this continuous process of sensory integration occurs is via a series of levels (Ayres, 1972). At level I, *sensory motor*; the body is alerted by the senses, including tactile (touch), vestibular (gravity and movement), proprioception (muscles and joints), visual, auditory, olfactory and gustatory; with filtering of this input undertaken at level II, *development* (Mauer, 1999). At level III, *perceptual-motor*, there is creation of an *action plan*, i.e. to coordinate hand and eye movements in order to undertake some purposeful activity (Mauer, 1999). At Level IV, *cognition*, integration of the specific input and action plan take place, resulting in accomplishing activities of daily living, or academic learning (Mauer, 1999). The end products of sensory integration include academic learning ability; ability to organise; self-control, self-confidence and resulting self-esteem; and abstract reasoning (Ayres, 1972; Mauer, 1999). In this way, Ayres (1972) purports that specific sensory and motor activities can lead to higher order learning.

The *sensory integration* approach to intervention can be further sub-classified. One sub-classification is the trademarked *Ayres Sensory Integration*[®], also known as *classical sensory integration therapy* or *classic sensory integration*; though, importantly, these terms can only be used if the intervention adheres to the core principles of Ayres' (1972) original therapy (Watling & Hauer, 2015). The intervention was trademarked by the Baker/Ayres Trust in order to delineate it from other interventions *using a sensory integration frame of reference*, without adhering to the core concepts and practices developed and espoused by Ayres over three decades of research (Roley et al., 2007). Thus, the other sub-classification is the *use of a sensory integration framework of reference* in guiding intervention, where there are variations to the original premise or intervention implementation (Kimball & May-Benson, 2013). As postulated by Ayres (1972), and further clarified by others (e.g. Parham et al., 2007; 2011; Roley et al., 2007; Watling & Hauer, 2015), *classical sensory integration therapy*, for the purposes of occupational therapy treatment, refers to *individualised* therapy using a sensory processing assessment to diagnose the child's particular *sensory processing disorder*. Further, specially designed equipment is used to provide 'child-customised' activities with 'just-right' challenges, ensuring physical safety in a meaningful and playful way (Roley et al., 2007; Watling & Hauer, 2015). Other critical elements include *fidelity* or adherence to treatment and measured *dosage* of intervention (Parham et al., 2007; 2011). Thus sensory and motor intervention programs

that use a group/whole-of-class, rather than individualised, approach, with a specific set of pre-planned activities are recognised as *using a sensory integration frame of reference*, but are not practising *Ayres Sensory Integration*®, according to the trademarked specifications (Parham et al., 2007; 2011; Roley et al., 2007; Watling & Hauer, 2015). Such interventions may alternatively or additionally be utilising a more generalised *sensorimotor* approach.

Sensorimotor approaches

Sensorimotor approaches are more diverse than *classic sensory integration*, with provision of a variety of sensory stimuli and motor activities, under the assumption that the coordination of sensory and motor information is essential to motor performance and development (Dunn, 1997; Polatakjo & Cantin, 2010). Inherent in use of these approaches is an assumption that a significant proportion of children have an impairment in *sensory processing* (Dunn, 1997) or simply inadequate development (Sugden, 2007). Retained or persistent primitive reflexes is noted as a common impairment (Hawke, 2011; McPhillips & Sheehy, 2004), while specific impairments are recognised for children diagnosed with conditions such as *autism* (Tomchek & Dunn, 2007) or *sensory processing disorder* or *sensory integration disorder* (Dunn, 1997). A further assumption for this approach is that the motor system requires the processing of sensory information in order for sensory motor integration to occur (Dunn, 1997), and that optimal motor function may require learning how to attend to sensory stimuli (Polatakjo & Cantin, 2010). Thus *sensory-based* activities, focused specifically on sensory stimuli (Polatakjo & Cantin, 2010), may be incorporated into a *sensorimotor* approach to intervention. Other activities included in a *sensorimotor* approach may be based on other theoretical perspectives, such as physiotherapy exercises and neuromotor activities (posture, seating, muscle tightening and strengthening, laterality exercises), as well as *sensory-based* activities (therapeutic riding; therapy balls), and movement therapies (clapping, singing, bouncing, crawling) (Polatakjo & Cantin, 2010).

This type of intervention is often implemented in the school setting with a group of children that may or may not have been diagnosed with a specific impairment, utilising a set program of activities. This fits within *a sensory integration frame of reference* as the intervention is not individualised but assumes some impairments in any class group of children. It is thus difficult to monitor adherence to treatment or intervention dosage for all children in the class (Polatakjo & Cantin, 2010) and to measure actual improvements (Lane & Schaaf, 2010), and it is more difficult to determine whether improvements relate to the specific treatment program or simply to developmental maturation (Hoehn & Baumeister, 1994; Leong, Carter, & Stephenson, 2015a; May-Benson & Koomar, 2010). Nonetheless, sensory and motor intervention programs using this approach are very popular in the school setting despite a lack of clarity about whether any intervention effects relate to sensorimotor

development, sensory motor integration, improvement in academic learning, or any of these (Leong, Carter, & Stephenson, 2015a).

Sensory-based approaches

A *sensory-based* approach requires the use of specific sensory stimulation, including sound therapy, weighted vests and brushing (Polatakjo & Cantin, 2010), where the aim of providing the targeted sensory stimulus is to decrease attention paid to other stimuli and allow for focusing of attention on a particular skill (Dunn, 1997; Polatakjo & Cantin, 2010). These approaches are used particularly for children with a diagnosed impairment or condition, such as *sensory processing disorder*, such as those with cerebral palsy, Down syndrome or autism (Dunn, 1997; Polatakjo & Cantin, 2010; Watling et al., 1999). Stimuli may include use of such items as a weighted vest, which feels like a warm hug, or use of specialised equipment including swings for vestibular stimulation, or sitting on balls as chairs to improve balance and postural awareness (Baranek, 2002; Watling & Hauer, 2015). Such approaches are usually highly individualised to the particular needs of the child (Polatakjo & Cantin, 2010) and thus are generally used in a clinic setting rather than a school setting.

Perceptual-motor development

Another intervention approach is based on the concept of *perceptual-motor development*, a term originally coined by Cole and Chan (1990, cited by Stephenson, Carter and Wheldall, 2007, p. 6). This is similar to *sensorimotor development*, where perceptual processes refer to detecting and interpreting sensory stimuli related to the motor processes involved in movement. Perception is considered a step further from *sensory integration*, as it refers to the notion that the child must perceive something from the sensation or motor activity (Mauer, 1999). That is, it is not enough to experience a sensation, there must be some meaning attached to the sensation and that meaning is then relayed into a motor movement in response to the perception, with the key outcome being the creation of an action plan (Mauer, 1999). The implication is that the child must correctly perceive in order to move appropriately and, if not, intervention activities then relate to improving perception and resulting motor movement. In this way, *perceptual-motor* programs are said to remediate underlying processes, such as retained primary reflexes, in order for the child to achieve academic or higher learning (Callcott, Hammond & Hill, 2015). Interventions using a *perceptual-motor* development approach focus on the processes required to coordinate perceptual and motor skills and include a variety of physical activities and exercises (Stephenson, Carter & Wheldall, 2007; Trost, 2005). These interventions may be viewed as also falling within the *performance-oriented* approach classification and are favoured by physical education teachers (Callcott, Hammond & Hill, 2015). Such programs are widely marketed to schools and have a long history of use in special education and

physical education school settings (Callcott, Hammond & Hill, 2015; Stephenson, 2009; Stephenson, Carter & Wheldall, 2007; Williams, 2007).

Sensory and motor interventions in schools

For all approaches previously discussed, the aim of practitioners, or intervention program operators, is to implement an early intervention for children with a diagnosed, recognised or potential impairment. As can be understood, the various sensory and motor interventions are implemented in varied settings by varied practitioners. Schools are one setting with a significant use of such interventions. Given the governmental school inclusion policies (e.g. Australian Government, Department of Education and Training, 2005; Ministerial Council on Education, Employment, Training and Youth Affairs, 2008), many children in mainstream schooling do have some type of impairment, such as difficulty with handwriting, concentrating or sitting still; or a specific diagnosed condition, such as autism, developmental coordination disorder or attention deficit-hyperactivity disorder. As well, early school-age children are still in a reasonably rapid developmental phase, progressing through significant developmental milestones over the years of schooling (Ball & Bindler, 2010). It is, thus, common for problems with development to be first recognised during the early schooling years when expectations for behaviour and learning are standardised. Part of the transition to schooling is meeting the requirement to be able to sit still and concentrate for periods of time (Hansom, 2015) and sometimes this has not previously been required of children in the home or early childcare setting (Fox & Geddes, 2016; Hansom, 2015). For these reasons, it is common for health and education professionals to seek easy-to-implement early intervention programs (e.g. Callcott, Hammond & Hill, 2015; Stephenson, 2009; Stephenson, Carter & Wheldall, 2007) in order to ease school transition for children. Thus, there is widespread implementation of sensory and motor interventions in schools (Stephenson, 2009; Stephenson, Carter & Wheldall, 2007), in an effort to address any impairments for children and improve schooling outcomes for all children (Callcott, Hammond & Hill, 2015; Hawke, 2011; Williams, 2007; 2015).

While interventions, for example, *perceptual-motor* programs, have a great deal of anecdotal and commercial support, and are widely used in Australian schools, there is a body of research refuting the claims of benefit of such programs (Snowling & Hulme, 2003; Stephenson, 2009; Stephenson, Carter & Wheldall, 2007). It is argued (e.g. Stephenson, 2009; Stephenson, Carter & Wheldall, 2007) that these programs have a long history and clinical tradition, despite having 'no evidence' for their benefit. Stephenson, Carter and Wheldall (2007) reviewed research into *perceptual-motor* programs and found no evidence of benefit for these programs and no evidence to support the claims attributed to them. One aspect of this research was a study of websites of Australian schools, finding that 117 schools specifically mentioned *perceptual-motor* programs, while 41% of these schools made specific claims about the effect of these programs on academic performance (Stephenson,

Carter & Wheldall, 2007). Stephenson, Carter and Wheldall (2007) acknowledge the possibility that an effective *perceptual-motor* program may be developed or proven one day, and that these programs are unlikely to do any harm and are probably enjoyed by children and teachers. However, they conclude that “uncritical acceptance of these programs by schools and teachers is of concern” (Stephenson, Carter & Wheldall, 2007, p. 6), arguing that directing funding and support to an unsubstantiated program takes funding, time and materials away from substantiated, evidence-based programs that assist, for example, with reading and learning. Nonetheless, there is reported evidence of effect from *perceptual-motor* interventions in Australia (e.g. Callcott, 2008; Callcott, Hammond, & Hill, 2015; Williams, 2007; 2015). It is within this broader context that a research problem arose.

Research Problem

The research problem studied in this program of research arose out of recognition of an issue within Queensland Schools, similar to that raised by Stephenson, Carter and Wheldall (2007), as noted above. Viewing the websites of Queensland schools identifies support for various sensory and motor interventions, with wide-ranging claims of benefit made about the specific programs being implemented in each school. In community engagement focus with this research student, principal supervisor and other key stakeholders, the directors of Catholic Education Schools throughout Queensland discussed the growing recognition of both: increasing numbers of children experiencing problems with school readiness and school transition, and increasing use/implementation of sensory and motor interventions, as a form of early intervention for such transition problems. This led to recognition of a research problem/question: *Is there evidence of any beneficial effect for young children from the implementation of sensory and motor interventions in mainstream early schooling?*

The research problem, as discussed, was that many teachers and school principals within the Brisbane Archdiocese of Queensland Catholic Education, the study setting, had noted a concerning increase in children that were not ready for formal schooling. The transition from preschool to formal schooling is a critical period in a child’s development. Early abilities and test scores are predictive of later academic achievement and school success (Davies, Janus, Duku, & Gaskin, 2016; Kettler, Glover, Albers, & Feeney-Kettler, 2014). Children in the first two years of formal schooling are usually between four to seven years of age and fall into two developmental stages: preschool and early school-age (Nagle, 2007). These children are in the transition from preschool to formal schooling (van Hartingsveldt, de Groot, Aarts, & Nijhuis-van der Sanden, 2011), referred to as very early school-age (Willis et al., 2013). Children at this age experience a rapid rate of developmental change (Nagle, 2007), though children develop at different rates and can seem very differently prepared to each other in terms of school-readiness (Fox & Geddes, 2016).

This difference in school-readiness was particularly notable when the Prep year, a further early formal year of schooling, was introduced into Queensland schools in 2007, for children that turned five years by 30 June in the year of attendance (Queensland Government, Department of Education and Training, 2016). Previously, children at that age attended a preschool in a separate building, with a more informal curriculum and focus on play-based learning (Queensland Government, Department of Education and Training, 2016). Attendance had previously been for half days or for only two to three days per week, while many children may have also attended a commercially-run kindergarten with semi-formal routines instead of curriculum (Fox & Geddes, 2016). As a result of this change in the Prep year, children were noted by teachers to be ill-prepared for a full week of full school days sitting in a classroom setting (Fox & Geddes, 2016), despite the stated focus still being play-based (Brisbane Catholic Education, 2016; Queensland Government, Department of Education and Training, 2016). This teacher observation fits with results from the national Australian Early Development Census undertaken in 2015 (Australian Government, 2016), which revealed that, overall, 22% of children in the first formal year of schooling were developmentally vulnerable in one or more of five developmental domains measured, with a further 11.1% developmentally vulnerable in two or more domains (Australian Government, 2016). This is not unique to Australia, with similar findings in USA national surveys (Child and Adolescent Health Measurement Initiative, 2017).

Children may be vulnerable for physical health and wellbeing, social competence, emotional maturity, language and cognitive skills and communication skills and general knowledge. Developmental vulnerability for young children is well recognised within the health professions. This researcher, a paediatric and child health nurse and lecturer in this nursing specialty, had noticed a significant increase in student assignments describing and discussing this topic within their case study assignments. Families are noted to be increasingly unaware of developmental milestones and the need to provide appropriate developmental activities and opportunities. Registered nurse students working within this specialty are increasingly being asked to intervene for children that are not developing appropriately for their age. This means that many children enter school with developmental vulnerability and are, therefore, technically not ready for formal schooling (Australian Government, 2016).

As a consequence of young children beginning school in an earlier, more formal year of schooling (Prep), developmental change needs to be more strongly supported than in the previous preschool system (Fox & Geddes, 2016). It is thus common for school principals, including those in the study setting context, to seek to implement early intervention programs to enhance children's school readiness and ease the transition to formal schooling. To this end, various sensory and motor

interventions are being widely implemented in the early school setting, in addition to usual physical education programs (Stephenson, Carter, & Wheldall, 2007; Trost, 2005), including in schools within the study setting. Sensory and motor interventions target areas of developmental vulnerability, as well as other recognised disabilities and conditions. Such easy-to-implement interventions (Stephenson, Carter, & Wheldall, 2007) can be seen to fit well within an activity or play-based curriculum in the preschool and kindergarten years. Of note, though, these interventions are marketed by commercial organisations, claiming wide-ranging benefits for academic learning (McCain & Mustard, 1999; Stephenson, Carter, & Wheldall, 2007). This takes on more significance when the concern over poor national NAPLAN results is considered (e.g. Fox & Geddes, 2016; Williams, 2015), which are first undertaken in Year 3. If early intervention programs are purported to improve academic learning outcomes and reduce developmental vulnerability, it is not surprising that these are viewed favourably with regard to longer term academic achievements for all children in the school system.

Rationale for Research

Given this background and within this context, the questions that arose, then, were: *Are sensory and motor intervention programs effective to address developmental vulnerability and academic outcomes?* and, *Are they necessary?*; and, if so, *Would it be best to direct more funding to such programs?*; or *Are they, in fact, taking funding away from other important support programs?*. Thus, the rationale and impetus for this study arose from this practical need in the school setting; to determine the effectiveness of programs supporting children's development and academic learning outcomes, particularly in the face of an apparent need to improve support for early development. As a credentialed Children and Young People's Nurse (CCYPN), with expertise in supporting and promoting children's development by nurses within school settings, and with an already established research connection with Brisbane Catholic Education, it was an ideal project for this research candidate to undertake, and was recognised to be of mutual benefit for Australian Catholic University, Brisbane Catholic Education and the Directors of Queensland Catholic Education Commission. It is important for teachers, school principals, and paediatric and child health nurses to know if they should recommend sensory and motor interventions for enhancing development, and behavioural and academic outcomes for very early school age children. As these interventions are already in use, knowing whether or not to recommend their uptake is very relevant.

Set against the context described above, and the widespread use of such intervention programs in Australian schools, the overall research aim evolved: *to examine the evidence of effect from sensory and motor interventions implemented in the school setting for young children in the transition to formal schooling.*

Research Question

What is the evidence of effect from sensory and motor interventions on the development, behaviour, and early academic skills of very young school-age children in the school setting?

Research Aim and Objectives

The following broad research aim and objectives were developed to address the research question.

Aim:

To examine the evidence of effect from sensory and motor interventions implemented in the school setting for young children in the transition to formal schooling, by:

- Identifying the nature and extent of sensory and motor intervention use with the identified school district context;
- Appraising the literature for research evidence of the effect of sensory and motor interventions and identifying any gap in research evidence related to intervention use in the school setting; and
- Designing a program of research to address the research question and any identified gap in research evidence.

The following chapters present the full program of research, with more specific research objectives for each phase of the study, designed to address this broad aim and specific objectives.

Conclusion

This chapter has presented an overview of sensory and motor interventions, including a comprehensive description of their theoretical underpinnings. A review of the typology of interventions has assisted with classifying such interventions within an international framework. This has clarified the types of intervention implemented by various health and education professionals in relation to the theoretical perspective of each profession. Classification has sharpened the focus of this study on interventions using an impairment-oriented approach to intervention. Recognition of the widespread implementation of such interventions in the school setting to ease the transition of very young school-age children to formal schooling has been shown to lead to the research problem studied for this thesis. A research problem, research question and broad research aim and objectives were developed from this context.

The remainder of the thesis sets out the results of a program of research, undertaken in six phases, to address the above research question, aim and objectives. Chapter Two presents a scoping study

undertaken as Phase 1, to address the first research objective, *to identify the nature and extent of sensory and motor intervention use within the study context* (pp. 23-31). A literature review detailing research evidence for effect of sensory and motor interventions, was undertaken in Phase 2 to address the second research objective, *appraising the literature for research evidence of the effect of sensory and motor interventions and identifying any gap in research evidence related to intervention use in the school setting*, is presented in Chapter Three (pp. 32-46). The methodology and research design of further phases of the research, including the main study, a randomised controlled trial designed to address the third research objective, *designing a program of research to address the research question and any identified gap in research evidence*, are presented in Chapter Four (pp. 47-63). Chapter Five details the results of a systematic scoping study, Phase 3, to identify a suitable intervention to trial (pp. 64-81) and Chapter Six presents a published paper detailing a critical evaluative review of measurement instruments, undertaken as Phase 4, to identify suitable instruments to use in a trial (pp. 82-102). Chapter Seven reports Phase 5, a pilot study, in which the selected intervention and measurement instruments were pilot-tested in the study setting (pp. 103-109). Chapter Eight presents a paper under review that details the main study within this program of research, undertaken as Phase 6, and its results (pp.110-121). Chapter Nine (pp. 122-132) provides a discussion of the results from the overall program of research and situates these within the wider context in which the research problem arose, highlights the strengths and limitations of this research program, as well as setting the scene for post-doctoral research.

Chapter Two. A Scoping Study

Introduction

Chapter One described the context and theoretical background of a research problem, resulting in the formulation of a research question. A broad research aim and three objectives were developed to address this research question. This chapter presents the first phase of a program of research designed to address the research aim and objectives within the research context and setting. Specifically, this chapter details a scoping study undertaken to address the first research objective: *To identify the nature and extent of sensory and motor intervention use with the identified school district context*. Although a research problem had been identified, the scope of the problem had not been identified. While school principals and other key stakeholders had noted the widespread implementation of sensory and motor interventions in Catholic Education schools in Queensland, the nature of these interventions and extent of their use had not been recorded. Thus, a scoping study was required, in order to be able to identify the need and plan for any research program. This chapter commences with a reminder of the research question, aim and objectives, highlighting the relevant objective for this chapter. It then proceeds with details of the scoping study and concludes with an identified need for addressing the next research objective: *Identifying the nature and extent of sensory and motor intervention use with the identified school district context*.

Setting

Following collaboration with key stakeholders that helped to identify the nature of the research problem, as stated in Chapter One, the setting for this study was determined to be the Brisbane Catholic Education Archdiocese. This is a large diocese covering the south-east corner of Queensland, extending from Childers in the north, the Gold Coast to the south and west to Gayndah (Brisbane Catholic Education, 2016). Specifically, the Brisbane region of the diocese was selected for the study, since it reaches south to Logan, north to Gympie and west toward Ipswich (Brisbane Catholic Education, 2016), and is thus readily accessible for travel from Australian Catholic University in Brisbane by the research team. This region encompasses schools from urban and regional/provincial locations, with a variety of primary and secondary configurations, i.e. primary only, primary and some secondary, and Preschool to Year 12 (Brisbane Catholic Education, 2016). Consultation with key stakeholders from Brisbane Catholic Education provided avenues for contact with school principals for recruitment purposes. Further details of the nature of schools within this setting are provided in this scoping study, which was undertaken within the Brisbane region of the Archdiocese.

Scoping Study - Research Design

A scoping survey of Brisbane Catholic Education primary schools was planned to explore and confirm the understanding of the nature and extent of the research problem within the research context and setting (Richardson, Wilson, Nishikawa, & Hayward, 1995). There is no single term used to label a scoping survey (e.g. scoping exercise, scoping study) and no single definition to describe its purpose and use (Levac, Colquhoun & O'Brien, 2010). However, there is some consensus that a scoping study can be used to examine the extent, range, and nature of a research problem (Arksey & O'Malley, 2005; Richardson et al., 1995). Given that there was a need to explore the nature of, and extent of use of, sensory and motor interventions within Brisbane Catholic Education schools, a scoping study was an appropriate choice of research design. A further purpose for undertaking a scoping study is the ability to include stakeholder consultation to inform or validate study findings (Anderson et al., 2008), in this case with school principals and teachers in the study setting. Another purpose is to undertake an examination of feasibility for a further stage of research (Levac, Colquhoun & O'Brien, 2010), such as a systematic literature review or a research trial, as was the case for this study.

The overall aim of this first phase of a research program was to undertake a survey to determine the nature, extent, and level of assessment of sensory and motor intervention programs already in use within the setting. Further potential resulting benefits were recognised, in that the study may be able to identify the suitability of schools to include in the research, as well as confirm the feasibility of conducting a research trial within the setting; therefore this was set as the secondary aim of the study. An online survey was selected as the method for the scoping survey. This method can be used to explore a situation, by accessing a relatively large sample from a dispersed population of interest (Tuten, 2010), in this case, Brisbane Education schools. An online survey also permits the collection of the required data in a reasonably rapid manner and at a relatively low cost (Kelley, Clark, Brown, & Sitzia, 2003; Tuten, 2010). Data were planned to be collected using a standardised form, via a questionnaire (Kelley, Clark, Brown, & Sitzia, 2003), using an online survey tool, *Survey Monkey*. Use of this type of tool eliminates the need for transcription or data entry and provides ease of data analysis for a large amount of data (Tuten, 2010).

Scoping Study Objectives

The main aim of this study was to identify and describe the type of sensory and motor intervention programs that were being implemented in Catholic primary schools in the Brisbane region of the Archdiocese of Brisbane. A set of objectives was determined by key stakeholders in response to the nature of the research problem, as outlined in Chapter One.

The specific objectives of the scoping survey were to:

- Identify which sensory and motor intervention programs were in common use already,
- Identify what percentage of schools already used sensory and motor intervention programs and their patterns of use,
- Of the programs in common use, identify the following:
 - Who was responsible for delivering the program, what position they held, and their qualifications,
 - In which school year(s) the program was delivered,
 - The key elements of the program,
 - The equipment required to deliver the program,
 - The cost of delivering the program,
 - The length of time for each session in the program,
 - The weekly frequency of delivery of the program,
 - The methods of assessment used to evaluate the benefits of the program.

In addition to the main aim, a secondary aim was to determine suitability and eligibility of schools within the Archdiocese to participate in a research trial in this program of research, should it be determined that there was a lack of research evidence for sensory and motor interventions. In order to address this secondary aim, a set of objectives was determined:

- To identify the number of pupils (based on average class size) that could be included in a research trial.
- To identify schools that did not have a sensory and motor intervention program in place and therefore may be suitable to be involved in a research trial.
- To identify schools that already had a sensory and motor intervention program in place and that may subsequently be unsuitable to be involved in a research trial.
- To identify potential schools to recruit in terms of location and differences (such as rural and urban, small and large schools, primary only and primary and secondary schools).

Methods

Data collection

Survey Questionnaire

A survey questionnaire was developed to address the identified aim and objectives of the scoping study. Survey questions were designed in collaboration with key stakeholders from the study setting, with this consultation also serving as validation and pilot-testing of the questionnaire. The survey contained six general questions about each school and its class sizes and seven questions about the

types of sensory and motor intervention programs being provided by the schools. A final question asked principals for expressions of interest to participate in a future trial.

Online Survey Tool

An online survey tool, *Survey Monkey™*, was used to gather data. A link to the survey was sent by email invitation to all primary and primary/secondary school principals in the Brisbane region of the Archdiocese of Brisbane. Generic school principal/school email addresses were used, which were obtained, with permission, from the Brisbane Catholic Education, Archdiocese of Brisbane website.

Ethical approval

Ethical approval for the scoping study was sought from the Australian Catholic University Human Research Ethics Committee. As well, approval was sought from the Ethics Committee of Brisbane Catholic Education, for approval of access to schools website data and for contact with school principals and teachers. The study was approved by the Brisbane Catholic Education Research Committee and ethical approval was granted by the Australian Catholic University Human Research Ethics Committee (reference Q2010 28).

Participants

One hundred and twenty primary or combined primary/secondary schools were identified via the website and principals were invited to participate in the survey. Data collection commenced in June 2010 and was concluded in October 2010. Due to an initial slow response, several reminders were emailed to potential participants.

Data analysis

Data analysis was undertaken using the collation tool in *Survey Monkey*. This generates a report of all collated responses for closed questions and lists responses to open-ended questions. This report was used to prepare a report of results.

Results

Schools

The final response rate to the online survey was 55% (n = 66). The majority of schools was primary only (n = 60; 90.9%). Most schools were located in an urban area (n = 51; 77.3%), with the remainder located in rural (n = 6; 9.1%), semi-rural (n = 3; 4.5%), or regional (n = 6; 9.1%) areas. The largest group of schools was primary/urban (n = 49; 74.2%).

The number of primary school pupils enrolled annually ranged from 85 to 1016 (mean 422.0, SD 212.3; n = 65). The mean number of primary pupil enrolments for primary schools (412.1; n = 59) was

less than that of combined primary/secondary schools (520.2; n = 6). Rural schools had the smallest number of enrolments (mean 221.8; n = 6), urban schools (mean 432.5; n = 50) and semi-rural schools (mean 428.7; n = 3) were similar, whereas regional schools had the highest number of enrolments (mean 532.0; n = 6).

In most schools (n = 46; 70.0%), the number of pupils in Prep classes was between 25-30, with the remaining schools having Prep class sizes with less than 25 pupils. In year 1, there was slightly more schools (n = 50; 75.8%) with class sizes between 25-30 pupils, with the remainder having class sizes less than 25 pupils. A minority (n = 13; 25.5%) of urban schools had Prep class sizes less than 25, whereas the majority of rural/semi-rural/regional schools has class sizes less than 25 (n = 9; 60.0%).

Sensory and motor intervention programs

Sixty one schools provided information about sensory and motor intervention programs, including availability, access, delivery, frequency and duration, and content and equipment.

Availability

The majority of schools (n = 59, 96.7%) provided some form of sensory and motor intervention program. All rural, semi-rural, and regional schools provided programs, whereas two urban primary schools did not. All of the primary/secondary schools that responded (n = 5) provided a program.

Access

Of the 61 schools that provided information, the majority (n = 42; 68.9%) provided a sensory and motor intervention program for both Prep and Year 1 pupils (see Table 2).

Table 2. Provision of intervention programs by year

School year	Pupil range		Location			
	Primary	Primary/ secondary	Urban	Rural	Semi-rural	Regional
PREP only	2	0	1	0	0	1
Year 1 only	16	1	14	0	1	2
PREP and Year 1	38	4	31	6	2	3
TOTAL	56	5	46	6	3	6

Delivery

Most programs were delivered by both a physical education teacher and a class teacher (n = 35; 57.4%). However, in a significant number of primary schools (n = 15) the program was delivered by a

physical education teacher only or a class teacher only (n = 10) (see Table 3). In five primary schools (of which four were urban and one was rural) the sensory and motor intervention program was provided either by an external provider or with external support.

Table 3. Delivery of intervention programs

Personnel delivering program	Pupil range		Location			
	Primary	Primary/secondary	Urban	Rural	Semi-rural	Regional
Physical Education teacher only	15	0	14	0	0	1
Class teacher only	10	1	9	1	0	1
Physical Education teacher and Class teacher	31	4	23	5	3	4
TOTAL	56	5	46	6	3	6

Frequency and duration

Most sensory and motor intervention programs were provided twice per week (n = 30; 45.5), and only ten (15.2%) schools provided a daily program. The length of the program was between 15-30 minutes in the majority of schools (n = 34; 51.5%). Of the ten schools that provided a daily program, the majority (n = 6) provided a program lasting 15-30 minutes (see Table 4).

Table 4. Frequency and duration of intervention programs

Weekly frequency	Duration (mins)			
	≤ 15	15-30	30-60	TOTAL (%)
Once	0	2	2	4 (6.6)
Twice	3	16	11	30 (49.2)
Three times	1	5	3	9 (14.8)
Four times	1	5	2	8 (13.1)
Daily	2	6	2	10 (16.4)
TOTAL (%)	7 (11.5)	34 (55.7)	20 (32.8)	61 (100)

Content and equipment

The majority of schools (n = 39; 59.1%) provided a mixed program of general and sensory-motor activities or exercises. Of these, most (n = 23) were 15-30 minutes duration. The majority (n = 23) of mixed programs was provided three or more times per week. Of the three schools providing a

sensory and motor (only) program, its duration was 15-30 minutes, and was provided once or twice per week (see Table 5).

Table 5. Duration and frequency by type of intervention program

Type of program	Duration			Weekly frequency				
	≤ 15	15-30	30-60	Once	Twice	Three times	Four times	Daily
General exercise only	2	1	0	0	1	1	0	1
General exercise and games	2	7	7	2	12	1	1	0
General exercise and sensory-motor exercise / activities	3	23	13	1	15	7	7	9
Sensory-motor exercise / activities	0	3	0	1	2	0	0	0
TOTAL	7	34	20	4	30	9	8	10

Most schools used a range of types of equipment with their sensory and motor intervention program (see Table 6). The majority (n = 40; 65.6%) used general exercise equipment and 34 (55.7%) schools used 'specialised' sensory and motor intervention equipment. Both games (n = 31; 50.8%) and playground (n = 28; 45.9%) equipment were also used widely. However, the type of equipment was not specified.

Table 6. Equipment used by type of intervention program

Type of program	Type of equipment used (number of schools using the equipment)			
	General exercise	Playground	Specialised sensory-motor	Games
General exercise only	2	1	0	0
General exercise and games	9	8	3	14
General exercise and sensory-motor exercises	28	19	30	16
Sensory-motor exercise / activities	1	0	1	1
TOTAL	40	28	34	31

Participation in further phases of the research study

Fifteen schools volunteered to participate in a pilot study phase of a research trial, of which ten were located in an urban area. Forty-six school principals volunteered their school to participate in a research trial, of which 34 were located in urban areas.

Summary

Sixty six schools participated in the survey, achieving a 55% response rate. Most schools were primary only, were located in urban areas, and averaged over 400 primary school enrolments annually. In most schools, both Prep and Year 1 class size was 25-30 pupils. However, in rural, semi-rural, and regional schools, class sizes tended to be smaller.

Sixty one schools (92.4%) provided information about sensory and motor intervention programs, with nearly all providing some form of regular intervention program. In most schools the program was provided for both Prep and Year 1 pupils, and was delivered jointly by physical education and class teachers. The majority (88.5%) of programs was at least 15 minutes duration, with most (93.4%) being provided twice or more per week.

Most programs were described as being a mix of general and sensory and motor exercises, with schools using a range of different types of equipment to support their program. A significant number of schools (n = 34; 55.7%) reported using specialised sensory and motor intervention equipment.

Scoping Study Conclusions

The findings of this survey are limited by the response rate of 55%. It is encouraging that most schools had a regular exercise program in place for PREP and Year 1 pupils. However, the results suggest that there is no standardised approach to the provision of sensory and motor intervention programs within Archdiocese of Brisbane Catholic primary schools. Whilst the majority of schools provided an exercise program, its frequency and duration was highly variable. A large number of schools reported that sensory and motor intervention programs were being employed and that specialised equipment was being used. Further investigation regarding the precise nature of exercise programs and the specific equipment used would help to clarify the extent of sensory and motor intervention program use. However, this was beyond the scope of this phase of the study.

Overall Conclusion

This chapter reports a scoping study undertaken to address the first research objective designed to address the research question. The scoping study was undertaken with the main aim to identify the nature of sensory and motor interventions and extent of their use with the identified school diocese context. A summary of sensory and motor interventions in use and their nature and type was gleaned from this scoping study. This confirmed the research problem, as outlined in Chapter One (pp. 18-20), that many schools within the study setting were implementing sensory and motor interventions in addition to usual physical education programs. A further aim of the scoping study was to determine eligibility and suitability of schools for a research trial, if needed, to address the

final research objective. It was determined that there was sufficient interest to participate from school principals of schools within the study setting. The completion of Phase 1 enabled the progression to Phase 2 of this program of research. The next step of the program of research is to address the second research objective: *To appraise the literature for research evidence of the effect of sensory and motor interventions and identify any gap in research evidence related to intervention use in the school setting.* This systematic review is detailed in the next chapter, Chapter Three.

Chapter Three Literature Review

Introduction

Chapter Two described a scoping study undertaken to address the first research objective of this program of research. Results from that phase identified that a significant number of schools in the study setting were implementing sensory and motor interventions in addition to usual physical education programs. Information is now needed on whether there is evidence of effect of such interventions. This chapter, therefore, presents a systematic review of literature undertaken to meet the second research objective: *To appraise the literature for research evidence of the effect of sensory and motor interventions and identify any gap in research evidence related to intervention use in the school setting.* This chapter commences with a reminder of the research question, aim and objectives, highlighting the relevant objective for this chapter. It then proceeds with details of the literature review undertaken and results; and concludes with an identified need for addressing the next research objective: *Appraising the literature for research evidence of the effect of sensory and motor interventions and identify any gap in research evidence related to intervention use in the school setting.*

Effect of Sensory and Motor Interventions

Overview

A major review of research conducted into children's development (McCain & Mustard, 1999) concludes that early stimulation, practice and experience are essential to enhance development of the young child's brain. McCain and Mustard (1999) emphasise that there are critical periods in which a lack of stimulation reduces the child's later potential. The influence of stimulation on maturation has been explored by examining possible relationships between maturation and the child's learning environment (Bee, 1997). Two models of relationships align with the two intervention approaches outlined in Chapter One (pp.11-17). Specifically, *facilitation*, via which experience is noted to speed up development of some maturation process (Bee, 1997), and addresses some type of impairment, such as developmental delay. Alternatively, *attunement*, in which experience is noted to increase the ultimate level of some skills or behaviours above the normal maturational level (Bee, 1997), relates to a *performance-oriented* approach. These models suggest that provision of a specific sensory and motor intervention may enhance developmental maturation and improve specific developmental skills for children.

Significantly, development does not progress well for all children and problems with sensory motor integration are recognised in some children (Ayres, 2005). Interventions to enhance sensory motor

integration, and subsequent development and learning, have been developed and evaluated over decades, showing positive results (McCain & Mustard, 1999; The Royal Society, 2011). Global research has demonstrated that early intervention is important for all children, especially in the pre-school years (McCain & Mustard, 1999). After the pre-school ages, most research tends to be focused on children with developmental problems or conditions (McCain & Mustard, 1999). Thus, there is stated evidence of benefit of sensory and motor interventions for disabled or disadvantaged children (Bumin & Kayihan, 2000; Levac et al., 2009; McCain & Mustard, 1999; Whittall, 2009), and children with autism (Baranek, 2002; Watling et al., 1999); but there is less evidence that these interventions influence development and learning in well, healthy children, without specific developmental problems (Levac et al., 2009; The Learning Connections Centre, 2000). This is of significance because many interventions are implemented in a whole-of-class manner/whole-of-school setting, as noted for the identified research problem and within the context for this program of research; which is supported by the results from Phase 1.

A review of research relating to neuroscience and education and learning was undertaken by The Royal Society (2011). It concluded that much research has previously focused on specific learning difficulties, with more current neuroscience research attempting to determine the actual basis of learning difficulties in the brain. While children with significant learning or developmental difficulties are usually readily identified, there is an understanding that many more children may have less-well identified problems with specific areas of learning and development, and that these children would also benefit from enhanced learning activities (The Royal Society, 2011). It is recognised that there is “no hard-and-fast dividing line between normality and abnormality” (The Royal Society, 2011, p. 5), making it difficult for teachers and parents to be able to determine if a child will simply ‘grow out of’ their learning difficulty as a matter of developmental maturation, or if there is a need to take action with a specific targeted intervention (Williams, 2007). Therefore, according to The Royal Society, there are many commercial interests promoting programs of “brain-training” (2011, p. 7), which are essentially sensory and motor integration interventions, presented with enthusiasm and testimonials, but unfortunately little authentic research. Given this context, it is critical to identify the extent of evidence for effect of any type of sensory and motor intervention using any intervention approach. The aim of this systematic literature review was to determine any evidence of effect of any sensory and motor interventions, particularly for children.

Method

Aim

To identify, evaluate and synthesise research literature pertaining to trials of sensory and motor interventions with children to determine if there is any evidence of effect.

Objectives

The objectives of this review were to:

- Identify published meta-analyses, systematic reviews and literature reviews reporting on research into sensory and motor interventions,
- Synthesise results to determine any evidence of effect provided by this literature, and, if necessary or possible,
- Use this review to determine a specific intervention to use in a research trial.

Systematic Search Strategy

A systematic search of the literature was undertaken to identify papers relevant to the objectives. The original search was undertaken in July 2009 to prepare for a program of research. The search was repeated in October, 2012 and again in October 2015 for the purposes of updating the review to present in this thesis. Databases searched included CINAHL, ERIC, MEDLINE (2008-present), PsychINFO, PubMed as well as multisource databases: Academic Search Complete, Ebscohost Research Databases, Education Research Complete, ProQuest Education Journals, ProQuest Central, and Sage Journals Online. The university library advanced search function was also used.

The search strategy included combinations of the following search terms, where possible used in exactly the manner shown below:

1. 'sensory motor development' OR 'sensory-motor development' OR 'sensorimotor development' OR 'sensory motor integration' OR 'sensory-motor integration' OR 'sensorimotor integration' OR 'perceptual motor development' OR 'perceptual-motor development'
2. effectiveness OR success OR evaluation OR review OR significance OR trial
3. program* OR therapy
4. child*

The key term 'early childhood' was not used as this may refer to neonatal and infancy stages, but was not excluded as it can also refer to various ages/stages of young children. Where available, the search terms NOT 'adult' and NOT 'infant' were added. Search limits included English language only. Since many studies still cited were published in the 1970s, no year limit was imposed.

Papers located by searching were initially screened and removed if they were:

- duplicates
- theory or educational articles, letters to the editor, website/book reviews, opinion pieces
- conference presentation abstracts, and policy statements

- not published in the English language.

Inclusion Criteria

Only papers that met the following criteria were retrieved for full review:

- Specified sensory and motor interventions designed for children, particularly those aged 4 – 13 years
- Meta-analyses, systematic reviews, literature reviews, research studies/evaluation of those interventions
- English language.

Evaluation method

Papers were evaluated by one reviewer, using a structured, modified Population, Intervention, Comparison, and Outcome (PICO) process (The Joanna Briggs Institute, 2014a) for evidence synthesis from meta-analyses, systematic reviews and literature reviews. Population/Participant (P) information derived from each review included the number of studies reviewed, and the total number of participants, age groups and gender (where reported) included in each review. Intervention (I) orientation approach and specific intervention type and domain studied were determined for each review. Comparison (C) was used to identify and compare the level of evidence provided by the study design. Outcome (O) was reported in terms of evidence for effect and effect size (where reported). Any reported study limitations and design problems were also recorded where reported.

Results

This search located a total of 323 papers, of which 256 were excluded during the screening process. Following further screening against the inclusion criteria, a further 22 papers were excluded, including six (6) examining a different topic, four (4) which used a focus group approach, three (3) which used parent report, three (3) which used a survey method, five (5) relating only to an older age group, and one (1) study protocol. A total of 45 relevant papers were identified for full review, including 31 high quality research papers, which comprised five (5) meta-analyses, 17 systematic reviews, and nine (9) literature reviews of various sensory and motor interventions. Evidence from these is synthesised in Table 7 (pp. 36 – 39). A further 14 separate research papers reporting on specific intervention trials were identified; however, these were not individually reviewed as they had all been reviewed in the published reviews located in this search. These papers were, however, retained for further review of specific interventions (presented in Chapter Five, pp. 64-81).

Table 7. Overview of the evidence for sensory and motor intervention effectiveness

Type of review	Details (Author, year)	Number of studies, (participants) [age groups] {gender} reviewed (P)	Levels of evidence of studies (C)	Intervention approach / type/s (I)			Outcome (O)		Limitations/ Problems
				Impairment – oriented (types of impairments)	Performance-oriented	Specific intervention type/s reviewed; Developmental domain/s studied	Evidence of effect	Effect size	
Meta-Analyses	Leong, Carter & Stephenson, 2015a	30 (1434) [<12 yr, 13+] {M = 511, F = 181*}	I – III	√ (DD, LD)		SI; Academic learning/ achievement	Weak; some statistically significant effect when compared to no treatment, no statistically significant effect when compared to alternate treatment	0.41 overall; 0.19 SI, PMD; long term 0.12 (NS)	Lack of blinding, failure to establish pre-test equivalence, failure to randomise, limited descriptions of interventions, diverse outcome measures used
	Pless & Carlsson, 2000	13 (219) [3 – 13 yr] {M = 142, F = 77}	I – III	√ (DCD)		Mixed, NDT, SI; Motor skill development	Some effect for specific skills approach with children of school age	Mean main effect size of 0.56	Design affected effect size
	Tinderholt Myrhaug, Østensjø, Larun, Odgaard-Jensen, & Jahnsen, 2014	38 (1407) [< 7 yr] {NR}	I – II	√ (CP)	√	Mixed, NDT, PT; Motor function	Authors claim increasing evidence regarding CIMT, though meta-analysis results are very mixed	Too heterogeneous for meta-analysis	Low power, blinding is not feasible in these studies
	Vargas & Camilli, 1999	32 (578) [3 – 10 yr; adult] {F:M = 1:6 children; = 1:1 adult}	I – II	√ (LD)		SI; Psychoeducational and motor	Some effect when compared to no treatment; effect sizes not homogenous and differ across outcomes	0.29 when compared to no treatment; 0.09 average effect size	Confounding effects in cluster analysis; lack of functional outcome measures
Systematic Reviews	Armstrong, 2012	19 (73, SR = NR) [4 – 12 yr] {NR}	I – IV	√ (DCD)	√	Mixed, PM, SB, SI, SM Daily activities	Mixed, critique only	NR	NR
	Blauw-Hospers & Hadders-Algra, 2005	34 (3255) [0 – 5 yr] {NR}	I – V	√		Mixed, NDT; Motor development	Lack of beneficial effect; inconclusive	NR	Studies are very heterogeneous in intervention type, methods, outcome measures
	Case-Smith, Frolek Clark & Schlabach, 2013	24 (NR) [0 – 5 yr] {NR}	I – III	√ (CP, various)		Mixed, NDT, Play-based, Visual-motor; Motor performance	Low positive short term effects; most inconclusive	Limited evidence for long term effects	Low sample sizes, short duration which can result in low effects and Type II error

	Frolek Clark & Schlabach, 2013	13 (NR) [0 – 5 yr] {NR}	I, IV		√	Mixed, Cognitive; Cognitive development	Gains from early infancy intervention; inconclusive by school age	NR	Lack of detail of interventions – not able to be replicated; short duration
	Hoehn & Baumeister, 1994	7 (366) [5 – 11 yr] {NR}	I – III	√ (LD)		PM, SI; All domains	Maturation the source of any improvement	No effect	No discernible effect on academic outcomes
	Hillier, 2007	31 (1105) [children any age] {NR}	I – III-3	√ (DCD)	√	Kinesthetic, Mixed, PM, motor skill, SI; Motor function	Intervention is better than nothing; PMT was inferior compared to alternate. 6 SIT studies report	Strong evidence	Meta-analysis not possible due to clinical heterogeneity of the studies;
	Krieder, Bendixen, Huang & Lim, 2014	38 (NR) [children, youth] {NR}	I – V	√	√	Mixed, NDT, PM, SI; Daily activities, All domains	Critique only	NR	Better study design needed
	Lang et al., 2012	25 (217) [2 – 12 yr] {M = 176, F = 31}	I – IV	√ (Autism)		SI; Academic learning, behaviour	Mixed results, mixed interventions and study designs	None (56%)	Serious methodological flaws
	Leong, Carter & Stephenson, 2015b	17 (70) [1 – 46 yr] {NR}	Single case design studies	√ (Autism, DD, LD)		SI; Academic achievement	Alternate treatment more effective than SI in 7 of 8 studies; positive results for SI compared to no treatment in 7 of 9 studies	Meta-analysis not possible due to poor quality of studies; Uninterpretable effect	Poor quality studies, poor experimental control, validity, descriptions
	May Benson & Koomar, 2010	27 (NR) [children] {NR}	I – IV	√ (Autism, LD, SPD, various)		NDT, PM, SI; All domains	A trend for positive results for SI interventions, esp. in contrast to no treatment; just as effective as other treatments under controlled conditions	Small to large; mostly moderate	Many Type II errors/ methodological concerns; fidelity and dosing measures and functional outcome measures needed; small sample size, power, dosing
	Ottenbacher, 1982	8 (317) [4 – 62 yr] {NR}	NR	√ (DD, LD)		SI; All domains	12 of 19 hypothesis tests found significant effect	0.68 medium	Functional outcomes other than motor needed
	Polatajko & Cantin, 2010	21 (284) [2 – 13 yr] {M = 94, F = 22}	I – IV	√ (various)	√	Cognitive, Mixed, SB, SM; All domains	Inconclusive; some positive results; great variation in study populations, interventions, quality	NR	Reduce heterogeneity of interventions and studies

	Polatajko, Kaplan & Wilson, 1992	10 (311) [4 – 13 yr] {NR}	I – III	√ (LD)		SI; Academic learning	No statistical evidence for academic performance; inconclusive re motor performance	< 0.25	Low power
	Reithmuller, Jones, & Okely, 2009	17 (1342) [2 – 6 yr] {M = 566, F = 549}	I – II			Motor, NDT; Motor function	60% reported statistically significant findings	NR	Poor methodological quality; Check sample size/power
	Smits-Engelsman et al., 2012	26(912) [any age] {NR}	I – III		√ (DCD)	Task-oriented, PT, OT, process oriented; Motor performance	Strong effects for task-oriented, PT, OT; Weak effect for process-orient	0.56 overall	Some effect for task-oriented intervention when compared to no intervention. Process-oriented not recommended;
	Soetching, 2014	13 (337) [3 – 12 yr] {NR}	I – IV	√ (SPD)		Classic SI; All domains	Positive effects on individualised occupational goals; Larger effects for SI than other interventions	NR	Larger sample sizes needed
	Watling & Hauer, 2015	23 (506) [2 – 39 yr] {majority M}	I – IV	√ (Autism)		Classic SI, SB; Daily activities and occupations	Mixed results; inaccurate terminology; various outcome measures	Moderate	Need larger sample sizes, better fidelity measures, careful definitions
	Weaver, 2015	23 (223) [3 – 17 yr, adults] {NR}	I – IV	√ (Autism)	√	Mixed, Cognitive; Occupational and academic perf.	Mixed results	NR	NR
Literature Reviews	Baranek, 2002	29 (835) [3 – 41 yr] {NR}	I – IV	√ (Autism)		Mixed, SB, SI, SM; All domains	Mixed results	NR	More control and specificity needed
	Griffer, 1999	5 (487) [school aged children] {NR}	NR	√		SI; Academic performance	Mixed results, inconclusive; Limited relevance to language skill measures used	None	Various outcome measures
	Hyatt, Stephenson, & Carter, 2009	Tinted Lenses only: 17 (1592) [1 – 67 yr] {NR}	NR	√ (various)		PM, SI, Tinted Lenses; Academic achievement	Anecdotal support; lack of empirical evidence	None	Well designed, empirical studies needed
	Leong & Carter, 2008	8 (126) [3 – 8 yr, 19 – 60+yr] {NR}	I – III	√ (various)		SI; All domains	No robust evidence for efficacy of SI	None	No functional outcome measures, design problems
	Mauer, 1999	NR	NR	√ (various)		SI; Academic success and language	Controversial	None	Small sample size, inconsistent definitions of dependent and independent variables, inconsistent outcome measures

	Morgan & Long, 2012	6 (85 parents, 35 children) [5 – 14 yr] {NR}	IV	√ (DCD)		PT, SB, SI; Daily activities – all domains	For parents - Intervention for child's ADLs is more important than remediation of disabilities	NA	Limitations in analysis and representation
	Patel, 2005	NR	NR	√ (CP)	√	Mixed, NDT, PM, PT, SB, SI; Development	Not clearly established; Equivocal at best	none	NR
	Stephenson, Carter, & Wheldall, 2007	Survey of 117 school websites	NA	√ (various)		PM; Academic performance	Lack of empirical evidence	none	Inconsistent methods and measures
	Watling, Dietz, Kanny, & McLaughlin, 1999	Review of OT practices (72)	NA	√ (Autism)		NDT, SI; All domains	Varied assessments and individualised treatments used	NA	NA

Note: * = where reported; F = female, M = male; NA = Not applicable; NR = not reported; SR = systematic review; Impairments – CP = cerebral palsy, DCD = Developmental Coordination Disorder, DD = developmental delay, LD = learning difficulties, SPD = Sensory Processing Dysfunction; Intervention Codes – Classic SI = Ayres Sensory Integration®, NDT = neurodevelopmental treatment, PM = perceptual-motor treatment, PT = physiotherapy, SB = sensory-based, SI = using a sensory integration frame of reference, SM = sensorimotor approach.

Discussion

Overall evidence for intervention effect

In a broad sense, the literature examining evidence of effect for sensory and motor interventions was well reviewed and analysed, providing ostensibly high quality research evidence for effect of intervention. The broad review undertaken here identified 31 reviews published on this topic, of which there are five meta-analyses (Leong, Carter & Stephenson, 2015a; Pless & Carlsson, 2000; Smits-Engelsman et al., 2012; Tinderholt Myrhaug, Østensjø, Larun, Odgaard-Jensen, & Jahnsen, 2014; Vargas & Camilli, 1999); seventeen systematic reviews (Armstrong, 2012; Blauw-Hospers & Hadders-Algra, 2005; Case-Smith, Frolek Clark & Schlabach, 2013; Frolek Clark & Schlabach, 2013; Hoehn & Baumeister, 1994; Hillier, 2007; Krieder, Bendixen, Huang & Lim, 2014; Lang et al., 2012; Leong, Carter & Stephenson, 2015b; May Benson & Koomar, 2010; Ottenbacher, 1982; Polatajko & Cantin, 2010; Polatajko, Kaplan & Wilson, 1992; Reithmuller, Jones, & Okely, 2009; Soetching, 2014; Watling & Hauer, 2015; Weaver, 2015); and nine literature reviews (e.g. Baranek, 2002; Griffer, 1999; Hyatt, Stephenson, & Carter, 2009; Leong & Carter, 2008; Mauer, 1999; Morgan & Long, 2012; Patel, 2005; Stephenson, Carter, & Wheldall, 2007; Watling et al., 1999). While not all reviewers had reviewed the same intervention approach or type, many reviews overlapped in the studies reviewed. Thus, despite reviewers having a specific purpose or aim for review, the overlap in intervention approach and type became evident when comparing several reviews. Reviewers had reached varying conclusions about specific intervention types and approaches and, at times, the effectiveness of these for certain conditions. However, the broader, more comprehensive review presented in this chapter enables some collective conclusions to be drawn about overall evidence for sensory and motor interventions.

Overwhelmingly, authors found mixed results and inconclusive evidence of intervention effect from review, including from one meta-analysis (Tinderholt Myrhaug, Østensjø, Larun, Odgaard-Jensen, & Jahnsen, 2014), nine systematic reviews (Armstrong, 2012; Blauw-Hospers & Hadders-Algra, 2005; Case-Smith, Frolek Clark & Schlabach, 2013; Frolek Clark & Schlabach, 2013; Krieder, Bendixen, Huang & Lim, 2014; Lang et al., 2012; Polatajko & Cantin, 2010; Watling & Hauer, 2015; Weaver, 2015) and five literature reviews (Baranek, 2002; Griffer, 1999; Mauer, 1999; Patel, 2005; Watling et al., 1999). One systematic review author determined moderate effect for intervention (Ottenbacher, 1982). Four reviews determined some evidence of intervention effect, including from one meta-analysis (Pless & Carlsson, 2000), two systematic reviews (Reithmuller, Jones, & Okely, 2009; Soetching, 2014), and one literature review (Morgan & Long, 2012). Three meta-analyses (Leong,

Carter & Stephenson, 2015a; Smits-Engelsman et al., 2012; Vargas & Camilli, 1999) and three systematic reviews (Hillier, 2007; Leong, Carter & Stephenson, 2015b; May Benson & Koomar, 2010) found there to be *some* statistical significance for effect of intervention when compared to no treatment, but no effect when compared to an alternate treatment/intervention. However, two systematic reviews (Hoehn & Baumeister, 1994; Polatajko, Kaplan & Wilson, 1992) and three literature reviews (Hyatt, Stephenson, & Carter, 2009; Leong & Carter, 2008; Stephenson, Carter, & Wheldall, 2007) found a lack of any effect for interventions. Thus, there is no clarity with regard to overall evidence for intervention effect.

Problems with previous reviews and research studies

Reviewers argue that heterogeneous populations, intervention approaches, and measurement outcomes that have been compared in reviews affect any obtainable evidence level (e.g. Polatakjo & Cantin, 2010; Watling & Hauer, 2015), i.e. a level of evidence cannot be determined when interventions cannot be compared easily. From a more detailed perspective, the actual reviews are also heterogeneous, with reviewers all using a somewhat different perspective and different approach toward review. Many compare unlike interventions, while some compare only a particular type of intervention, e.g. sensory integration interventions. Reviewers have also argued that published papers did not include enough detail of the specific interventions employed (e.g. Leong, Carter, & Stephenson, 2015a; Smits-Engelsman et al., 2012), while the nomenclature of intervention type was noted to be problematic (e.g. Polatakjo & Cantin, 2010; Watling & Hauer, 2015), leading to mixed reviews and inconclusive results. A further argument concerns measurement of intervention dosage and fidelity, since a method of measuring intervention effect has not yet been fully elucidated (e.g. Gannotti, Christy, Heathcock, & Kolobe, 2014; Parham et al., 2007; 2011; Schaaf et al., 2014). Clear descriptions of interventions and research methods are required to enable accurate evidence appraisal (Leong, Carter, & Stephenson, 2015a) and this is not evident from previous reviews.

Methodological limitations of research studies were noted by several reviewers. These limitations included: small sample sizes; lack of power; short study duration; lack of control group and/or randomisation; inconsistency in measurement outcomes; variable intervention dosage (frequency and time) and lack of fidelity to intervention (e.g. Lang et al., 2012; Leong, Carter, & Stephenson, 2015a; May-Benson & Koomar, 2010; Polenick & Flora, 2012). Further research addressing these limitations has been recommended (May-Benson & Koomar, 2010; Polatakjo & Cantin, 2010; Schaaf et al., 2014). From the methodological limitations noted in previous studies, conclusions can be drawn about the importance of using a randomised controlled trial with a large sample size and long

duration for any future evaluation of an intervention (e.g. Leong, Carter & Stephenson, 2015a; Watling & Hauer, 2015).

Hence, the level of evidence of effect for intervention determined from these reviews remains significantly mixed and inconclusive overall. Thus far, this review cannot be used to determine any evidence of effect of intervention, nor which intervention type or specific intervention to use for a research study. In order to assist in the selection of one intervention to use in this research study, it was necessary to undertake further examination of the evidence from reviews for each separate intervention type.

Evidence for specific intervention type

Perceptual-Motor

Reviewers of perceptual-motor interventions, from the field of education (e.g. Callcott, Hammond, & Hill, 2015; Hyatt, Stephenson, & Carter, 2009; Leong & Carter, 2008; Stephenson, Carter, & Wheldall, 2007; Stephenson & Wheldall, 2008) determined a lack of evidence of effect of perceptual-motor interventions, with some rather scathing criticism of their continued use in Australian schools (e.g. Hyatt, Stephenson, & Carter, 2009). Historically, much criticism from the medical and psychology professions has also been directed toward the continued use of these interventions despite no evidence of effect (e.g. Bishop, 2007; Hoehn & Baumeister, 1994; Snowling & Hulme, 2003). Perceptual-motor interventions have been labelled as controversial (e.g. Hyatt, Stephenson, & Carter, 2009; Jordan-Black, 2005; Stephenson & Wheldall, 2008) with particular programs attracting worldwide criticism, including the Dore (2006) program, *Dyslexia, Dyspraxia and Attention Treatment (DDAT)*, the *Primary Movement Program* (McPhillips, Hepper & Mulhern, 2000), *Brain Gym®/Educational Kinesiology (Edu-K)* (Dennison, 2006), *Move to Learn* (Chapparo, 2005), and those offered by the *Institute for Neuro-Physiological Psychology* (Goddard-Blythe, 2005). Nonetheless, recent research trials within the field of education have concluded that there is effect from a perceptual-motor intervention program to address retained primary reflexes in Indigenous children (Callcott, 2012). This is particularly so where combined with specific teaching instruction, in, for example, phonological awareness, an aspect of early language development (Callcott, Hammond & Hill, 2015). Examination of the results of reviews here that have specifically addressed perceptual-motor interventions (see Table 7) shows largely a stated lack of evidence of effect (Hoehn & Baumeister, 1994; Hyatt, Stephenson, & Carter, 2009; Stephenson, Carter, & Wheldall, 2007), with some reviewers finding *some* effect when compared to no treatment (Hillier, 2007; May-Benson &

Koomar, 2010). Therefore, these results, combined with the criticism outlined, show that it is difficult to support use of this type of intervention approach for this research study.

Sensory Integration

While an early systematic review of sensory integration interventions showed moderate effect across a number of studies (e.g. Ottenbacher, 1982) and a further meta-analysis (Pless & Carlsson, 2000) and literature review (Morgan & Long, 2012) showed *some* effect, there is generally mixed results or inconclusive evidence for this type of intervention. In a meta-analysis, Vargas and Camilli (1999) noted a chronological trend toward decreasing evidence of effect, though this may also be seen as a chronological increase in expectation for methodological quality and a more stringent approach to review. More recent meta-analyses and reviews have concluded that there is a lack of evidence of effect for these interventions, especially when compared to alternate treatments, though there is some evidence of intervention effect when compared to no treatment, but effect size was small (e.g. Leong, Carter & Stephenson, 2015a). A proviso, however, about this outcome comes from occupational therapist reviewers who state that dissimilar interventions have been compared in reviews (May-Benson & Koomar, 2010; Polatakjo & Cantin, 2010; Watling & Hauer, 2015). It is argued that reviewers should not compare interventions that use *Ayres Sensory Integration*[®], also known as classical sensory integration therapy, with interventions that use a sensory integration frame of reference (e.g. Kimball & May-Benson, 2013; May-Benson & Koomar, 2010; Polatakjo & Cantin, 2010; Roley et al., 2007; Watling & Hauer, 2015). Reviewers of interventions that use *Ayres Sensory Integration*[®] have determined that there is *moderate* evidence of effect for these interventions (e.g. Watling & Hauer, 2015). Given that classic sensory integration is an individualised therapy used specifically by an occupational therapist with one child and specialised equipment (Kimball & May-Benson, 2013; Roley et al., 2007), this type of intervention would not be suitable for a research trial with groups of children in the school setting. It was therefore necessary to examine evidence for other types of intervention.

Interventions using a sensory integration framework of reference, sensorimotor and sensory-based approaches

Reviewers of interventions that use a sensory integration framework of reference (e.g. May-Benson & Koomar, 2010; Polatakjo & Cantin, 2010) have determined that this approach to intervention may have *some positive outcomes* for children, and that intervention is shown to have more effect than no treatment or compared to nothing (Kimball & May-Benson, 2013; May-Benson & Koomar, 2010). Reviewers of interventions using approaches other than a sensory integration approach, including mixed impairment-oriented approaches, such as sensorimotor and sensory-based approaches, found

that children with difficulty processing and integrating sensory information may benefit from these interventions, though the results from studies are mixed and inconclusive (Polatajko & Cantin, 2010; Watling & Hauer, 2015). The great variability of interventions, populations and study types practised, evaluated and reviewed, precludes the determination of any level of evidence from review (Polatajko & Cantin, 2010; Watling & Hauer, 2015). However, it may be that some specific interventions utilising this framework of reference approach are suitable for trial or use in a school setting, as there are able to be used for groups (Polatajko & Cantin, 2010; Watling & Hauer, 2015).

Evidence for specific domain effect

This review demonstrates that most interventions have been studied for evidence of effect on child development in general, i.e. across multiple domains of development. For children in the school setting, interventions are most often put in place to effect some enhancement in academic learning or performance, sometimes specifically for children with learning difficulties. Other interventions are focused toward specifically enhancing motor development or performance for children with specific motor or performance difficulties. From this review, the following conclusions can be drawn with regard to level of intervention effect for specific developmental and academic domains.

For motor performance, there is evidence of some intervention effect from one meta-analysis (Pless & Carlsson, 2000), where the population studied were children with Developmental Coordination Disorder, and from one systematic review (Reithmuller, Jones, & Okely, 2009), studying children at usual schooling; as well as evidence of some effect compared to no treatment from two meta-analyses, one where children had Developmental Coordination Disorder (Smits-Engelsman et al., 2012), and another where children had learning difficulties and psychoeducational performance was also studied (Vargas & Camilli, 1999), and also from one systematic review (Hillier, 2007), where children had Developmental Coordination Disorder. There is also mixed results / inconclusive evidence demonstrated for motor performance from one meta-analysis (Tinderholt Myrhaug, Østensjø, Larun, Odgaard-Jensen, & Jahnsen, 2014), and one systematic review (Case-Smith, Frolek Clark & Schlabach, 2013), both with a population of children with cerebral palsy, and from one another systematic review (Blauw-Hospers & Hadders-Algra, 2005).

Where academic performance was the main intervention effect studied, there is evidence of some effect compared to no treatment from two meta-analyses (Leong, Carter & Stephenson, 2015a; Vargas & Camilli, 1999), where the population studied was children with learning difficulties, and from one systematic review (Leong, Carter & Stephenson, 2015b), where the children had Autism, learning difficulties or developmental difficulties. There is also mixed results / inconclusive evidence

demonstrated for academic performance from two systematic reviews, one where the population was children with Autism (Lang et al., 2012), and one where cognitive development was the particular review focus (Frolek Clark & Schlabach, 2013); as well as from two literature reviews with a particular review focus on language disorders (Griffer, 1999; Mauer, 1999). A further one systematic review (Polatajko, Kaplan & Wilson, 1992) and three literature reviews (Hyatt, Stephenson, & Carter, 2009; Leong & Carter, 2008; Stephenson, Carter, & Wheldall, 2007) demonstrated a lack of evidence for academic performance effect from intervention.

The effect of intervention on the performance of daily activities has been studied, with evidence of some intervention effect from one literature review (Morgan & Long, 2012) where children with Developmental Coordination Disorder were the study focus; while mixed results / inconclusive evidence were demonstrated from one systematic reviews where children with Developmental Coordination Disorder were the review focus (Armstrong, 2012), and another broader systematic review (Krieder, Bendixen, Huang & Lim, 2014) as well as two literature reviews where children with autism were the review focus (Watling & Hauer, 2015; Weaver, 2015).

The best level of evidence is provided from studies where intervention effect is examined across all developmental and academic domains. However, this also suggests that if enough measures are examined, some statistically significant difference will be found. There is evidence for moderate intervention effect for all domains from one systematic review (Ottenbacher, 1982), where children with learning and developmental difficulties were the review focus; and evidence for some intervention effect from one systematic review (Soetching, 2014) where sensory processing disorder was the focus. There is evidence of some effect compared to no treatment from one systematic review (May-Benson & Koomar, 2010), and mixed results / inconclusive evidence demonstrated from one systematic review (Polatajko & Cantin, 2010) and three literature reviews, of which two were focused on children with Autism (Baranek, 2002; Watling, Dietz, Kanny, & McLaughlin, 1999), and one was focused on children with cerebral palsy (Patel, 2005). One review demonstrated a lack of evidence of intervention effect across all domains (Hoehn & Baumeister, 1994).

Limitations

The use of varied population search terms in this review cast a wide net, whereas the use of standardised PICO search terms relevant to each database would have enhanced and refined this search. Given this lack of standardisation, it is possible that some suitable literature has been missed. Since only one reviewer reviewed the studies, it is possible that the review results include

some bias. A lack of reported detail for many interventions in reviews could have led to further bias. Design limitations of many studies included in reviews constrains the evidentiary level obtainable from this review.

Conclusion

A systematic search and literature review was undertaken to address the second research objective: *To appraise the literature for research evidence of the effect of sensory and motor interventions and identify any gap in research evidence related to intervention use in the school setting.* This review has found the research evidence to be already well appraised by several meta-analyses, systematic reviews, and literature reviews. However, due to the heterogeneity of the research literature, these reviews have failed to clearly identify evidence of effect for sensory and motor interventions. A gap in the literature exists in that it is not clear if there is any evidence of effect relating to intervention use in the school setting. This gap could be addressed by a well-designed research trial to examine the effect of a specific sensory and motor intervention on young children's development. This review failed to identify any particular type of intervention for this purpose.

Chapter Five details a further specific literature search and review to identify a specific intervention to use in a research trial of intervention effect. In order to address methodological limitations noted in previous reviews (stated earlier on p. 41), any research study would need to be of randomised controlled trial design and long duration with a large sample size. Since most interventions, as marketed, are purported to support children's development, behaviour and academic learning outcomes, these would be measured as the effectiveness of any intervention. The next chapter, Chapter Four, details the methodology and research design for research planned and undertaken to address this identified research gap.

Chapter Four Methodology and Design

Introduction

The context and theoretical background for the stated research problem was established in Chapter One, with a research question developed from the problem. The research aim and objectives developed from this problem were addressed through a program of research, presented in this thesis. A scoping study, reported in Chapter Two, addressed the first research objective by identifying the nature and extent of the research problem within the study setting, while a literature review, reported in Chapter Three, addressed the second research objective by identifying a gap in the research literature related to evidence of effect of sensory and motor interventions on young children's development, behaviour and academic learning outcomes. This presented the rationale to undertake research which addresses previous methodological limitations noted in other studies. The need for a well-designed trial using a randomised controlled trial design, with long duration and large sample size was established. This chapter presents the methodology used to address the research problem and outlines the specific research design for the next three phases of the program of research. Further detail on research design is provided in future chapters, which contain published papers. Therefore, flagging of the location of these details is provided in this chapter, in order to avoid repetition. This chapter commences with a reminder of the research question and proceeds with methodological justification for a research study to address the third research objective.

Research Question

What is the evidence of effect from sensory and motor interventions on the development, behaviour, and early academic skills of very young school-age children in the school setting?

Research Aim and Objectives

To examine the evidence of effect from sensory and motor interventions implemented in the school setting for young children in the transition to formal schooling, by:

- Identifying the nature and extent of sensory and motor intervention use with the identified school district context.
- Appraising the literature for research evidence of the effect of sensory and motor interventions and identify any gap in research evidence related to intervention use in the school setting.
- *Designing a program of research to address the research question and any identified gap in research evidence.* [This chapter]

Methodology

Research Design

As determined from a review of literature, presented in the previous chapter, there is a lack of clear evidence for effect of sensory and motor interventions, with methodological limitations noted in prior research. In order to determine evidence of effect, this study employed an experimental research design, where quantitative research data were collected and analysed using the method of experimental design (Mertens, 2010). Experimental design is categorised as Level 1, the highest level of design for studying effectiveness (The Joanna Briggs Institute, 2014b). The main phase of the study, Phase 6, specifically employed a randomised controlled trial, while other phases of the study also employed quantitative data collection and analysis methods, as will be outlined in this chapter. It is important to acknowledge that a randomised controlled trial is considered the 'gold standard' (Schultz, Altman & Moher, 2010) of research evidence for a single study "when determining the effectiveness of policy and practice interventions" (Solomon, Cavanaugh & Draine, 2009, p. 3). A randomised controlled trial is categorised as providing Level 1.c evidence of effectiveness, the highest level of evidence one study can provide, with higher levels reserved for systematic reviews of more than one randomised controlled trial study (The Joanna Briggs Institute, 2014b).

The purpose of employing a randomised controlled trial design in this study was to seek evidence of benefit of a specific daily sensory and motor intervention on children's development, behaviour and early academic skills. In this study, the intervention is the sensory and motor intervention. Sensory and motor interventions have been previously studied but evidence for their effectiveness has not been confirmed, as previously stated in Chapter One (pp. 1-22), while Chapter Three provided more detailed reporting of the state of research evidence (pp. 32-46). Therefore, a randomised controlled trial design was used for this study to provide evidence for the effectiveness of a specific daily sensory and motor intervention on children's development, behaviour and early academic skills. Data collection and analysis were conducted in an objective, systematic manner, in accordance with scientific principles of such research (Graziano & Raulin, 2007; Polit & Beck, 2008), with details provided below in this chapter and further details provided in a proceeding chapter. Chapter Eight presents a manuscript under review by a journal for potential publication, entitled, *Two-year cluster randomized-controlled trial of a school-group sensorimotor early intervention*, which contains details of methods used in the study (pp. 110-121). More detail of the specific research design is now provided.

Typology of Randomised Controlled Trial

Randomisation

A randomised controlled trial is classified and reported according to many aspects of study design and control. According to the Consolidated Standards of Reporting Trials (CONSORT) group, the ideal randomised controlled trial is where research participants are randomly allocated to receive or not receive an intervention, and are blinded as to whether or not they are receiving the intervention (Campbell, Elbourne & Altman, 2004). The CONSORT group agrees that random allocation of groups of individuals, known as *clusters*, may be preferable in some circumstances to reduce the risk of contamination (where some individuals know to what group they have been assigned) (Campbell, Elbourne & Altman, 2004). Indeed, cluster allocation, may be the only feasible method of conducting a trial in some settings (Campbell, Elbourne & Altman, 2004), such as schools. Cluster allocation can also be used to address any expected within-cluster correlation that may be due to the influence of the teacher and the teaching methods, classroom interaction and types of learning activities (Ghisletta & Spini, 2004; Hardin, 2005), such as within this study. However, it is important that data analysis methods also account for any expected within-cluster correlation (Ghisletta & Spini, 2004; Hardin, 2005), as is the case for this study, with specific data analysis methods reported in Chapter Eight, in a section labelled *Data Analysis* (p. 113-114).

When working with young children, assigning particular children to an intervention could be construed as unethical (Schulz & Grimes, 2002; Ungar, Joffe, & Kodish, 2006), is certainly impractical when working with children within school and class clusters, and may, in fact, be undesirable (Campbell, Elbourne & Altman, 2004). Previous studies have found that potential bias by some teachers that, in one study, allocated children with learning difficulties to the experiment group, confounded results (Chapparo, 2005). Therefore, cluster design is more practical for this study. A cluster randomised controlled trial design is used with 'pre-existing groups of participants' (Campbell, Elbourne, Altman, 2004), which, in this study, includes pre-existing classes within schools. Therefore, for this study, children were not randomly selected to receive or not receive the intervention; rather, random allocation was undertaken at the school cluster level, as is appropriate for cluster randomised controlled trials (Campbell, Elbourne & Altman, 2012). In order to meet ethical requirements, school principals initially volunteered their schools to participate in the research study. Volunteered schools were then randomly allocated to either the control (no intervention) or experimental (intervention) arms of the study, after which, formal consent to participate was sought. Specific details of the randomisation process are provided in Chapter Eight, which reports on the main study, a randomised controlled trial, in a Methods section labelled *Study*

Sample, Recruitment and Setting (p. 111). Reporting of how this cluster randomised controlled trial met CONSORT requirements for reporting is shown in a check list in Appendix A (pp. 146-150).

Blinding

When trialling an intervention in a school setting, with implementation undertaken by class teachers, teachers would know if they were working with the sensory and motor intervention or not; therefore, blinding to the intervention would be extremely difficult. With this particular intervention, it would be difficult to blind participants (children and teachers) as to whether or not they were providing or receiving the intervention, as sensory and motor interventions are already known by many teachers (Callcott, Hammond & Hill, 2015). It would also be difficult to use a sham or placebo intervention, since the type of intervention activities are already known by teachers due to the widespread use of such interventions in the school setting (Leong, Carter, & Stephenson, 2015a). As well, use of sham movements and activities may actually have their own effect on the outcome measures and potentially confound results (McPhillips, Hepper, & Mulherrin, 2000). Thus, this study employed an un-blinded randomised controlled trial design, where the participants were not blinded to the intervention allocation.

Participants may also be blinded to measurement outcomes in a randomised controlled trial (Thorpe et al., 2009). For this trial, it was not possible to blind teachers to the specific outcome measures used, since teachers directed the self-completion of most outcome measurements by their class participants (children), i.e. the children self-completed the measurement tasks under teacher direction using standardised instructions. Teachers were required, through voluntary cooperation in the study, to actually complete one measurement instrument, by observing and documenting children's development and behaviour. A further degree of voluntary cooperation was desired from school principals and teachers in this study, since they were required to use specific measurement instruments that they may not otherwise use, and direct the intervention activities with children in their classes. Therefore, in this respect, the randomised controlled trial is open or un-blinded, which is appropriate for a pragmatic randomised controlled trial, providing this is reported to the reader (Zwarenstein et al., 2008). However, teachers were not previously familiar with the measurement instruments used and were blinded to the scoring and final outcomes from the measurement instruments, since scoring was undertaken by the researchers. This means that teachers were not able to influence scoring for their pupils. Furthermore, four of the six measures used were designed to be completed by the children themselves in a whole-of-class activity, blinding the teacher to the actual outcomes of the measures for individual children. The teacher simply directed the activity as per standardised written instructions and collected the completed measures, without individually

reviewing or scoring the measures, and sent these by mail to the researchers for scoring. The specific details of the measurement instruments used, and the data collection, data scoring and data entry processes used in this study are provided in Chapter Eight, which reports on the main study, in a Methods section labelled *Instruments* (pp. 112-113). The selection process used to select instruments is detailed in Phase 4, reported in Chapter Six (pp. 82-102), while the actual instruments used are also shown in Appendix D (pp. 157-169).

Pragmatism

There is a general call for pragmatic studies, which compare an intervention to ‘standard care’ or ‘usual practice’ / ‘usual conditions’ (e.g. usual schooling), under flexible conditions (Thorpe et al., 2009; Zwarenstein & Treweek, 2009). In a pragmatic trial, the control group is, by definition, standard/usual practice, so one is unlikely to use a placebo group (Thorpe et al., 2009). According to Schwartz and Lellouch (1967, cited by Zwarenstein et al., 2008), pragmatic randomised controlled trials “favour design choices that maximise applicability of the trial’s results to usual care settings” (p. 2); in other words, they are designed to examine an intervention in an everyday setting, such as a school. A pragmatic randomised controlled trial suits this study as it is difficult to control elements within a school (Schulz & Grimes, 2002) and is considered unethical and impractical to randomly assign young children to a particular intervention (Schulz & Grimes, 2002; Ungar, Joffe, & Kodish, 2006). As well, as noted in Chapter Three (pp. 39-43), previous reviews have shown *some* evidence of intervention effect when compared to no other treatment, so a pragmatic design can test the extent to which an intervention has an effect in this study.

Reporting of the actual research design is important to inform the end reader of the applicability of the randomised controlled trial to their own setting (Zwarenstein et al., 2008). Poor reporting can reduce the usefulness and applicability of pragmatic trials, with an extension of the CONSORT statement specifically designed for improving the accuracy of reporting pragmatic trials (Zwarenstein et al., 2008). Therefore, this research study is reported accurately as employing a pragmatic design, where the intervention was compared to no intervention, under usual conditions; with conduct of the trial guided by recommendations for pragmatic trials (Thorpe et al., 2009). Appendix B (pp. 151-153) provides further details of the reporting of this research trial against the CONSORT guidelines checklist for the reporting of pragmatic randomised controlled trials (Zwarenstein et al., 2008).

Hypothesis

A randomised controlled trial is also classified according to hypothesis, and this randomised controlled trial is classified as a superiority trial, in that the intervention (the sensory and motor

intervention) is hypothesised as superior to usual conditions (no sensory and motor intervention) in a statistically significant way (Piaggio et al., 2012). In other words, it is hypothesised that using this sensory and motor intervention would be better than not using it for improving children's development, behaviour and early academic skills; thereby attempting to provide evidence that there is benefit to using this sensory and motor intervention.

Hypotheses

The null hypothesis for this experiment is:

- There will be no difference in development, behaviour and academic outcomes between experiment and control groups.

The alternate hypothesis is that the means are not equal across the groups.

Research Methods

Setting

Following collaboration with key stakeholders that helped to identify the nature of the research problem, as stated in Chapter One, the setting for this study was determined to be the Brisbane Catholic Education Archdiocese. This is a large diocese covering the south-east corner of Queensland, extending from Childers in the north, the Gold Coast to the south and west to Gayndah (Brisbane Catholic Education, 2016). Specifically, the Brisbane region was selected for the study, since it reaches south to Logan, north to Gympie and west toward Ipswich (Brisbane Catholic Education, 2016), and is thus readily accessible for travel from Australian Catholic University in Brisbane by the research team. This region encompasses schools from urban and regional/provincial locations, with a variety of primary and secondary configurations (Brisbane Catholic Education, 2016). Consultation with key stakeholders from Brisbane Catholic Education provided avenues for contact with School Principals for recruitment purposes. Further details of the nature of schools within this setting were provided in Chapter Two, which reported a scoping study undertaken within the Brisbane region of the Archdiocese. Chapter Eight provides further details regarding the recruitment process and study setting, in a methods section labelled *Study Sample, Recruitment and Setting* (p.111).

Sample size calculation

When planning recruitment for any study design, such as a randomised controlled trial, it is important to consider an appropriate sample size. In order to detect a small difference in effect, among other factors, a large sample size is needed, because size of effect is inversely related to sample size (Moher et al., 2010). The original power and sample size calculation undertaken for this

study was based on an intervention producing a small effect size for a one-tailed test at a power level of .80 with the limit for Type 1 errors set to .05 (Fritz, Morris & Richler, 2012). This calculation indicates a sample size of 310 children in each of the intervention and control groups would provide sufficient power to detect evidence of effect (Fritz, Morris & Richler, 2012). Thus recruitment was undertaken with this in mind, using the process specified in Chapter Eight, Methods: Study Sample, Recruitment and Setting (p. 111), which details the conduct of the main study, the randomised controlled trial, in this program of research. However, this sampling related to an assumption of individual randomisation and analysis of results (analysis for each child's mean test results) (Zopluoglu, 2012), and did not specify expected mean test scores on which this analysis would be undertaken. Since the final design for this study was refined and determined as a cluster randomised controlled trial, with data analysis of clustered results with schools as clusters, power calculations were adjusted for cluster analysis, using the mean scores expected for the instruments selected for the study.

Where cluster randomised controlled trials are used, the degree of similarity across the individuals in a cluster must be considered (Zopluoglu, 2012). Cluster randomised controlled trials may require a larger sample size to obtain statistical power, since the clustered individuals are considered to not be independent as they do not bring unique information in to the analysis (Zopluoglu, 2012) because of the similarity of teaching, school and environmental influences on the clusters (Ghisletta & Spini, 2004). However, this is largely dictated by the value of an intra-class correlation coefficient used to calculate the power of such a study (with larger correlation values requiring larger sample sizes) and effect sizes (with smaller values requiring larger sample sizes). On the other hand, a repeated-measures over time research design, such as in this study, increases the statistical power for detecting changes among the groups being compared (Moher et al., 2010). An intra-class correlation coefficient can receive values from zero to one (0 to 1), with values closer to zero indicating more variability within cluster participants, that is, unique information is provided by each individual within the cluster (Zopluoglu, 2012). Given that clusters in this randomised controlled trial are pre-existing groups of children in classes within schools (with school level clusters analysed), there is an assumed dependence (similarity) within clusters due to "shared experiences in the same environment" (Zopluoglu, 2012, p. 245). Zopluoglu (2012) undertook a study to establish appropriate intra-cluster correlation coefficient values for specific countries by using databases of International results for specific International mathematic and literacy testing outcomes. The reported Australian values were used, since these were the most appropriate and available intra-cluster correlation coefficient measure to use for planning and analysing educational research with

Australian children, with the proviso that the intra-cluster correlation coefficient determined by Zopluoglu was for children in 4th grade (Year 4), not the younger years included in this study. No intra-cluster correlation coefficient value has been determined for earlier grades.

Further sample size calculations were retrospectively undertaken for each measurement instrument selected for use in the randomised controlled trial, using mean scores and their standard deviations obtained at baseline (Prep) and at the end of the first year of the study (Year 1). The calculations were computed for a requirement for 80% power (level of .08) and significance of 0.05, to detect a change in means and standard deviations, using an intra-class correlation coefficient value of 0.29, for average cluster size of 10. Details of the selection process for instruments are provided in Chapter Six (pp. 82-102), an evaluative review of instruments, while details of the actual instruments used are provided in Chapter Eight, Methods: Instruments (p. 112-113). The results of these sample size calculations varied greatly by measurement instrument (Table 8).

Table 8. Sample size calculation results by instrument

Measurement Instrument	Estimated number required in each arm	Explanation
Astronaut Invented Spelling Test, 2 nd ed. (AIST-2)	70	This sample size is small because there was a large change in mean score from baseline AIST-2 to Year 1 AIST-2
Behaviour Assessment System for Children, 2 nd ed. – Teacher Rating Scale - Internalising Behaviours (BASC-2 TRS IB)	50,030	This is large because there was very little difference between the baseline and year 1 mean values
Draw a Person (DAP)	250	
Early Mathematics Concepts A (EMCA)	190	

These results show that there is sufficient power within the sample (n = 480 children in 10 clusters) to detect statistically significant differences in three instruments (AIST-2, DAP, EMCA), but not in one other comprehensive instrument (BASC-2 TRS IB).

A further analysis of power was undertaken using the Astronaut Invented Spelling Test (AIST-2), using the same intra-class correlation coefficient value of 0.29, and the normative values of the AIST-2 instrument, estimating the expected change in score over a period of one year with the study assumption that: “Primary pupils in the intervention arm will score higher than their controls”; that is to say, the scores of both the intervention and control groups will rise over time but it is assumed that the intervention group would score higher because of the intervention. Under this, estimation

of the sample size needed in each arm with power of 80%, and significance set at 0.05, while accounting for cluster effect (with an average of 10 clusters) and holding the standard deviation constant at 5. Results (Table 9) show that a mean score difference change of 3.5 between the intervention and control groups would provide sufficient power to detect a statistically significant effect with the sample size in the study (n = 480 children in 10 clusters).

Table 9. Sample size calculation for AIST-2 by mean score difference with SD of 5

Expected mean difference in score between intervention and control in AIST-2 over 1 year period	Sample needed in each arm	Overall sample needed
1	2,350	4,700
1.5	1,050	2,100
2	600	1,200
2.5	390	780
3	270	540
3.5	210	420
4	160	320
4.5	130	260
5	110	220
6	90	180

A further calculation was conducted for this instrument under the same conditions, but setting the standard deviation at 7.9, based on instrument test score results from Neilson (2003a). Actual test score results for the study are higher than this. Results from this further sample size calculation (Table 10) show that a mean score difference change of 5.5 between the intervention and control groups is required to provide sufficient power to detect a statistically significant effect with the sample size in the study (n = 480 children in 10 clusters).

Table 10. Sample size calculation for AIST-2 by mean score difference with SD of 7.9

Expected mean difference between intervention and control in AIST-2 over 1 year period	Sample needed in each arm	Overall sample needed
1	5,850	11,700
1.5	2,610	5,220
2	1,470	2,940
2.5	950	1,900
3	660	1,320
3.5	490	980
4	380	760
4.5	300	600
5	250	500
5.5	210	420

Thus sample size calculations for this study show that, based on predicted test scores for four instruments, this study was sufficiently powered to detect statistically significant differences in three instruments (AIST-2, DAP, EMCA), but not in one other comprehensive instrument (BASC-2 TRS IB). As well, based on actual scores and standard deviations for the AIST instrument, this study has sufficient power to detect a statistically significant difference between the intervention and control groups for the AIST-2 test. It is important to note that longitudinal data gain statistical power with repeated measures (Muth et al., 2016), as with this study.

Data analysis

Given the cluster design of this randomised controlled trial, data analysis should employ statistical techniques used for cluster analysis. A common error in cluster randomised controlled trials is for data analysis to be undertaken at the individual instead of cluster level (Hedges, 2011). Given that observations within a cluster tend to be more alike than observations selected entirely at random (Wears, 2002), individual analysis of clustered data may lead to an overstatement of the precision and statistical significance of the results and to misleading estimates of effect sizes (Hedges, 2011). Thus, analysis of within-group and between-group differences for all independent and dependent variables was undertaken in SPSS (Version 23) using cluster-adjusted *t*-tests (Hedges, 2011; Pallant, 2016). Multivariable data analysis was undertaken using the Generalized Estimating Equations modelling approach, which is able to control for the effects of clustering and time (Ghisletta & Spini, 2004; Hardin, 2005). Details of specific data analysis methods are provided in Chapter Eight, a manuscript under review, in a methods section, labelled *Data analysis* (p. 113-114), while results of data analysis are reported in a results section, labelled *Study Outcomes* (pp. 114-118). Nonetheless, given the word-limit constraints of journals, limited detail is provided in Chapter Eight, so further information on the main data analysis method used is provided here.

The Generalized Estimating Equations modelling approach utilised for data analysis was undertaken via the Stata statistical program (Version 14, Stata-Corp). Generalized Estimating Equations modelling is a semi-parametric approach that models outcome measures of different scales, such as categorical responses, dichotomous, and continuous measures (Twisk, 2003). It is ideally used for longitudinal data with repeated measures over time, as it is able to account for the effect of time as well as for any cluster effect (Ghisletta & Spini, 2004; Hardin, 2005). Thus it is highly suitable to this study design of a longitudinal cluster randomised controlled trial.

Generalized Estimating Equations modelling is a marginal statistical approach that combines both within-subject and between-subject relationships between the longitudinal development (over time)

of the predictor variable (in this study, the intervention and, separately, all other independent variables – gender, school location and school parent educational advantage [as detailed in Chapter Eight]) and the longitudinal development (over time) of each outcome variable (the mean score for each measurement instrument - as detailed in Chapter Eight) (Barrett, Teesson, & Mills, 2014). These relationships are combined within a matrix, where each outcome is modelled separately and compared to all other variables (both dependent and independent) within the matrix (Hin & Wang, 2009). This enables the user to determine which variables had a statistically significant effect on each other. This regression also adjusts for the effects of other independent variables, which in this study included gender, school location (metropolitan or rural) and a measure of parent educational advantage for each school (see Chapter Eight), as well as the possible effects of clustering and time (Ghisletta & Spini, 2004; Twisk, 2003).

The user selects and specifies the correlation structure for the matrix, based on the correlation structure of the observed data (Twisk, 2003), looking at the best fit for the data set (Hin & Wang, 2009). For this study, an exchangeable structure was deemed suitable (see Chapter Eight), where all measurements on the same unit are equally correlated; a plausible assumption in clustered data (Hin & Wang, 2009), as in this study. This working correlation structure assumes that correlations are of the same variance (more than zero), since it was evident from observation in this study that they were not independent (where all correlators are zero or assumed to be zero) (Twisk, 2003). Importantly, though, even if the correlation structure is mis-specified, Generalized Estimating Equations modelling allows for robust inference with its in-built estimating capacity (Hubbard et al., 2010).

The results of modelling are represented for each outcome by a β regression coefficient, Wald confidence intervals and p -significance value (Hardin, 2005; Twisk, 2003). The β regression coefficient shows the magnitude of the relationship between the longitudinal development of the outcome and predictor variables (Twisk, 2003). The Wald Chi-squared test is performed as part of modelling to determine whether explanatory variables in a model are significant (Agresti, 1990). Variables with a value of zero add nothing to the model and can be removed without affecting the modelling, so the results of the Wald test are a check of the goodness of fit of the model to the data and can confirm the selection of an appropriate model structure (Agresti, 1990). The Wald test is a rough approximation of the likelihood ratio test and is more broadly applicable (Agresti, 1990). As Generalized Estimating Equations modelling is a quasi-likelihood model (Hardin, 2005), the Wald test

suits this modelling and is used to compare and analyse the β regression coefficient outcomes of the modelling to define a p -significance value that can be interpreted (Agresti, 1990).

It must be noted that the Generalized Estimating Equations modelling approach is a quasi-likelihood model rather than a maximum likelihood model (Hardin, 2005; Twisk, 2003) and, as such, the outcomes highlight statistically significant effect and likelihood of effect/outcomes, rather than maximum effect and specific effect sizes (Agresti, 1990; Muth et al., 2016). Use of traditional regression analysis without accounting for clustering and time effects would provide effect sizes, but would also result in Type I errors (Muth et al., 2016; Twisk, 2003), given the sample size, clusters and longitudinal data in this study. If correlation or clustering between and across repeated measures is not accounted for, standard errors can be underestimated, and this is likely to occur where traditional statistical analysis assumes equal variance between measures (Hedges, 2011; Muth et al., 2016). The greatest disadvantage of traditional analytic methods for this type of data is the assumption of a linear relationship between the outcome measures and time, assuming equal variance between measures, which can lead to inflated Type I errors (Muth et al., 2016; Twisk, 2003).

Generalized Estimating Equations modelling takes account of clustering effect and effect of time using marginal modelling, that estimates the average response of the population rather than prediction of response or effect (Twisk, 2003). The relationships between the variables of the model at different time-points are analysed simultaneously, with all available data used, thus random missing data does not pose a challenge (Twisk, 2003). This is important for this study, as some children would have been absent on the day a measurement outcome was administered at a school; meaning that data for that child for that outcome would be missing from the final data set. In traditional analytic methods, such as ANOVA, deletion of an entire data record for one individual with any missing data occurs, which reduces the sample size available for analysis (Muth et al., 2016). Further to this, in Generalized Estimating Equations modelling, a variance estimator, the cluster Huber-White sandwich estimator of variance (Freedman, 2006) is used to robustly estimate and confirm the modelling structure and estimates of variance, thus further confirming the model structure, reducing standard errors and enhancing the outcomes of modelling (Hardin, 2005; Twisk, 2003). It is evident that the Generalized Estimating Equations modelling approach offers a suitable method of data analysis for the type of data collected from this cluster randomized controlled trial with repeated measures over time.

Two further aspects of data analysis were undertaken to interpret statistically significant results from the Generalized Estimating Equations modelling, in terms of incidence risk ratios and effect sizes. The Stata statistical program (Version 14, Stata-Corp) command for Poisson regression was used to report exponentiated coefficients from the data, in order to provide incidence-rate ratios. For effect size, the method recommended by Morris (2008) for measuring effect size in studies with repeated measures in both intervention and control groups, was utilised. This requires a calculation based on the mean pre-post change in the intervention group minus the mean pre-post change in the control group, divided by the pooled pre-test standard deviation for a given test score (Morris, 2008). For this study, actual or raw results for both mathematical test scores at the beginning of the study and at the end of Year One were used as the pre-post change in test scores for one effect size calculation; while a further calculation was made for results in these tests at the end of Year One and at the end of Year Two as the pre-post test scores. Results of these calculations are expressed as effect sizes (Cohen's *d*) in Chapter Eight, in the results section, labelled *Study Outcomes* (pp. 114-118). Expression of the magnitude of effect size was guided by Cohen (1988).

Methods of six phases of research

This program of research was designed to address the research problem and achieve the research aim and objectives, as stated earlier in the chapter. As a result of exploring the nature and extent of the research problem and appraising the research literature, six phases of research developed as the research progressed. These phases, and the methods used in each phase, are now presented.

Phase 1

A scoping survey of Brisbane Catholic Education primary schools undertaken to address the first research objective, to identify the nature and extent of the research problem within the study context and setting, was presented in Chapter Two. Specific methods for this study were presented in that chapter (pp. 23-31).

Phase 2

A systematic review of the literature to appraise the evidence for effect of sensory and motor interventions, undertaken to address the second research objective, was presented in Chapter Three. Specific methods for this study were presented in that chapter (pp. 32-46).

Phase 3

As determined from Phase 2, reported in Chapter Three (pp. 32-46), a systematic review of literature was unable to determine a suitable sensory and motor intervention to trial in this program of

research. Thus, a systematic scoping review of published and unpublished literature relating to research trials of specific sensory and motor interventions, in order to determine a specific intervention to use in a research trial, was undertaken in Phase 3 and reported in Chapter Five (pp. 64-81). A systematic scoping review may be used where an area of literature contains many poor quality and/or unpublished papers that are not suitable for identifying through a methodical, systematic search of journals or databases, and/or where these papers do not contain reported research elements necessary for systematic analysis (Arksey & O'Malley, 2005; Levac, Colquhoun & O'Brien, 2010). Thus, the scoping review may utilise an unsystematic search, including a search of grey literature and hand-searching of reference lists and documentation from various sources, such as websites, in order to undertake a comprehensive search (Arksey & O'Malley, 2005). This type of non-linear search is undertaken when it is suspected or known that the literature contains papers discussing many different study designs and, in this case, different types of interventions that may not be readily identifiable from narrow search terms (Arksey & O'Malley, 2005; Dijkers, 2015).

A systematic scoping type of review may not fully address or critique the quality of studies included in the review (Arksey & O'Malley, 2005), given the comprehensive nature of the search (Levac, Colquhoun & O'Brien, 2010). Some notation of such quality, however, may be important to the purpose of the review (Dijkers, 2015), such as for this study purpose, to assist with intervention choice and research design. Minimal extraction of data is required to answer a particular unfocused question in such a scoping review (Arksey & O'Malley, 2005). In other words, a systematic tabular synthesis of data using strict protocol may not be undertaken, particularly given the circumstances of funding and resources required for a full systematic review (Levac, Colquhoun & O'Brien, 2010). Given that a systematic search had already been undertaken for this program of research, a systematic scoping review was selected to address a question critical to the next phase of research. A Population, Intervention, Comparison, and Outcome (PICO) process (The Joanna Briggs Institute, 2014a) was used for this study, with specific methods detailed in Chapter Five. For this scoping review, the question was, '*What sensory and motor interventions are used within school settings that may be suitable to use in a research trial of such interventions?*', with this question deriving from the research problem (Richardson et al., 1995). The review was undertaken as Phase 3 in an attempt to answer this question, with specific methods used in this review presented in Chapter Five (pp. 66-68).

Phase 4

A systematic scoping review of research trials of interventions, undertaken in Phase 3 and reported in Chapter Five, found that a large variety of measurement instruments was used in such trials (Table

11, pp. 70-76). Thus, that review did not provide a way to identify specific, suitable instruments for a research trial. Therefore, a systematic, critical / evaluative review of standardized instruments measuring development, behaviour and early academic skills was undertaken in Phase 4, in order to select measurement instruments suitable for use in a research trial. Instruments used for the assessment of children are largely published and marketed by commercial publishers, rather than published as research studies in the research literature. Therefore, a systematic search and review of such instruments, using the accepted criteria for systematic reviews (e.g. The Joanna Briggs Institute, 2014a), was not possible to achieve. Nevertheless, a scoping search of publishing websites and other sources was undertaken systematically in Phase 4, as reported in Chapter Six. As well, instruments were critically reviewed and evaluated systematically, using specific methods and accepted criteria, as detailed in Chapter Six (pp. 86-90). Chapter Six is reported in the form of a published paper detailing this critical evaluative review, which is entitled: *Evaluation of standardized instruments for use in universal screening of very early school-age children: suitability, technical adequacy and usability*.

Phase 5

Given that an intervention and measurement instruments were selected for a research trial from reviews of literature, it is critical to trial these in the study setting prior to commencing a research trial (Eldridge et al., 2016). If problems are identified with implementing interventions or using measurement instruments during a research trial, these may result in a loss of data or abandonment of the trial (Polit, Beck, & Hungler, 2001). If, for example, some data are collected and then an aspect of the intervention is changed, the previously collected data may not be useable in the trial results (Polit, Beck, & Hungler, 2001). Similarly, if a measurement instrument is deemed not suitable for purpose, or not readily useable within the study setting, some data already collected prior to this determination may not be retainable and/or the start of a trial may have to be delayed (Eldridge et al., 2016). To avoid these problems, a pilot study, which is a small scale run of the study (Polit, Beck, & Hungler, 2001), is undertaken to assess the feasibility of undertaking a large randomised controlled trial, with particular focus on areas of uncertainty (Eldridge et al., 2016). Thus, a pilot study was undertaken in Phase 5, in a single school within the study setting, with the primary aim to assess the feasibility of conducting the trial as planned (Eldridge et al., 2016), by determining the suitability of the study setting, intervention and instruments. The objectives of the pilot study were to test the use of the intervention and measurement instruments, make any necessary modifications, and ensure that teachers are readily prepared to use these in a research trial. This study is reported in Chapter Seven, with specific methods and outcomes presented in that chapter

(pp. 103-109), in line with extended CONSORT guidelines for the reporting of randomised pilot and feasibility studies (Eldridge et al., 2016).

Phase 6

The main phase of this program of research was a randomised controlled trial, undertaken as Phase 6 and reported in Chapter Eight. The methodology for this trial was reported earlier in this chapter, with specific methods presented in Chapter Eight (pp. 111-114), as flagged previously in this chapter.

Ethical Issues

Ethical approval for three phases of this research program was sought and obtained from the Australian Catholic University Human Research Ethics Committee. As well, approval was sought and obtained from the Ethics Committee of Brisbane Catholic Education, for approval of conducting a trial on school premises and access to establish contact with primary school principals and teachers, and the parents/guardians of children in the classes included in the research.

The specific ethics application approvals attained are as follows, with all approvals included in Appendix C (pp. 155-156):

Phase 1

Approval to undertake a scoping exercise, comprising an online survey of primary school principals or their delegate regarding PREP and Year 1 classes, numbers of children, and current sensory and motor interventions within the Brisbane Archdiocese of Brisbane Catholic Education (Q2010 28) [Appendix C].

Phase 5

Approval to undertake a pilot study in one Brisbane Catholic Education school to test the intervention and measurement instruments (Q2010 55) [Appendix C].

Phase 6

Approval to undertake a randomised controlled trial in twelve (12) Brisbane Catholic Education schools (Q2010 56) [Appendix C].

This trial was retrospectively registered with the Australian New Zealand Clinical Trials Registry <http://www.anzctr.org.au/> (ACTRN12616001566426).

All data collected were maintained confidentially. No child, teacher or parent was identified by any data collected by the researcher. Coding of pupils within classes and use of coding on all measurement instruments returned to researchers ensured that only teachers knew the identity of their pupils. Formal consent to participate was sought from school principals and teachers and parents of children in each Prep class. Assent was sought from the children as a form of respect and engagement (Ungar, Joffe, & Kodish, 2006), as recommended by the Australian Catholic University Human Research Ethics Committee.

Conclusion

This chapter has presented the methodology and research design used to address the research problem presented in Chapter One, in particular to address the third research objective, designing a program of research to address the research question and any identified gap in research evidence. Particular explanation and justification was provided for the use of a randomised controlled trial design, which is the most appropriate design for determining evidence of effect of an intervention. Further justification was provided for the use of a pragmatic un-blinded trial, undertaken in the usual school setting, and the use of cluster allocation and analysis. An outline of six phases within a program of research were presented, with specific methods for each phase flagged as being reported in other chapters with their respective research activity and phase. Having flagged the need for a research trial to test a specific sensory and motor intervention, the next chapter presents a systematic scoping review of published and unpublished literature, undertaken in order to determine a suitable intervention to trial in Phase 6 of this program of research.

Chapter Five Systematic Scoping Review of Interventions

Overview

In Chapter Three, a systematic literature review undertaken to appraise the literature for research evidence of the effect of sensory and motor interventions was presented (pp. 32-46). The literature review identified a gap in research evidence related to sensory and motor intervention use in the school setting, which is addressed by this program of research trialling a specific intervention. Authors of previous reviews of research literature in this field noted the poor quality of research conducted and literature published on this topic. Due to the heterogeneous nature of sensory and motor interventions studied and reported, conduct of a literature review did not identify a suitable intervention to use in a research trial. Thus, this chapter presents a systematic scoping review of published and unpublished literature relating to trials of specific sensory and motor interventions able to be used in Queensland schools with very early – early school-age children. This scoping study of literature aims to identify a specific suitable intervention to use in the main study, Phase 6, a randomised controlled trial in the study setting.

Background

There are many different types of sensory and motor interventions offered by various professional groups and commercial organisations being implemented in schools. Given that this research study aims to examine the effects of a specific sensory and motor intervention in a school setting, it is critical to review relevant literature to determine one suitable intervention to study. A suitable intervention must be able to be implemented in the Queensland school context, be suitable for the age group of children, easy to implement by class teachers and adhere to the principles of an impairment-oriented approach to intervention, as already discussed in previous chapters. As well, given that this study examines the effects of such an intervention for very early school-age children in the transition to formal schooling, it is important to appropriately measure the effects on this age group. Very early school-age children are in the preschool and early school age developmental groups, so any instruments used to measure effect for this age group must be age-appropriate and suitable to the research context. With a study with a large sample size across a two year study period, instruments must be standardized, easy-to-use, able to be repeated across timeframes and cost effective. Thus this review will also consider the reported measurement instruments used in intervention trials.

A systematic literature review, detailed in Chapter Three (pp. 32-46), summarised the lack of evidence for sensory and motor intervention effect, as particularly noted by Leong, Carter and Stephenson with regard to academic performance (2015a). However, as also noted, evidence level varies for particular types of interventions. Some evidence of effect has been noted for sensory integration type of interventions, particularly for those using *Ayres Sensory Integration*[®] or classical sensory integration therapy, and these are stated to have moderate evidence of effect e.g. for children with Autism (Watling & Hauer, 2015). Interventions using a sensory integration framework of reference, including *sensorimotor* and sensory-based approaches, may have some positive developmental outcomes for children, with intervention shown to have more effect than no treatment / compared to nothing (Kimball & May-Benson, 2013; May-Benson & Koomar, 2010; Polatajko & Cantin, 2010). However, there is great disparity in intervention type and study design precluding the determination of clear evidence. There is mixed evidence and mixed support for use of interventions using a perceptual-motor approach to intervention to improve academic performance (Callcott, 2012; Callcott, Hammond, & Hill, 2015; Hyatt, Stephenson, & Carter, 2009).

The overall summary of the evidence from reviews of sensory and motor interventions is, thus, mixed, with limited evidence of developmental or academic effect for any intervention, especially when methodology concerns and methodological limitations are taken into account. This is even the case for systematic reviews that have specifically reviewed the evidence for like interventions (May-Benson & Koomar, 2010; Polatakjo & Cantin, 2010; Watling & Hauer, 2015). From the literature review results, then, it would be relevant to trial interventions that use any of the intervention approaches, if one is seeking to determine evidence of effect. However, when reviewing the research problem, it becomes clear that not all intervention approaches are suitable for the study context and identified research problem.

Interventions using a sensory-based approach require specialised sensory processing equipment, such as weighted vests, brushes, and swings (Polatakjo & Cantin, 2010). As these would be costly to purchase for a large trial and are usually used in an individual manner, it is not feasible to consider interventions using a sensory-based approach for this program of research. This type of intervention will therefore be excluded from this review of potential interventions for use in a research trial. Interventions using a performance-oriented approach are suitable for direct skill teaching and coaching purposes (Polatakjo & Cantin, 2010), as identified in Chapter One (pp. 1-22), and these are generally implemented in the physical education setting, rather than the classroom. Therefore, these types of interventions are not suitable to the research problem and study context, which is to

examine the effect of a group intervention implemented in a classroom setting, on developmental and academic outcomes, as this is how more intervention programs are conducted, and these will also be excluded from this review. Given the need for a group intervention, interventions that use *Ayres Sensory Integration*[®] or classical sensory integration therapy in an individualised manner - as required for fidelity to intervention (Roley et al., 2007; Watling & Hauer, 2015) - are not suitable or feasible for this research study. These interventions were therefore excluded from this review. Thus a review particularly focused on interventions, aimed at enhancing development and academic performance and designed for groups, instead of the individual therapist-led interventions that featured most prominently in previous research reviews, and excluding other non-feasible intervention approaches, as outlined, was the subject of this review. This includes review of interventions using a sensory integration framework of reference, including sensorimotor and mixed sensory-integration approaches, or a perceptual-motor development approach.

The literature review detailed in Chapter Three also demonstrated that research into sensory and motor interventions has been reasonably prolific, but inherently flawed. There are many unpublished research studies not included in the systematic reviews and meta-analyses cited in previous paragraphs, as the reviewers included published research studies and studies with higher quality of methodology. While this is appropriate for such reviews, it ignores a large body of literature directly relevant to this research study and study setting. As a literature review failed to identify a specific intervention to use in a research trial, this systematic scoping review sets out to scope interventions used in the school setting and summarise any research evidence and other unpublished literature in this area.

The aim of this systematic scoping review was to address the scoping question: 'What group-based sensory and motor interventions are used within school settings that may be suitable to use in a research trial of interventions that may have effect on developmental and academic outcomes?'

Method

Aim

To identify and evaluate published and unpublished literature pertaining to research trials of group-based sensory and motor interventions used in the school classroom setting with school-age children in order to determine a suitable intervention to use in a research trial in the study setting.

Objectives

The objectives of this review were to:

- Identify published literature reporting on research trials of sensory and motor interventions used in the school setting with groups of very early- early school-age children.
- Identify unpublished literature reporting on research trials of sensory and motor interventions used in the school setting with very early- early school-age children.
- Identify other sensory and motor interventions used in the school setting with very early- early school-age children.
- Evaluate all identified interventions for suitability and feasibility for use in a research trial using the Population, Intervention, Comparison, and Outcome (PICO) process (The Joanna Briggs Institute, 2014a) and referring to the scoping study results from Chapter Two.

Search Strategy

A previous systematic search of the literature, detailed in Chapter Three (pp. 33-35), identified 14 research papers relevant to the first objective for this review and these were included. Hand-searching of reference lists from these and other papers identified in the systematic search was also undertaken to identify further published papers.

Website and Internet search

An Internet search was undertaken to identify unpublished research trials and/or evaluation reports of specific interventions. Search terms included combinations of those detailed in the Literature Review in Chapter Three (p. 34), along with names of specific intervention programs and organisations identified in the literature review, gleaned from the key stakeholders that identified the research problem, or identified by schools in the Scoping Survey, reported in Chapter Two (pp. 23-31). School and organisation websites were searched for documents pertaining to research or evaluation of specific interventions. This search was originally undertaken in 2010 to identify a suitable intervention to trial in this program of research. Further sources have been included in this chapter, using an updated 2016 search, for the purposes of providing an updated review for this thesis.

Inclusion criteria

Only interventions that met the following inclusion criteria were retrieved for full review:

- Population (P): Designed for groups of very-early or early school-aged children
- Intervention (I): Utilised an impairment-orientation approach to intervention, such as a sensory integration framework of reference, including sensorimotor and mixed sensory-integration approaches, or a perceptual-motor development approach or other mixed impairment-oriented approaches
- Readily available for use in the study setting

- Able to be used by teachers in a school classroom setting, and
- Comparison (C): Intervention compared to something else or nothing else; Control (C): comparison of level of research design and controls used
- Outcome (O): Demonstrated evidence of suitability and feasibility for use in a large research trial, with developmental and academic achievement outcomes, and detailed administration data for determining this
- Published in the English language.

Screening

Some screening occurred during the search process, with papers screened out if they did not meet the inclusion criteria for age group, e.g. trialled interventions for infants, older adolescents or adults, or were clearly identified as using a performance-oriented approach to intervention, e.g. utilised a cognitive or exercise science approach, or were clearly duplicates.

Evaluation method

Papers were evaluated by one reviewer, with part of the evaluation process being to identify the specific type of intervention and/or intervention approach being used in a trial or being discussed in the paper and if it was offered in Queensland for use in the school setting. Similar interventions were then grouped using a structured, modified Population, Intervention, Comparison, and Outcome (PICO) process (The Joanna Briggs Institute, 2014a).

Results

A number of published research papers (n = 14) was retained from the systematic literature search undertaken as specified in Chapter Three. Further searching using the identified search strategy above, and following initial screening, located a further 49 papers. These 63 papers were screened against the inclusion criteria, with 42 excluded, comprising six duplicates, three theoretical papers, three commentaries/ critiques of intervention research, five reports – not of interventions, and 25 reporting on excluded interventions: 11 performance-oriented approach interventions, three sensory-based approach interventions, three (3) classic sensory integration interventions, two physiotherapy interventions and six undertaken in the clinic not school setting. A total of 20 relevant papers were identified for full review, including ten journal articles, two theses and nine reports from commercial/school websites, with all but one, an evaluation, reporting on a research trial of a specific intervention. Specific intervention approaches trialled include six using a specific perceptual-motor approach, two (2) a mixed Neurodevelopmental therapy and perceptual-motor approach, two a mixed neurodevelopmental therapy, perceptual-motor and sensorimotor approach, one a mixed perceptual-motor and sensorimotor approach, one a mixed perceptual-motor and sensory-based

approach, one a mixed perceptual-motor and sensory integration frame of reference approach, six a mixed sensory integration frame of reference and sensorimotor approach, one a mixed sensorimotor approach and one a mixed sensory integration frame of reference, sensorimotor and perceptual-motor approach. Evidence from these is synthesised in Table 11 (pp. 70-76).

Table 11. Results of PICO process evaluation

Author, Year	Study Objective/ Purpose	Population (P): Setting; sample: (number*) # [age*] {gender*}	Intervention (I): Program, intervention type; activities; implementation and duration	Comparison: Control, Design (C)	Developmental domain studied; Measures used	Outcomes (O)	Review Conclusions / Any Limitations
Brace & Hatch, 2002	Evaluate the effect of the SMART program on academic success and motor development	2 Kindergarten classes in 1 school in Knox County, TN USA; (28) no diagnosed delays or conditions [5 – 6 yr] {M = 18, F = 10}	<i>Stimulating Maturity for Accelerated Readiness Training</i> program, Mixed SI/SB/PM approach; In-class desktop activities such as listening games, colouring, drawing, printing, learning letters and numbers; in class floor activities such as rolling, spinning, balancing, mobility; 10 min daily in class and 30 min in gym 3 times / week with trained class teacher, and extra sessions in gym with Phys Ed teacher, for 3 months	No control, no randomisation 1 class spent more time on the SMART program than the other class Action research with pre- and post-testing	Aspects of academic and motor performance: <ul style="list-style-type: none"> • Figure drawing • Timed rote counting • Reciting alphabet • Letter recognition • Letter writing • Motor skills test 	Class spending more time on SMART program showed <i>less</i> improvement	No benefit to academic or motor performance. Lack of control, short duration
Callcott, Hammond & Hill, 2015	Investigate the synergistic effect of practising specific movements through daily actions and songs alongside the explicit teaching of phonological awareness and phonics in 400 preschool children	Two Preschool classes from each of 8 schools in Perth, WA Australia (400) [4 – 5 yr] {NR}	<i>Let's Decode</i> literacy program and/or <i>Moving on with Literacy</i> (MowL) movement program, PM approach; Program comprises 30 action songs - whole class sing and perform together. Targeted movement practice of fine motor, eye-tracking, balance, rhythm, cross-lateral movement and gross motor skills, core strength and aerobic capacity. 15-30 min daily in class with trained class teacher for one school year	Quasi-experimental design; 2 schools (4 classes) received both the literacy and movement interventions, 2 schools (4 classes) received only the literacy intervention, 2 schools (4 classes) received only the movement intervention, 2 schools (4 classes) – the control group – no intervention. Schools matched on ICSEA – not randomised. Pre- and post-testing; Statistical Analysis	Aspects of academic performance: <ul style="list-style-type: none"> • <i>The Test of Phonological Awareness (TOPA)</i> • <i>Developmental Spelling Test (DST)</i> • <i>Wide Range Achievement Test-Revised: Spelling Subtest</i> • <i>Movement ABC (M-ABC)</i> 	The literacy and movement group performed significantly better than the control group on literacy and movement measures, and than the movement group on movement measure.	Some effect on literacy; No benefit for movement program. Well designed study which needed modelling for more statistical analysis.
Callcott, 2008	Investigate the effect of the Primary Movement program on the Asymmetrical tonic neck reflex, motor skills, vocabulary and visual motor ability in a cohort of preprimary	9 Preschool classes in 3 schools (3 classes each) in Perth, WA Australia, (206) [5 yr] {M = 96, F = 99}	<i>Primary Movement Programme</i> , Mixed NDT, PM approach, Specific movement sequence replicating the movements generated by primary-reflex system during fetal and neonatal life, 15 min daily in class with trained class teacher for 8 months	3 groups: Grp 1: Primary movement (intervention group) Grp 2: Control (gross motor movements) Grp 3: Control (free play) Random allocation of group to classes at each school. Statistical analysis	Motor and School Readiness: <ul style="list-style-type: none"> • <i>Movement ABC (M-ABC)</i> • <i>Dyslexia Screening Test</i> • <i>Schilder Test</i> for Asymmetric Tonic Neck Reflex (ATNR) • <i>Developmental Test of Visual-Motor Integration (VMI)</i> • <i>Peabody Picture Vocabulary Test (PPVT)</i> 	Some effect for intervention group on movement and reflex tests and on teacher assessed classwork.	Limited evidence of effect on motor and school performance, multivariable statistical analysis needed.

	children.				• Teacher assessed classwork		
Chapparo, 2005	Investigate the impact of MTL program on school performance	13 schools in NSW/SA/ WA Australia, NZ, SA; (n = 209: Pre-primary = 18, Kindergarten = 59, Year 1 = 102, Year 2 = 30) # [mean age 5.7 yr] {approx. 1:1}	<i>Move to Learn</i> program, PM approach; Movement sequences on the floor that mimic infant reflex movements and typical infant/toddler floor movements; 15 min daily with trained class teacher for one school term (10wk)	During Term 3: 5 wk no MTL, then MTL for 2 x 5 wk blocks in Terms 3 and 4 No control, no randomisation	Academic performance: <ul style="list-style-type: none"> • <i>Non-word Reading Test</i>, • Handwriting of one sentence and copy 5 nonsense words, • <i>Goodenough Draw-a-Man</i>, • Classroom performance skills rating scale 	“statistically significant” improvements but this is clarified as an immediate improvement once MTL commenced	No statistical analysis provided = no evidence. Researcher states: Teacher bias? Other variables responsible?
Goddard Blythe, 2005	Assess whether neurological dysfunction is a significant factor underlying academic achievement and evaluate effect of two programs: <i>INPP Test Battery</i> and <i>Developmental Exercise Program</i>	Various schools in United Kingdom; (671) DD, LD [7 – 10 yr] {NR}	<i>INPP Developmental Exercise Program</i> , PM approach; Four developmental movements (prone, supine, sitting and four-point kneeling for developing postural ability, before training balance in upright position) each day for 6 weeks then change to next set of four, etc.; Daily for 10 min with trained class teacher over 1 school year	4 groups: 1 st intervention group (235) INPP and DEP; 2 nd intervention group (205) INPP only; 3 rd group (200) control; 4 th group (31) placebo	Academic performance and development: <ul style="list-style-type: none"> • Reading (unspecified) • Spelling (unspecified) • <i>Draw a Person</i> (Harris) test • <i>INPP test battery</i> - Neurological and reflex tests 	Improvement in academic achievement; Failure to demonstrate statistical significance; Greater improvement for Group 1	No evidence due to lack of clarity regarding study design and results. Different study designs across schools
Jordan-Black, 2005	To evaluate the effectiveness of the <i>Primary Movement Programme</i> on children in a school setting over two years	Years 3, 5 and 7 in 13 schools in the South Eastern Education and Library Board (SEELB) area in Northern Ireland; (1136) [7 - 11 yr] {NR}	<i>Primary Movement Programme</i> , Mixed NDT, PM approach, Specific movement sequence replicating the movements generated by primary-reflex system during fetal and neonatal life, 10 min daily in class with trained class teacher for one year	Two year large comparative longitudinal study; Pre- test, one year intervention then post-test at end of two years; A second quasi-experimental study in which two groups of children formed an intervention group (n = 82) and control group (n = 97) (usual schooling); Multiple regression analysis	Aspects of academic performance: <ul style="list-style-type: none"> • <i>Schilder Test</i> for Asymmetric Tonic Neck Reflex (ATNR) • <i>Wechsler Objective Reading Dimensions</i> • <i>Wechsler Objective Numerical Dimensions</i> • <i>Non-reading Intelligence Test</i> 	All measures showed significantly higher results. However, time / maturation could have been a factor.	Not clear that intervention was the source of improvements in academic perf. No randomisation. Comparisons made across different children, year levels
Krog, 2010	Investigate if movement programs are a means to learning readiness	1 Year 2 class in 1 primary school in Gauteng Province in South Africa (14) LD [7 – 9.5 yr] {M= 9, F = 5}	Movement program developed by researcher, based on four other programs, Mixed PM/SM approach, Various locomotor, tactile and visual activities, 30 min daily (rotate through 5 movement activity stations) plus 5	Quasi-experimental design, Pre- and post-testing, One group, no control, convenience sample	Learning readiness: <ul style="list-style-type: none"> • <i>7/8 year old group test</i> • <i>Bender Visual-Motor Gestalt Test</i> • <i>Basic Scholastic Assessment</i> • <i>Movement Proficiency Assessment</i> 	t-tests only reported	No evidence. No control, no randomisation, small sample, short duration

			min daily of visual activities with trained class teacher for 10 weeks				
Lowden, Powney, Davidson & James, 2001	Evaluate pilots of <i>The Class Moves!</i> [®] program	47 classes in 6 schools in Scotland and Wales, (NR) [4 – 10 yr] {NR}	<i>The Class Moves!</i> [®] program, Mixed SM approach, Playful relaxation exercises, stability, postural movements, 10 – 15 min daily with trained class teacher for up to 12 months	Evaluation of feasibility, suitability, replicability. Observation of classes, teacher and children interviews	School readiness: <ul style="list-style-type: none"> • None 	Anecdotal support	No evidence.
McPhillips, Hepper & Mulhern, 2000	Assess the efficacy of an intervention replicating primary-reflex movements on specific reading difficulties in children: a randomised, double-blind, controlled trial	Primary schools in Belfast, Ireland (66) Dyslexia, RD [8 – 11 yr] {M = 50, F = 16}	<i>Primary Movements Programme</i> , Mixed NDT, PM approach, Specific movement sequence replicating the movements generated by primary-reflex system during fetal and neonatal life, 10 min daily at home after sequence taught by Psychologist researcher, movements changed every 2 months, for 12 months	Randomised, double-blind, placebo-controlled trial; Matching of children, then randomising into 3 groups (6 children could not be matched) Intervention group (n=20), Control group (n=20) usual schooling, Placebo-Control group (n=20) did a set of non-specific movements. Pre- and post-testing.	Reading performance: <ul style="list-style-type: none"> • <i>Schilder Test</i> for Asymmetric Tonic Neck Reflex (ATNR) • <i>Wechsler Objective Reading Dimensions</i> • <i>Wechsler Objective Spelling Dimensions</i> • <i>Neale analysis of reading ability</i> • Timed writing test • Saccadic eye movement frequency 	Interv. group sig. decrease in level of persistent ATNR (p<0.001). All groups improved over time for reading, spelling but interv. group significant improvement (p<0.001) and clinically significant.	Some effect on reading performance. All had persistent ATNR and RD. Selection bias to children not responding to traditional reading support with parents seeking help – may enhance treatment effect.
Mirabella, Sasse, Schriever, Young, Young & Rawlings, 2008	Establish objectively whether or not a sensorimotor and speech development program [<i>No Child Should Fail</i> and <i>Special Reading Program</i>] would obtain superior results in reading improvement compared with the standard reading programs	5 schools in Melbourne; Years 1 – 5, two classes from one year level at each school (NR) [NR] {NR}	<i>No Child Should Fail</i> and the <i>Special Reading Program</i> are actually the <i>Unlocking Potential Program</i> by <i>GymbarOO</i> with an added speech development program, Mixed NDT/PM/SM approach and speech development, with reflex inhibition activities; 25 min daily in classroom with trained class teacher and with phone support for 38 weeks in one school year	Experimental approach: Random selection of schools and year level from each school. One class (intervention group) used the sensory-motor and speech development program; the other class (control group) used the standard reading program for that school. Each group further sub-divided, only half had pre-test and all had post-test.	Reading performance: <ul style="list-style-type: none"> • <i>Reading Progress Test 1 and Test 2</i> for Years 1 and 2 • <i>Progressive Achievement Tests in Reading</i> for Years 3, 4, 5 	Special Reading Program classes in Year 1, 2 were behind Standard reading classes in pre-test, with statistically significant improvement after intervention. ANOVA for Years 3, 4, 5 – mixed results but statistically significant effect for comprehension in favour of the Special reading classes. Multivariate analysis showed all children did better on post-test (time).	No evidence of effect on reading overall. Small sample size in each group and different ages compared; Intervention replaced scheduled reading classes

Paul et al., 2003	Examine the effects of a sensory motor activities protocol based on the theory of sensory integration on children diagnosed with preprimary impairments	2 classes in 2 schools in Kalamazoo, MI USA (31) Diagnosed with pre-primary impairments [4 – 4.5 yr] {M = 13, F = 18}	<i>Sensory Motor Activities Protocol</i> , Mixed SI/SM approach Vestibular, proprioceptive, postural control, tactile, fine motor and speech training activities in developmental sequence, 1 hour daily for 5 day/week for 12 weeks by Special Education Teacher or Occupational Therapist or other professional	Quasi-experimental design, Intervention group (n=15) and control group (n=16) usual schooling, no randomising, Pre- and post-testing, ANOVA	Motor and Sensorimotor performance: <ul style="list-style-type: none"> • <i>Miller Assessment Tool</i> • <i>DeGangi-Berk Test of Sensory Integration (TSI)</i> 	Test scores “increased considerably” for intervention group,	Limited evidence - only test scores provided no ANOVA results. Limited analysis of results, short duration.
Peens, Pienaar, Nienaber, 2008	Compare the effect of a motor intervention with psychological intervention, or combined, for children with DCD	9 schools in Potchefstroom, South Africa (58) DCD [7 – 9 yr] {M = 36, F = 22}	Motor-based intervention program, Mixed PM/SI approach, Task-specific, kinaesthetic and SI activities – locomotor, vestibular stimulation, fine motor, eye control, Group 1 30 min x 2/week for 8 weeks by trained professional Group 2 45 min x 1/week for 8 weeks by Psychologist Group 3 30 min x 2/week and 45 min x 1/week for 8 weeks Group 4 usual schooling	Experimental design, Randomly grouped into 4 groups and random intervention allocation: 1 st group (20) motor-based intervention; 2 nd group (10) psych. Interv only; 3 rd group (11) integrated psycho-motor interv; 4 th group (17) control – no interv. Pre-test, post-test and 2 month follow-up test Computerised statistical analysis, ANOVA	Motor proficiency and Self-concept: <ul style="list-style-type: none"> • <i>The Movement Assessment Battery for Children MABC</i> • <i>Tennessee Self-Concept Scale (Child Form)</i> • <i>Child Anxiety Scale</i> 	A statistically significant ($p = 0.00$) and practical significance ($d = 1.07$) improvement for motor intervention, and combined intervention groups	Some effect on motor performance. Limited duration, small sample.
Pienaar, van Rensburg & Smit, 2011	To determine the effect of a Kinderkinetics programme on components of children’s perceptual-motor and cognitive development	2 pre-primary schools in Potchefstroom, South Africa (40) [4 – 6 yr] {M = 7, F = 6}	<i>Kinderkinetics Programme</i> , PM approach, Locomotor skills, body awareness, balance, body coordination, hand-eye and foot-eye coordination, fine motor activities, 1 hour/week for 7 months, separate to classroom by trained professionals	Pre- and post-test design, Convenience sample, 20 in intervention group, 20 in control (usual schooling) but final sample of 13 (incomplete data), no blinding, t-tests, ANCOVA	Perceptual-motor and cognitive development: <ul style="list-style-type: none"> • <i>Peabody Developmental Motor Scales – 2</i> • <i>Junior South African Individual Scale</i> 	Statistically significant difference between pre- and post-tests for several items but only practical significance for 2 items (balance, locomotor skills)	Some effect on some performance items. Randomisation, larger sample needed.
Reynolds, Nicolson & Hambly, 2003	To investigate the effects of the DDAT exercise regime	1 school in Warwickshire, UK (35) all at risk of RD, some diagnosed with LD, dyslexia, dyspraxia, ADHD [7 – 9 yr] {M = 19, F = 16}	<i>Dyslexia, Dyspraxia and Attention Treatment (DDAT)</i> , Mixed PM, SB approach based on Cerebellar-deficit theory, Sensory stimulation incorporating visuomotor, vestibular activities – balance board, throwing and catching bean bags, stretching and coordination, 180 home sessions, parent administered, over 6 months	Intervention group did DDAT at home, control group – no intervention. Pre- and post-testing by blind tester, looking at ‘value-added’ effect of DDAT	Aspects of academic performance: <ul style="list-style-type: none"> • <i>Dyslexia Screening Test</i> • Cerebellar and vestibular tests (bead threading, postural stability, memory and rapid naming) • <i>Nelson NFER test of reading</i> • <i>National Standardised Attainment Tests (SATs)</i> in writing, comprehension and 	t-tests Direct benefit on balance, dexterity and eye movement control, statistically significant improvements in reading, verbal fluency, dexterity. Some maths improvement.	Inconclusive / Not clearly demonstrated, limited statistical analysis. No randomisation, limited details, difference noted in children’s reading etc. at baseline.

					numeracy		
The Learning Connections Centre, 2008	Conduct a trial of <i>The Learning Connections School Program</i>	2 Gold Coast schools, QLD Australia (175) # [4.6-5.11yr, 5.0-6+yr] {NR}	<i>The Learning Connections School Program</i> (LCSP), mixed SI/SM; Movement sequences on floor that mimic infant reflexes and typical infant/ toddler floor movements; Details NR	Pre- and post-test design Details NR	School Readiness: • <i>The Kindergarten Screening Test</i>	Means and SD only reported, no analysis	Inconclusive. Insufficient details provided.
The Learning Connections Centre, 2004	To test the impact of two programs on children with diagnosed LD – and to compare with the performance of children receiving only a literacy tuition program	1 school at Coombabah, QLD Australia (38) all identified as requiring learning support Years 3, 4, 5, 6, and 7 [varied ages] {NR}	<i>The Learning Connections School Program</i> (LCSP), mixed SI/SM; Movement sequences on floor that mimic infant reflexes and typical infant/ toddler floor movements; and SAMONAS <i>Sound Therapy Program</i> , SB; Listening and music activities; 40 – 60 min per week depending on group allocation, for 4 months (July – November)	4 groups - Grp 1: 43 sessions x 10 min ea. SAMONAS (n = 12); Group 2: 44 sessions x 10 min ea. LCSP (n = 10); Group 3: <i>The Literacy Tuition Program</i> , 2 x 30 min sessions per week (n = 8); Group 4: 44 sessions x LCSP (10 min) & SAMONAS (10 min) plus literacy tuition. All groups x literacy tuition. No control, no randomisation Pre- and post-testing	Aspects of academic performance and behaviour: • <i>Learning Connections Behaviour Rating Scale</i> • <i>Neale Analysis of Reading</i> • <i>Waddington Spelling Test</i> • <i>First Draft Writing Sample</i> • <i>SCAN-C Screening Test for Auditory Processing Disorders</i> • <i>TAPS-R Auditory Number Memory</i>	Average change in reading and spelling scores provided. No statistical analysis. Anecdotal support – great improvement	No evidence that intervention led to changes in reading performance as all children also received literacy tuition. Lack of reported details, different ages of children compared, small groups.
The Learning Connections Centre, 2002	Ascertain whether a sensory movement program has any effect of student word recognition and spelling age test results	1 school at Bermagui, NSW Australia (35) 12 with LD, Year 1 (n = 8) Year 2 (n = 8) Year 6 (n = 19) {M = 15; F = 20}	<i>The Learning Connections School Program</i> (LCSP), mixed SI/SM; Movement sequences on floor that mimic infant reflexes and typical infant/ toddler floor movements; 10 min daily in class for 18 school days in Term 2 with trained class teacher	Action research No control, no randomisation Pre- and post-testing t-tests of pre and post-test scores	Aspects of academic performance: • <i>The Burt Word Reading test</i> • <i>The Ark Spelling Test</i> • <i>Learning Connections School Program – Reading Ability Assessment Form</i> • <i>Learning Connections Centre checklist</i> (list of LCSP activities and rate each child's ability to complete them accurately on a scale of 1 - poor to 5 - excellent)	An increase in the mean reading and spelling results overall. Claim of significant results but not demonstrated.	Limited duration, lack of evidence due to lack of control/ comparator. Lack of reporting detail.

The Learning Connections Centre, 2001	Evaluate quantitatively and qualitatively the effect of an intensive program of instruction in sensory motor integrating exercises for Year 1	1 school at Killarney, QLD Australia (18) 14 with LD, 4 with DD Year 1 {NR}	<i>The Learning Connections School Program</i> (LCSP), mixed SI/SM; Movement sequences on floor that mimic infant reflexes and typical infant/ toddler floor movements; 7 min on each of 4 activities (28 min) daily in classroom with trained class teacher for six months (July-Dec)	No control, no randomisation Pre- and post-testing Lack of reporting detail	Academic performance and development: <ul style="list-style-type: none"> • Learning Connections Centre checklist (list of LCSP activities and rate each child's ability to complete them accurately on a scale of 1 - poor to 5 - excellent) • PM/Reading Recovery Program level • Attention and Behaviour 4 point scale assessment • OT Assessment for 4 children with diagnosed DD 	Improvement from a mean of 2.6 to a mean of 4.11 on activity checklist; Reading levels increased from a mean of 5 to a mean of 11; All attention and behaviour scores show improvement; Occupational therapy able to be done in class via program instead of clinic; Anecdotal support from School Principal, School teachers, parents, children and Occupational Therapist	Insufficient details for analysis of results; No evidence that intervention is responsible for improvements in academic performance or development. No statistical analysis, no control.
The Learning Connections Centre, 2000	Summary of "results obtained by teachers working with children and <i>The Learning Connections School Program</i> "	8 schools in QLD Australia: <ol style="list-style-type: none"> 1. Year 5 (26) 1997 2. Year 4 (28) 1997, Year 4 (26) 1998 3. Year 2&3 (16) 1998 4. Year 6&7 (16) 1998 5. Year 6&7 (31) 1999 6. Year 2 (18) 2000, Year 3 (27) 2000 7. Year 2 (19) 1999 8. Year 8 (9 Interv.) (20 Control) 1996, Year 8 (12 Interv) (12 Control) 1997, Year 8 (18 Interv) (50 Control) 1998, Year 8 (9 Interv) (19 Control) 1999 	<i>The Learning Connections School Program</i> (LCSP), mixed SI/SM; Movement sequences on floor that mimic infant reflexes and typical infant/ toddler floor movements; 20 min, 4 – 5 times/week in classroom with trained class teacher for one school year in various years (1997 – 2000)	No control for primary school groups; Control for 4 high school groups; no placebo No randomisation Pre- and post- testing; t-tests for 4 groups with controls	Reading performance: <ul style="list-style-type: none"> • <i>Neale Analysis of Reading or St Lucia Reading Test or The Burt Word Reading Test or Salford Reading Test</i> • <i>South Australian Spelling Test or Newberry Spelling Test</i> 	Change in pre- and post-tests, with average change in test age said to be greater than time elapsed between pre- and post-test. 1996 Year 8 t-tests were significant ($p < 0.05$) Anecdotal support from teachers, children and parents	Some evidence of effect on reading performance for one small group. Inconsistent ages and tests across groups.

Watson & Kelso, 2014	To empirically investigate the effect of <i>Brain Gym</i> ® on academic engagement for children with developmental disabilities	After school care class at 1 school in Nacogdoches, TX, USA, (3) Autism, DD [7 – 9 yr] {M = 3}	<i>Brain Gym</i> ® program, Educational Kinesiology – PM approach, Variety of movements to help the body recall the movements from the first stages of life, One-on-one instruction after school, 20 min for 2 – 3 days/week for 7 – 8 weeks	Single subject design	Academic performance: • Academic engagement noted by an observer	No improvement noted	Lack of evidence. Short duration.
Williams, 2015	Determine the effectiveness of the <i>Unlocking Potential Program</i>	(150) [5 – 8 yr] {NR}	<i>Unlocking Potential Program</i> by <i>GymbaROO</i> , mixed NDT/PM/SM; 25 min daily in classroom with trained class teacher and with phone support for 38 weeks in one school year	No control, no randomisation Pre- and Post-testing	Academic performance: • <i>Draw a Person test</i> • Teacher questionnaire • NAPLAN scores	Stated as statistically significant improvement in drawing (no control group for comparison) Anecdotal support from teachers who noted improvements	No evidence demonstrated. Intervention replaced scheduled literacy or numeracy classes

Note: * = where reported; # = diagnosed impairments - if tested and reported; F = female, M = male; NR = not reported; Impairments – ADHD = Attention Deficit Hyperactivity Disorder, DD = developmental delay, LD = learning difficulties, RD = Reading Difficulty; Intervention Codes – PM = perceptual-motor treatment, SB = sensory-based, SI = using a sensory integration frame of reference, SM = sensorimotor approach.

Summary of Evidence for Sensory and Motor Interventions Trialed in a School Setting

Some evidence of effect was noted for six trials reviewed (Callcott, 2008; McPhillips, Hepper & Mulhern, 2000; Paul et al., 2003; Peens, Pienaar, Nienaber, 2008; Pienaar, van Rensburg & Smit, 2011; The Learning Connections Centre, 2000), while 12 studies identified a lack of evidence (Brace & Hatch, 2002; Callcott, Hammond & Hill, 2015; Chapparo, 2005; Goddard Blythe, 2005; Jordan-Black, 2005; Krog, 2010; Lowden, Powney, Davidson & James, 2001; Mirabella, Sasse, Schriever, Young, Young & Rawlings, 2008; The Learning Connections Centre, 2004; 2002; 2001; Watson & Kelso, 2014; Williams, 2015) and two demonstrated inconclusive results (Reynolds, Nicolson & Hambly, 2003; The Learning Connections Centre, 2008). There was no evidence for any one specific intervention approach being more beneficial than another. Thus, the review at this level was not able to identify a specific intervention to use in Phase 6, a research trial in the study setting.

Most trials were noted to have one or more methodological limitation, which impeded the establishment of evidence, including small sample sizes, short study/trial duration, lack of a control group, lack of randomisation/random allocation. Some trials compared results from children of different ages or school year levels, or where variations across study years or sites had occurred. For many trials, there was insufficient detail reported to enable the determination of evidence level, while statistical analysis was incomplete for some studies. Studies used various measurement instruments; however, most instruments used measure aspects of academic achievement, including reading, writing, drawing, spelling or mathematics, or measure developmental or functional outcomes suitable to the age group studied. Since an impairment-orientation approach is used, some studies used instruments for assessing for specific impairments in sensory, perceptual or motor processing or functioning.

Suitability and feasibility for use in a trial in a Queensland school setting

A total of 13 intervention programs were identified from review, including the *Brain Gym*[®] program, the *Dyslexia, Dyspraxia and Attention Treatment (DDAT)*, the *Institute for Neuro-Physiological Psychology (INPP) Developmental Exercise Program (DEP)*, the *Kinderkinetics Programme*, the *Move to Learn (MTL)* program, the *Moving on with Literacy (MowL)* program, the *No Child Should Fail* program (aka *Unlocking Potential Program* or *GymbaROO* or *KindyROO*), the *Primary Movements Programme (PMP)*, the *Sensory Motor Activities Protocol*, the *Stimulating Maturity for Accelerated Readiness Training (SMART)* program, the *The Class Moves!*[®] program, the *Learning Connections School Program (LCSP)* and the *Unlocking Potential Program* (aka *GymbaROO* or *KindyROO*). Twelve of these programs were further examined to determine their availability, suitability and feasibility for use in a trial in a Queensland school setting with a large sample size and implementation by a trained class teacher in a classroom setting. One of these programs and one other movement program included in

the review were developed specifically for a specific trial each and were thus not suitable or not available for further review (Callcott, Hammond & Hill, 2015; Krog, 2010).

Further examination of results from the website and internet search reveals that one program (SMART) is only available in the USA, three other programs (INPP DEP, DDAT, *The Class Moves!*[®]) are based in the UK, with one of these (DDAT) discredited and not available (Callcott, Hammond, & Hill, 2015), and one program (*Kinderkinetics*) only available in South Africa. *GymbaROO* and *KindyROO* (aka *Unlocking Potential Program*) are run at centres by program operators instead of school/class teachers. The *Primary Movement Programme*, originally from Ireland, studied in three trials in this review (Callcott, 2008; McPhillips, Hepper & Mulhern, 2000; Jordan-Black, 2005) is available in Queensland via the Learning Connections Centre as the *Learning Connections School Program*, which was studied in five trials in this review. Likewise, the *Sensory Motor Activities Protocol* operates as the *Learning Connections School Program* in Queensland. The *Learning Connections School Program* and *Brain Gym*[®] programs are available for use or already used by class teachers in Queensland schools. Further scrutiny of the results of the scoping study of the school setting, reported in Chapter Two, reveals that the *Learning Connections School Program* is used in the study setting. As this program was already familiar to the setting, it seemed feasible to use this in the study setting. The program is classified as very low cost according to the classification of education interventions by the Education Endowment Foundation (2016). As can be seen from this review, the Learning Connections Centre, as program operator of the *Learning Connections School Program* has participated in research with small and large study samples, with some demonstrated effect (The Learning Connections Centre, 2000), and inconclusive results related to methodological limitations. This intervention would therefore be suitable for studying in Phase 6.

Discussion

A systematic scoping review of the published and unpublished literature surrounding specific sensory and motor interventions was undertaken for available evidence to determine an appropriate sensory and motor intervention that can be tested systematically. No one particular type of intervention approach was identified from Population, Intervention, Comparison, and Outcome (PICO) process (The Joanna Briggs Institute, 2014a) examination of the papers located in this search. Further examination of results from a website and internet search as part of this review revealed interventions available in Queensland for implementation in schools, with the *Learning Connections School Program* identified as the most suitable for the trial in Phase 6. The rest of this chapter provides specific details about this program and how it was used in this program of research.

The Learning Connections School Program

The *Learning Connections School Program* (LCSP) utilises a variety of sensory motor activities and sensory stimuli (Table 12) in an effort to improve children's learning and academic success (Hawke, 2011). Whilst the program typology is not specified by its operators, it is classifiable within an impairment-orientation approach to intervention (Polatajko & Cantin, 2010), also referred to as a process or deficit approach (Sugden, 2007) and a general abilities approach (Wilson, 2005). It is normally delivered to a whole class of children, in the classroom setting, coordinated by their class teacher, after receiving training by Learning Connections Centre staff.

Table 12. Key activities in Learning Connections School Program

Type of Sensorimotor Activity	Description
Homolateral Brain Boosters	Lying face down on the floor, head turned to one side, leg and arm on that side flexed; change smoothly from one side to the other
Homolateral Commando Crawl	Coordinated low crawl using the above with forward movement from pushing with toes and hands
Cross Pattern Brain Boosters and Commando Crawl	Use above but alternate head and limb flexion on opposite sides
Cross Pattern Walking	Alternate head and limb flexion on opposite sides while walking
Creeping	Kneeling creep in rhythmical pattern
Reflex Movements	Rocking, curling, standing and spinning
Balance Activities	Skipping, rolling, swinging and hopping
Enhancing (vision, cognition) Activities	Inclusion of a sight word or photo mat with creeping; addition of rhythm and timing to activities; stretching
Self-calming Activities	Humming; self-smoothing of arms/hands/legs

(Source: Hawke, 2011)

When implemented in a school situation, children are usually not assessed specifically for any impairment, or deficit in performance prior to participation in the *Learning Connections School Program* (Hawke, 2011). Inclusive education policies and disability standards ensure equity and access to formal schooling for all children (e.g. Australian Government, Department of Education and Training, 2005; Ministerial Council on Education, Employment, Training and Youth Affairs, 2008). This means some early school-age children will have not yet reached their full potential for development relative to their age (Sugden, 2007) and this may manifest later in an academic or behavioural problem (Kettler et al., 2014; Wilson, 2005). In the impairment-oriented approach, there is a premise that these problems are as a result of an impairment in sensory (or sensory motor) or cognitive and information processing (Sugden, 2007), or sensory integration dysfunction (Leong, Carter, & Stephenson, 2015a), depending on the theory of development and learning (Sugden, 2007)

favoured by the proponent of the approach. However, from a developmental or maturational perspective, this may be considered to be mainly due to lack of opportunity for practice with a resulting low movement confidence (Wilson, 2005) which further manifests in behavioural and learning slowness. Not all children develop at the same rate, so the *Learning Connections School Program* may be considered to be an early intervention approach to enhance developmental learning, though there is theoretical support for the notion that children will catch-up if provided a supportive environment with opportunity for learning and practice.

Within the impairment approach, interventions are further sub-classified (Polatajko & Cantin, 2010). The *Learning Connections School Program* utilises a *sensorimotor approach* based on the assumption that coordination of motor and sensory information is essential to improve information processing (Polatajko & Cantin, 2010; Sugden, 2007), while it contains elements of a sensory integration approach (Parham et al., 2007; 2011), referred to as a program using a sensory integration frame of reference in guiding the intervention (Kimball & May-Benson, 2013). It cannot, however, be sub-classified as a sensory integration therapy because an occupational therapist does not provide individualised intervention for each child (May-Benson & Koomar, 2010; Parham, 2007; Polatajko & Cantin, 2010) and it does not adhere to the strict core principles of Ayres, the founder of this approach (Watling & Hauer, 2015). Thus, the *Learning Connections School Program* is based on a sensory integration perspective, utilising a mixed sensory integration and sensorimotor approach, from an impairment orientation approach to intervention.

The *Learning Connections School Program* intervention was selected as it was already in use in some schools within the study setting and is already widely used throughout Queensland, and its operators demonstrate impetus to seek evidence and a theoretical basis for its activities (e.g. Hawke, 2011; The Learning Connections Centre, 2008). The Learning Connections Centre (2008; 2004; 2002; 2001; 2000) has co-operated with and collaborated on several research trials of its *Learning Connections School Program* intervention. As with many other trials of sensory and motor interventions, previous research into the effect of the *Learning Connections School Program* has some methodological limitations affecting the level of evidence achievable from trial, including small sample size, mixed samples of children of varying ages and school grades, lack of a control group and/or lack of randomisation, short duration, and use of non-comparable and/or non-standardised outcomes, limited statistical analyses or limited reporting of processes and inadequate descriptions of the specific intervention utilised in each study (The Learning Connections Centre, 2008; 2004; 2002; 2001; 2000).

The Learning Connections Centre Director was approached and found to be amenable to a large research trial of the *Learning Connections School Program*. A memorandum of understanding for the scope and limitations of this trial collaboration was developed and agreed upon by Australian Catholic University and Learning Connections Centre. Learning Connections Centre directors and staff had no input into the conduct of the trial but were willing to provide in-kind support for two-day training workshops for all teachers and two, six hour (2x6 hour) follow-up one-on-one sessions with teachers to guide and monitor teacher implementation of the program (fidelity to intervention), as per the memorandum of understanding.

In summary, the *Learning Connections School Program* (LCSP) (Hawke, 2011) offered by the Learning Connections Centre in Queensland, Australia is the sensory and motor intervention program to be studied in this trial in Phase 6. This program was selected due to its popularity and widespread use, and because its elements and training are well described.

Measurement Instruments

Studies reviewed in this scoping review have used many varied measurement instruments and outcomes. This review was not able to identify any consistently used measurement instruments for use in a research trial. It has also not been able to determine appropriate outcomes for measurement, as each study has focused on different aspects of development, play, sensory or motor achievement, function, and academic learning or skills. Thus this review has also not been able to identify any specific intervention outcomes to measure in a research trial. Therefore, an evaluation of suitable instruments to use in a research trial of an intervention in the school setting with young school-age children was undertaken and is reported as Phase 4 in Chapter Six. This review was published in 2016, in the *Journal of Psychoeducational Assessment*.

Conclusion

From this systematic scoping review of published and unpublished research trial literature, it is clear that there are methodological limitations affecting the level of evidence for various sensory and motor interventions. A high quality research study is needed to determine any effect from such an intervention, using appropriate instruments to measure any effect or benefit in the specific population being studied. Thus, the aim of the main research study was to provide evidence for the effects of a specific sensory and motor intervention program through the conduct of a randomised controlled trial. The use of large numbers of children, a control group of children and standardised assessment tools is supported by the results and recommendations of previous research in this area.

Chapter Six: Evaluative Review of Instruments

Overview

A scoping study review undertaken in Phase 3 and reported in Chapter Five (pp. 64-81), demonstrated that there are no consistent measurement instruments used in research trials of sensory and motor interventions. Therefore, that review did not identify suitable instruments to use in a trial of a specific intervention for Phase 6. It was thus necessary to undertake a specific review of instruments in order to identify suitable instruments for the trial. Part of this instrument review was to determine a way to identify the suitability of instruments, so a review of literature pertaining to instrument use in the very early school-age group was required. This review identified characteristics of this age group of children that needed to be considered when selecting instruments for use in a trial. As well the review identified suitable criteria for evaluating instruments, while other criteria were further developed for this review and are reported here. This chapter presents a published paper which reports on the results of conducting an updated evaluative review of instruments, undertaken as Phase 4. The results from this review in relation to instruments to use in the trial are reported in Chapter Eight (pp. 110-121).

[Please note: this chapter contains minor differences in spelling and other details due to the requirements of the USA journal where this was published as an article. This is an updated review from that used to identify suitable instruments for the main research study in this program of research, since a further updated edition of many instruments had been published following the initial instrument review undertaken for this study.]

Title: Evaluation of standardized instruments for use in universal screening of very early school-age children: suitability, technical adequacy and usability.

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Miles, S.J., Fulbrook, P. & Mainwaring-Mägi, D. (2016). Evaluating suitability, technical adequacy and usability of standardized instruments for use in universal screening of very early school-age children. *Journal of Psychoeducational Assessment*, 1-21 (online first version). Doi: 10.1177/0734282916669246

Abstract

Universal screening of very early school-age children (age 4-7 years) is important for early identification of learning problems that may require enhanced learning opportunity. In this context, use of standardized instruments is critical to obtain valid, reliable and comparable assessment outcomes. A wide variety of standardized instruments is available for screening and assessment purposes, though previous reviews have revealed some technical inadequacies. Suitability and

usability of instruments should be considered as well as technical adequacy, making instrument selection a challenge for education professionals. This review used a systematic search to identify 48 instruments that measured development and early academic skills in very early school-age children. Instruments were evaluated and mapped against established psychometric and usability criteria, and rated as good, adequate or not adequate. The results provide education professionals with a guide to selection of standardized instruments suitable for this age group and assessment purpose.

Introduction

Universal screening is a key role component for education professionals. Effective screening helps to identify children who will benefit from early intervention to create better learning opportunities (Kettler, Glover, Albers, & Feeney-Kettler, 2014). Since early academic and behavioural problems can lead to ongoing schooling issues, it is imperative that screening is conducted in the early school years. Use of standardized instruments for this purpose ensures valid and reliable data, which allows for comparison between young children and a normative group (Naglieri, 2013; Willis, Dumont, & Kaufman, 2013). The psychometric quality of instruments varies, so users need to choose wisely to have confidence in the outcome of instrument use (Naglieri, 2013). A wide variety of instruments is advertised and recommended, meaning that instrument selection can present a challenge (Glover & Albers, 2007). This article reports on a review of standardized instruments measuring relevant aspects of development and early academic skills suitable for use with very young school-age children (aged 4-7 years). Established criteria for evaluating psychometric and usability properties were used to determine suitability of instruments for use in screening and assessment.

Suitability

When selecting standardized instruments, it is imperative to consider suitability for age, since children continuously develop in capacity in recognized stages (Ford, Kozey, & Negreiros, 2012; Nagle, 2007). Children in the first two years of formal schooling are usually between 4 and 7 years of age and fall into two developmental stages: preschool and early school age (Nagle, 2007). These children are in the transition from preschool to formal schooling (van Hartingsveldt, de Groot, Aarts, & Nijhuis-van der Sanden, 2011), referred to as very early school-age (Willis et al., 2013). It is critical to conduct screening in this transition phase, since test scores at this time are predictive of future academic achievement and school success, whereas early intervention can address any identified problems (Dever & Kamphaus, 2013; Kettler et al., 2014; van Hartingsveldt et al., 2011). Any assessment instrument must, therefore, be suitable to this age group and the stages being assessed, or must include more than one test variation/scale (e.g., 2-5 and 6-8 years) to accommodate development across stages and allow for difference in rates of development among the group of

children being assessed (Ford et al., 2012). This also allows for re-evaluation or pre- and post-testing to monitor progress and intervention effectiveness (Nagle, 2007).

Suitable instruments sample aspects of development across a number of domains, including cognitive, behavioural and social/emotional (Alfonso & Flanagan, 2009; Ford et al., 2012; Gokiert, Georgis, Tremblay, Krishnan, Vendenberghe, & Lee, 2014; Kettler et al., 2014; Nagle, 2007), as well as early academic skills relevant to this age group, including language/literacy (Nagle, 2007) and mathematics (Clarke, Hammond & Gersten, 2014; Purpura, Reid, Eiland, & Baroody, 2015). It is also important to consider suitability for purpose of assessment. Early childhood education experts and organizations, such as the National Association for the Education of Young Children (NAEYC, 2015), emphasise that play-based and observational assessments should also be used for a more holistic assessment of each child. Nonetheless, there is a place for use of standardized instruments for universal screening purposes within a more holistic assessment setting.

Technical Adequacy

A critical aspect of instrument selection is technical adequacy, which refers to an instrument's psychometric properties, including standardized norms, and reported evidence of validity and reliability. Although there are many standardized instruments available for use with young children, previous reviews have demonstrated that many do not meet all, or inadequately report on, required standards (e.g. Alfonso & Flanagan, 2009; Bogue, DeThorne & Schaefer, 2004; DeThorne & Schaefer, 2004; Flanagan & Alfonso, 1995; Gokiert et al., 2014; Visser, Ruiters, van der Meulen, Ruijsenaars, & Timmerman, 2012; Williams, Sando, & Soles, 2014). To determine adequacy, it is important to review instruments in line with established standards. The American Educational Research Association (AERA), the American Psychological Association (APA) and the National Council on Measurement in Education (NCME) [AERA, APA, & NCME] (2014) provide *Standards for Educational and Psychological Testing*, while several other experts have informed and progressed a framework of established psychometric criteria, including standardization or norm-referencing, and various aspects of reliability and validity (e.g. Alfonso & Flanagan, 2009; DeThorne & Schaefer, 2004; Flanagan & Alfonso, 1995; Glover & Albers, 2007; Salvia, Ysseldyke & Bolt, 2013).

Standardization refers to the testing of an instrument on a normative population sample with characteristics of the general population (Alfonso & Flanagan, 2009). Evaluation considers representativeness of demographic variables such as gender, race/ethnicity/culture, geographic region, and parent education/socioeconomic status in the norm group (Alfonso & Flanagan, 2009; DeThorne & Schaefer, 2014). The adequacy of size of the norm group is evaluated, with greater than 200 per age year grouping being considered ideal (Alfonso & Flanagan, 2009; Salvia, et al., 2013). Comparative norm data should ideally have been collected within the previous 10 years, because

population characteristics and education concepts change over time (Alfonso & Flanagan, 2009). Further evaluative criteria relate to reliability, referring to the degree to which instrument scores are consistent across items (internal consistency), across time (test-retest) and across different examiners (inter-rater) (DeThorne & Schaefer, 2004), with these criteria measured by coefficients, such as Chronbach's alpha (Alfonso & Flanagan, 2009; Salvia, et al., 2013). Validity criteria include judgement by experts that the instrument measures stated concepts which relate to the domain being measured (content validity), factor analysis of internal structure of each instrument item (construct validity) and correlation with other tests measuring the same concepts or domains (criterion validity) (Alfonso & Flanagan, 2009; DeThorne & Schaefer, 2004; Salvia, et al., 2013). Details of how these evaluation criteria were graded for this review are included in the "Method" section.

Usability

A further aspect of instrument selection is usability, which considers how feasible it is to use the instrument for the required purpose, specific context and available funding (Glover & Albers, 2007). Since universal screening is typically undertaken with a large group of children across a whole grade (Glover & Albers, 2007; Kettler et al., 2014), it is important to consider usability properties such as time and monetary resources required (Dever & Kamphaus, 2013), including test administration time (Bogue et al., 2014, Visser et al., 2012). Because very young school-age children have high activity levels and short attention spans, testing should not take too long (Nagle, 2007; Visser et al., 2012), yet the design of most standardized instruments relies on individual observation and interaction, which are time consuming (Brassard & Boehm, 2007). Greater emphasis should be given to usability as it may influence test selection at the expense of technical adequacy (Gokiert et al., 2014). Although there are no established criteria to evaluate usability, several components have been addressed in previous reviews. These include feasibility aspects relating to ease of administration, such as whether a test is administered to a whole class or individually (Christ & Nelson, 2014); length of administration time in minutes (Bogue et al., 2014; Gokiert et al., 2014; van Hartingsveldt et al., 2011; Visser et al., 2012); costs (Bogue et al., 2014; Dever & Kamphaus, 2013; Glover & Albers, 2007); and qualification requirements to administer and score the instrument and/or interpret results (Christ & Nelson, 2014; Glover & Albers, 2007; van Hartingsveldt et al., 2011). In the absence of standardized evaluation criteria for usability, we developed our own usability evaluation protocol based on these previously reported components, as detailed in the "Method" section.

The aim of this review was to identify and evaluate the suitability, technical adequacy and usability of standardized instruments measuring relevant aspects of development and early academic skills in the very-early school-aged (4-7 years) child.

Method

Search Strategy

An extensive systematic search of literature was undertaken in late 2015 to identify suitable instruments. Sources searched included (a) electronic databases (A+ Education, ACER, Academic Search Complete, British Education Index, Education Source, ERIC, PsychInfo, PsycTests), (b) multisource databases (ProQuest Education Journals, ProQuest Psychology Journals, Sage Journals Online), (c) university library catalog and electronic book collections (for compendium texts on assessing young children and reviews of standardized instruments), (d) test publisher websites. Database search terms included combinations of the following: 'young child*' OR 'early school-age' OR 'preschool' OR 'kindergarten' OR 'PREP'; AND 'instrument' OR 'test' OR 'assess*' OR 'measure*'; AND a domain search term, such as 'math*', 'cognitive', 'intelligence', 'literacy', 'language', 'read*', 'spelling', 'phoneme', 'phonological awareness'. Where available, the search term NOT 'adult' was added, while the only search limit applied was English language.

Only instruments that met the following inclusion criteria were retrieved for full review: (a) designed for children 4 to 7 years of age (very early school age), (b) measuring a relevant developmental domain (overall development or behaviour / social and emotional / cognitive development or intelligence) or early academic skill (early reading / language / literacy / spelling / phoneme or phonological awareness concepts or early mathematical concepts), (c) published in English language, (d) readily available, (e) able to be used by education professionals in a school setting, and (f) demonstrating evidence of published psychometric testing data and detailed administration data for determining usability.

Because screening needs to be able to be undertaken across a variety of education settings, requirement for computers or consultation with parents to complete instruments was considered to be non-feasible for the purposes of widespread screening and, therefore, instruments requiring these did not form part of the inclusion criteria for this review. As well, instruments that informed a wider teaching program and program evaluation were not considered suitable for screening (Nagle, 2007).

The search identified a total of 1222 publications, reduced to 611, after duplications removed, for initial screening, with 246 reviewed against the inclusion criteria, leaving 48 instruments which met the inclusion criteria for full review (Figure 1).

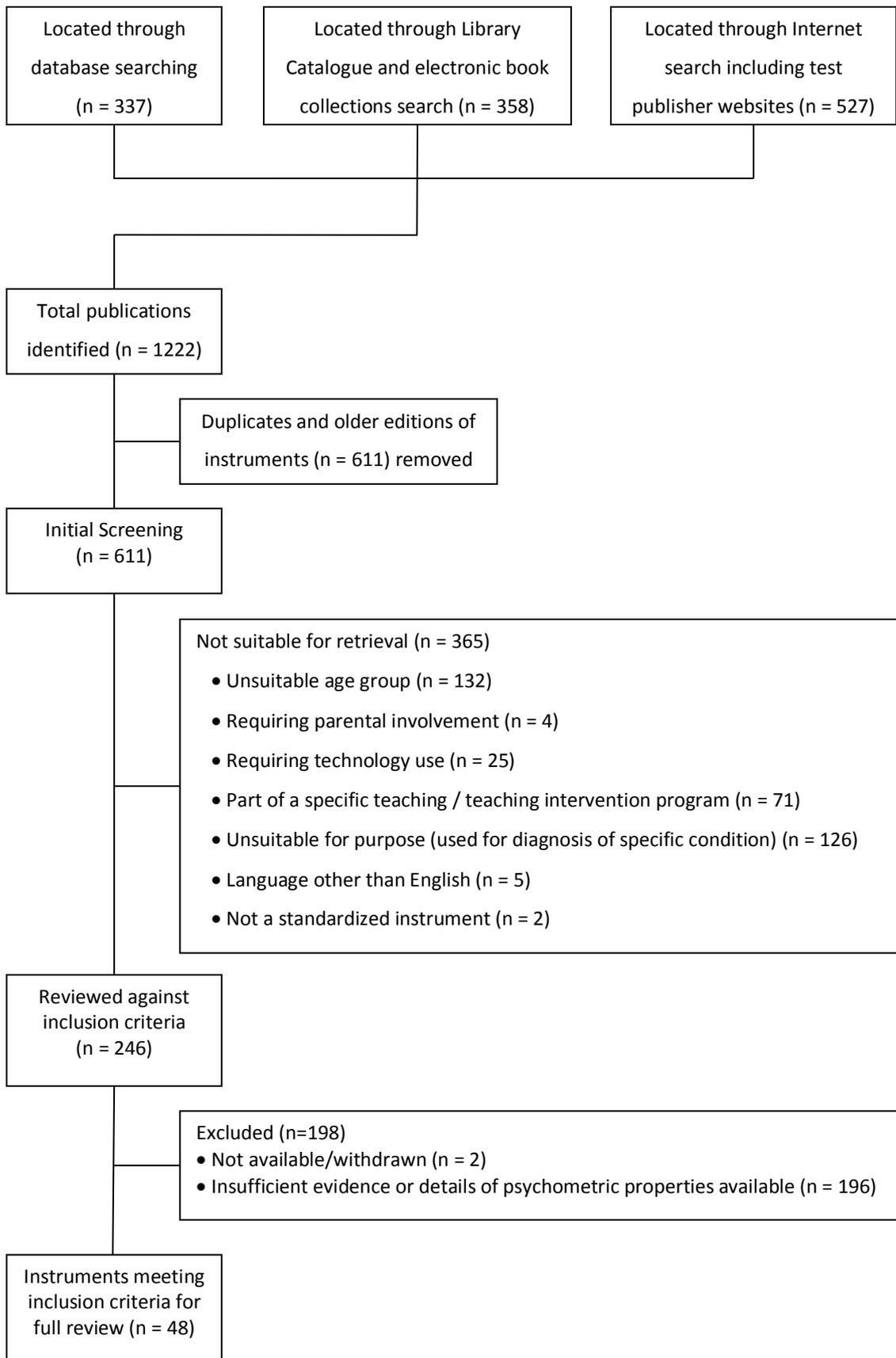


Figure 1. Instrument selection process.

Evaluation method

Instrument properties were evaluated separately by two reviewers against a psychometric evaluative criteria framework derived from the literature (Table 10) and a usability evaluative criteria framework developed by ourselves (Table 11), which was based on assessment criteria reported in previously published reviews (described above) as well as findings from our review. We contributed the following usability criteria: per class comparison of administration time and costs, based on administration time and instrument cost (for a 25 student class size); quantity of age-appropriate test variations available and/or need to repeat post-screening test to evaluate progress or effectiveness of interventions; and complexity of scoring methods, such as whether simple hand scoring or more complex calculations or computerized data entry was required. These criteria were included based on the premise that funding would be an important factor for most schools when considering the use of screening assessment tools. Only the most recent edition of each instrument was reviewed. Several sources of information were used for review, including vendor websites, technical manuals and published test reviews in databases, including Mental Measurements Yearbook Tests in Print and compendium texts. Each criterion was graded as: Good (✓), Adequate (±) or Not Adequate (✗) (adapted from Alfonso & Flanagan, 2009; Cancilla-Menasche, 2011; Williams, Sando, & Soles, 2014), in concert with established frameworks of evaluation criteria.

Table 13. Key to grading of instrument psychometric properties

Evaluation Criteria		✓ Good	± Adequate	* Not Adequate
Standardization	Norm sample group characteristics	Well documented stratified sampling across key demographic variables/population characteristics	Some over or under representation of some variables/ population characteristics in norm sample	Sampling not clearly demonstrated/reported or inadequate sampling across demographic variables/ population characteristics
	Norm Group Size	≥ 200 children for each year level tested	100-199 children for each year level tested	≤ 100 children for each year level tested
	Norm Group Recency	Collected or updated within last 10 years	Collected or updated within last 11–15 years	Collected or updated > 15 years ago
Reliability	Internal consistency	Coefficient ≥ .90	Coefficient = .80-.89	Coefficient < .80 or not tested
	Test-retest reliability	Coefficient ≥ .90	Coefficient = .80-.89	Coefficient < .80 or not tested
	Inter-rater reliability	Coefficient ≥ .90 or ≥ 90%	Coefficient = .80-.89 or 80 - 89%	Coefficient < .80 or < 80% or not tested
Validity	Content validity	Strong evidence of expert review and/or valid curriculum content for concepts and ages tested	Limited evidence of expert review and/or valid curriculum content for concepts and ages tested	Content deemed not valid for concepts and ages tested; no content validity testing or review
	Construct validity	Favourable factor analysis of constructs	Mixed factor analysis results	No factor analysis or construct testing
	Criterion validity	Compares well to other tests measuring the same concepts	Mixed results from comparison to other tests measuring the same concepts	Not compared to other tests or poor testing results

(Adapted from: Alfonso & Flanagan, 2009; AERA, APA, & NCME, 2014; DeThorne & Schaefer, 2004; Glover & Albers, 2007; Salvia, Ysseldyke & Bolt, 2013; Williams, Sando, & Soles, 2014)

Table 14. Key to grading of usability properties

Evaluation Criteria		✓ Good	± Adequate	* Not Adequate
Administration	Administration time per class of 25 ^a	Whole class at once	≤ 15 minutes per child = ≤ Total of 375 minutes per class	> 15 minutes per child; > Total of 375 minutes per class
	Scoring ^b	Simple scoring or template for hand scoring	Template plus calculator; or consideration required; or computerized scoring papers for online scoring	Several sub-tests to score and compute; or computerized scoring papers requiring manual data entry or optical scanning
Materials/equipment required	Cost ^c of starter kit	US\$0 - 250	US\$251 - 999	≥ US\$1000
	Cost ^c for class batch of 25 test papers	US\$0 - 25	US\$26 - 74	≥ US\$75
	Test paper variations ^d	Multiple variations (> 2) of test available for each age/data collection stage, e.g. Forms A, B, and C	At least two variations or two scales available e.g. Form A and Form B; or 2-5 and 6-8 years	Only one version/scale of test available
Qualification Level required to administer and interpret results		APA Assessment Training Level A: any Teacher	APA Assessment Training Level B (Master's level)	APA Assessment Training Level C: Educational Psychologist or Specialist Teacher; or requires training program

^aBased on adequate administration time of ≤ 15 minutes per child (Gokiert et al., 2014) and converted to class of 25 children; ^bbased on ease of scoring, calculation/score conversion requirement and/or requirement for specialized equipment such as optical scanners and computers; ^cbased on assumption that lower cost is better; ^dbased on availability of different forms and ages for tests.

Results

Of the 48 instruments reviewed, seven measured aspects of overall development, including behavioural and social emotional development; 17 measure cognitive development/intelligence; 21 measure early language skills and two measure early mathematics concepts/skills. The details of each instrument evaluated are shown in Table 12. Table 13 details the results of psychometric property evaluation, whereas Table 14 details the results of usability evaluation.

Table 15. Instrument Details

Domain	Instrument Name	Abbrev.	Author/s, publication year of most recent edition	What it measures
Cognitive Development/ Intelligence	Boehm Test of Basic Concepts 3 rd ed.	Boehm-3	Boehm, 2000	Understanding of basic relational concepts
	Draw a Person [aka Goodenough Draw-a-Man Test; Goodenough-Harris Drawing Test; Koppitz Developmental Inventory]	DAP	Goodenough, 1926; Harris, 1963; Koppitz, 1968	Understanding of reality and stage of development; Intelligence level (controversial use) or intellectual maturity
	Draw-A-Person Intellectual Ability Test	DAP:IQ	Reynolds & Hickman, 2004	Intellectual ability
	Kaufman Assessment Battery for Children 2 nd ed.	KABC-II	Kaufman & Kaufman, 2004a	Cognitive ability
	Kaufman Brief Intelligence Test 2 nd ed.	KBIT-2	Kaufman & Kaufman, 2004b	Verbal and non-verbal ability, intelligence
	Pictorial Test of Intelligence 2 nd ed.	PTI-2	French, 2001	General intelligence
	Primary Test of Nonverbal Intelligence	PTONI	Ehrler & McGhee, 2008	Reasoning ability
	Reynolds Intellectual Assessment Scales 2 nd ed.	RIAS-2	Reynolds & Kamphaus, 2015b	Verbal and non-verbal intelligence, memory
	Reynolds Intellectual Screening Test 2 nd ed.	RIST-2	Reynolds & Kamphaus, 2015c	General intelligence
	Slosson Intelligence Test for Children and Adults-Revised 3 rd ed.	SIT-R3	Slosson, Nicholson & Hibpshman, 2002	Intelligence/cognitive ability
	Stanford-Binet Intelligence Scales for Early Childhood 5 th ed.	Early-SB-5	Roid, 2003	Intelligence/cognitive ability
	Wechsler Preschool and Primary Scale of Intelligence 4 th ed.	WPPSI-IV	Wechsler, 2012	Intelligence, cognitive development
	Woodcock-Johnson IV Tests of Achievement Complete Battery	WJ IV Complete	Schrank, Mather, & McGrew, 2014a	General intellectual ability, cognitive ability, language, academic achievement
	Woodcock-Johnson IV Tests of Achievement	WJ IV Ach	Schrank, Mather, & McGrew, 2014 b	General intellectual ability, academic achievement
	Woodcock-Johnson IV Tests of Cognitive Abilities	WJ IV Cog	Schrank, Mather, & McGrew, 2014c	Cognitive ability
	Woodcock-Johnson IV Tests of Early Cognitive and Academic Development	WJ IV ECAD	Schrank, Mather, & McGrew, 2014d	Cognitive ability and early academic skills
	Young Children’s Achievement Test	YCAT	Hresko, Peak, Herron, & Bridges, 2000	Academic ability, school readiness
Overall Development/ Achievement	Batelle Developmental Inventory 2 nd ed.	BDI-2	Newborg, 2005	Developmental milestones
	Behaviour Assessment System for Children – 3 rd ed. Teacher Rating Scales	BASC-3 TRS	Reynolds & Kamphaus, 2015a	Behaviour, emotions and feelings
	BASC-3 Behavioural and Emotional Screening System	BASC-3 BESS	Kamphaus & Reynolds, 2015	Behavioural and emotional functioning
	Brigance Inventory of Early Development 3 rd ed. Standardized	IED-III	French, 2013	Developmental skills / milestones
	Qualls Early Learning Inventory	QELI	Qualls, Hoover, Dunbar, & Frisbie, 2003	Cognitive knowledge and classroom behaviours
	Wechsler Individual Achievement Test 3 rd ed.	WIAT-III	Psychological Corporation, 2009	Academic achievement
	Social Skills Improvement System Rating Scales	SSIS	Gresham & Elliott, 2008	Social behaviours
	Teacher-Child Rating Scale 2 nd edition	T-CRS 2.1	Perkins, & Hightower, 2002	Social and emotional skills and behaviours
Early Language skills	Astronaut Invented Spelling Test 2 nd ed.	AIST-2	Neilson, 2003a	Phonemic awareness
	Clinical Evaluation of Language Fundamentals 5 th ed.	CELF-5	Wiig, Semel, & Secord, 2013	Expressive and receptive language
	Clinical Evaluation of Language Fundamentals Preschool 2 nd ed.	CELF P-2	Wiig, Secord, & Sempel, 2006	Expressive and receptive language
	Comprehensive Assessment of Spoken Language	CASL	Carrow-Woolfolk, 1999	Language comprehension, expression and retrieval
	Comprehensive Test of Phonological Processing, 2 nd ed.	CTOPP-2	Wagner, Torgesen, Rashotte, & Pearson, 2013	Phonological processing abilities
	Expressive one-word picture vocabulary test 4 th ed.	EOWPVT-4	Martin & Brownell, 2011a	Expressive language
	Montgomery Assessment of Vocabulary Acquisition	MAVA	Montgomery, 2008	Expressive and receptive language
	Oral and Written Language Skills 2 nd ed.	OWLS-II	Carrow-Woolfolk, & Williams, 2011	Oral and written language
	Peabody Picture Vocabulary Test 4 th ed.	PPVT-4	Dunn & Dunn, 2007	Receptive vocabulary, scholastic

				ability
	Preschool Language Scales 5 th ed.	PLS-5	Zimmerman, Steiner, & Pond, 2011	Expressive and receptive language
	Receptive One-Word Picture Vocabulary Test 4 th ed.	ROWPVT-4	Martin, & Brownell, 2011b	Receptive vocabulary
	Sutherland Phonological Awareness Test – Revised	SPAT-R	Neilson, 2003b	Phonological awareness no norms
	Test for Auditory Comprehension of Language 4 th ed.	TACL-4	Carrow-Woolfolk, 2014	Receptive language
	Test of Early Language Development 3 rd ed.	TELD-3	Hresko, Reid, & Hammill, 1999	Expressive and receptive language
	Test of Early Reading Ability 3 rd ed.	TERA-3	Reid, Hresko, & Hammill, 2002	Reading ability
	Test of Early Written Language 3 rd ed.	TEWL-3	Hresko, Herron, Peak & Hicks, 2012	Written language
	Test of Expressive language	TEXL	Carrow-Woolfolk & Allen, 2014	Expressive language
	Test of Language Development – Primary 4 th ed.	TOLD-P:4	Newcomer & Hamill, 2008	Oral language
	Token Test for Children 2 nd ed.	TTFC-2	McGhee, Ehrler & DiSimoni, 2007	Receptive language
	Wiig Assessment of Basic Concepts	WABC	Wiig, 2004	Basic concepts
	Woodcock Johnson IV Tests of Oral Language	WJ IV OL	Schrank, Mather, & McGrew, 2014e	Oral language
Early Math skills	Early Math Diagnostic Assessment	EMDA	Pearson Psychcorp, 2003	Math skills
	Test of Early Mathematics Ability 3 rd ed.	TEMA-III	Ginsberg & Baroody, 2003	Mathematics performance

Table 16. Psychometric Properties of Instruments

Domain	Instrument	Standardization			Reliability			Validity		
		Norm Charact	Size	Recency	Intern. consist.	Test-retest	Inter-rater	Content	Construct	Criterion
Cognitive Development/ Intelligence	Boehm-3	✓	✓	✗	±	±	✗	✓	±	±
	DAP	±	✗	✗	±	✗	✓	✓	✗	±
	DAP:IQ	✓	±	±	✗	±	✓	✓	✓	±
	KABC-II	✓	✓	±	±	±	✗	✓	✓	±
	KBIT-2	✓	±	±	✗	±	✗	✓	✓	±
	PTI-2	±	✗	✗	±	±	±	✓	±	±
	PTONI	✓	±	✓	✓	✓	✓	✓	✓	✓
	RIAS-2	±	±	✓	✓	±	✗	✓	±	±
	RIST-2	±	±	✓	✓	±	✗	✓	±	±
	SIT-R3	✓	±	✗	±	✓	✗	±	±	±
	Early-SB-5	✓	✓	±	±	✓	±	✓	✓	±
	WPPSI-IV	✓	±	✓	±	±	✓	✓	✓	±
	WJ IV Complete	✓	✓	✓	±	±	✗	✓	✓	±
	WJ IV Ach	✓	✓	✓	±	±	✗	✓	✓	±
	WJ IV Cog	✓	✓	✓	±	±	✗	✓	✓	±
WJ IV ECAD	✓	✓	✓	±	±	✗	✓	±	±	
YCAT	✓	✓	±	±	✓	✓	±	±	±	
Overall Development	BDI-2	±	✓	±	±	±	±	✓	✗	±
	BASC-3 TRS	✓	±	✓	±	±	✗	✓	±	±
	BASC-3 BESS	✓	±	✓	±	±	✗	✓	±	±
	IED-III	±	±	✓	±	±	✓	✓	±	±
	QELI	✗	✓	±	±	✗	✗	±	✗	±
	WIAT-III	✓	✓	✓	±	±	✓	✓	±	±
	SSIS	✓	✓	✓	✓	±	±	✓	±	±
	T-CRS 2.1	✗	±	±	±	✗	✗	✓	±	±
Early Language skills	AIST-2	±Aust	✗	±	✗	✗	✓	✓	✗	±
	CELF-5*	✓	✓	✓	±	✗	✓	✓	±	±
	CELF P-2*	✓	✓	±	±	✗	✗	✓	±	±
	CASL	✓	✗	✗	✗	±	✗	±	±	±
	CTOPP-2	±	✓	✓	✗	✗	✗	✓	±	±
	EOWPVT-4	±	✗	✓	✓	✓	✗	✓	✓	✓
	MAVA	✓	±	✓	✓	✓	✓	✓	✓	✓
	OWLS-II	✓	±	✗	✗	±	✗	✓	✓	±
	PPVT-4	✓	±	✓	✓	✓	✗	✓	✓	✓
	PLS-5	✓	±	✓	✓	✗	✗	✓	±	±
	ROWPVT-4	±	✗	✓	✓	✓	✗	✓	✓	✓
	SPAT-R	±Aust	✗	±	✓	✓	✓	✓	✓	±
	TACL-4	✓	±	✓	✓	✓	✗	✓	±	±
	TELD-3	✓	✓	✗	±	±	✗	±	±	±
	TERA-3	✓	±	✗	✓	±	✓	✓	✗	±
	TEWL-3	±	✓	✓	✓	±	✗	±	±	±
	TEXL	✓	±	✓	✓	✓	✗	✓	±	±
	TOLD-P:4	✓	✓	✓	±	±	✓	✓	±	±
TTFC-2	±	±	✓	±	✓	✓	✓	±	±	
WABC	±	±	±	✓	✗	✓	✓	±	±	
WJ IV OL	✓	✓	✓	±	✓	✗	✓	±	±	
Early Math skills	EMDA	✓	✓	✗	✓	✓	✗	✓	±	±
	TEMA-III	✗	±	±	✓	±	✓	✓	±	±

*CELF-5 and CELF P-2 only meet age group criterion together, not individually

Table 17. Usability Properties of Instruments

Domain	Instrument	Administration		Materials required			Training Level
		Time	Scoring	Cost: kit	Cost: test papers	Test variations	
Cognitive Development/ Intelligence	Boehm-3	✓	✗	✓	±	±	✓
	DAP	✓	✓	✓	✓	✓	✓
	DAP:IQ	±	±	✓	±	✓	±
	KABC-II	✗	✗	✗	±	✗	±
	KBIT-2	✗	✗	±	±	±	±
	PTI-2	✗	✓	✓	±	✗	✓
	PTONI	±	✓	✓	±	✗	✗
	RIAS-2	✗	✓	±	✗	✗	✗
	RIST-2	±	✓	✓	±	✗	±
	SIT-R3	±	±	±	±	✗	✗
	Early-SB-5	✗	±	✗	✗	✓	✗
	WPPSI-IV	✗	✗	✗	✗	±	✗
	WJ IV Complete	✗	±	✗	✗	±	✗
	WJ IV Ach	✗	±	✗	✗	±	✗
	WJ IV Cog	✗	±	✗	✗	±	✗
WJ IV ECAD	✗	±	±	✗	±	✗	
YCAT	✗	±	✓	±	✗	±	
Overall Development	BDI-2	✗	✗	✗	✗	✓	±
	BASC-3 TRS	±	✗	✗	±	✓	±
	BASC-3 BESS	±	✗	±	±	✓	±
	IED-III	✗	✗	✓	✗	✗	±
	QELI	±	±	✓	±	✗	✗
	WIAT-III	✗	✗	±	±	✗	±
	SSIS	±	✗	±	±	✗	±
	T-CRS 2.1	±	±	✓	±	✗	✓
Early Language skills	AIST-2	✓	±	✓	✓	✗	±
	CELF-5	✗	✗	±	✗	±	±
	CELF P-2	✗	✗	±	✗	±	±
	CASL	✗	✗	±	±	✗	±
	CTOPP-2	✗	✗	±	±	✗	✓
	EOWPVT-4	✗	±	✓	±	✗	✓
	MAVA	✗	±	±	±	✗	✓
	OWLS-II	±	✗	±	±	±	±
	PPVT-4	±	±	±	±	±	✓
	PLS-5	✗	±	±	✗	±	±
	ROWPVT-4	✗	✓	✓	±	±	✓
	SPAT-R	✓	✓	✓	✓	±	±
	TACL-4	✗	±	±	✗	±	±
	TELD-3	✗	±	±	±	±	±
	TERA-3	✗	±	±	±	±	±
	TEWL-3	✗	±	±	±	±	±
	TEXL	✗	±	±	±	✗	±
	TOLD-P:4	✗	✗	±	✗	✗	±
TTFC-2	±	±	±	✗	±	±	
WABC	±	✗	±	±	±	±	
WJ IV OL	✗	✗	±	✗	±	✗	
Early Math skills	EMDA	✗	✓	±	✗	✗	✓
	TEMA-III	✗	±	±	±	±	✓

Psychometric properties

Standardization

Most instruments ($n = 31$) demonstrated good stratified sampling across key demographic variables/ population characteristics for norm groups. Fourteen instruments showed some under- or over-representation on some demographics/characteristics (adequate), including two instruments with Australian norms (Astronaut Invented Spelling Test-2nd ed. [AIST-2], Sutherland Phonological Awareness Test-Revised [SPAT-R]). Three instruments did not adequately meet the norm sample

characteristics criterion, including the Teacher-Child Rating Scale-2nd edition (T-CRS 2.1) that reports only on gender and locale; and the Qualls Early Learning Inventory (QELI) and Test of Early Mathematics Ability (TEMA-III) that did not clearly report on norm sample characteristics. Nine instruments did not meet the criterion for recency of norm data collected before 2000 (within the last 15 years). Twenty-six instruments had good recency with norm data collected within the last 10 years (since 2005). The remaining 13 instruments had adequate recency with norm data collected 11-15 years ago (2001-2005). Twenty instruments were normed with a sample size of 200 children or more in each year level (good), while a further 21 instruments had an adequate norm sample size with at least 100 children in each year level. Only seven instruments did not meet adequate norm sample size.

In summary, only nine instruments provided evidence for a “good” rating across all three norm criteria of characteristics, size and recency (Clinical Evaluation of Language Fundamentals-5th ed. [CELF-5], Woodcock-Johnson IV Tests of Achievement Complete Battery [WJ-IV Complete], Woodcock-Johnson IV Tests of Achievement [WJ IV Ach], Woodcock-Johnson IV Tests of Cognitive Abilities [WJ IV Cog], Woodcock-Johnson IV Early Cognitive and Academic Development [WJ IV ECAD], Wechsler Individual Achievement Test-3rd ed. [WIAT-III], Social Skills Improvement System Rating Scales [SSIS], Test of Language Development-Primary-4th ed. [TOLDP:4], Woodcock-Johnson IV Tests of Oral Language [WJ IV OL]). Twenty-four instruments had a combination of good or adequate rating across the three norm criteria. All other instruments ($n = 15$) did not meet (inadequate) at least one norm criterion.

Reliability

Seventeen instruments reported good internal consistency measures, with a further 25 deemed adequate. Six instruments showed inadequate internal consistency, of which one had no stated internal consistency measures (AIST-2). Thirteen instruments demonstrated good test-retest reliability, while a further 25 instruments had adequate test-retest reliability. Ten instruments had inadequate test-retest reliability. Most instruments did not specifically or clearly report on inter-rater reliability. Only eighteen instruments stated a specific good inter-rater reliability. All other instruments had inadequate inter-rater reliability.

In summary, only two instruments reported good internal consistency, good test-retest and good inter-rater reliability (Primary Test of Nonverbal Intelligence [PTONI] and Montgomery Assessment of Vocabulary Acquisition [MAVA]). Six instruments demonstrated good internal consistency and good test-retest reliability (Expressive One-Word Picture Vocabulary Test-4th ed. [EOWPVT-4], Peabody Picture Vocabulary Test-4th ed. [PPVT-4], Receptive One-Word Picture Vocabulary Test-4th ed.

[ROWPVT-4], Test for Auditory Comprehension of Language-4th ed. [TACL-4], Test of Expressive Language [TEXL], Early Math Diagnostic Assessment [EMDA]). All other instruments demonstrated varying combinations of reliability test outcomes or a lack of testing.

Validity

Most instruments presented good evidence of content validity confirmed via expert or curriculum review for concepts valid for age group or concepts tested. Six instruments were deemed by test review to provide adequate evidence of content validity. No instruments were deemed inadequate on this criterion. Fifteen instruments provided good evidence of construct validity by good factor analysis results. Only five instruments failed to provide evidence of adequate construct validity, whereas the other 28 instruments provided adequate evidence for this criterion. Only four instruments provided good evidence of criterion validity as judged by test reviewers. All other instruments provided adequate evidence of criterion validity from comparison with other instruments testing the same concepts.

In summary, four instruments provided good evidence for all three types of validity (PTONI, EOWPVT-4, PPVT-4, ROWPVT-4). Five instruments (DAP, BDI-2, QELI, AIST-2, TERA-3) failed to provide adequate construct validity. All other instruments adequately met only two of the three validity criteria.

Usability properties

Administration

Only four instruments could be administered for a whole class at once (Boehm-2, DAP, AIST-2, SPAT-R), with all other instruments designed for individual testing. Thirteen instruments could be administered in 15 min or less per child, whereas all other instruments ($n = 31$) required longer. Eight instruments required hand scoring with a simple template but the majority ($n = 23$) required the use of more complex templates or calculator use to determine scores. Eighteen instruments required complex scoring or manual data entry for computerized scoring. In summary, the DAP and SPAT-R achieved a good rating for both administration time and scoring, whereas the PTONI and Reynolds Intellectual Screening Test-2nd ed. (RIST-2) were rated as good for scoring and adequate for administration time with the AIST-2 achieving good for time and adequate for scoring. A further six instruments (Draw-A-Person Intellectual Ability test [DAP:IQ], Slosson Intelligence Test for Children and Adults-Revised 3rd ed. [SIT-R3], QELI, T-CRS2.1, PPVT-4, Token Test for Children-2nd ed. [TTFC-2]) achieved adequate ratings for both administration time and scoring.

Materials/equipment required

Only one instrument (DAP) was available free-of-charge (which used the original freely published scoring details and ordinary drawing paper). Fourteen instruments were priced modestly at less than US\$250 per kit, with 21 instruments costing between US\$251 and US\$1000 to purchase, and all other instruments ($n = 8$) priced expensively at more than US\$1000 per kit. Two instruments (WJIV Complete, WJIV Ach) cost more than US\$2000 per kit. After an initial cost, test papers for two instruments were available from a photocopy master (AIST-2, SPAT-R), whereas another instrument (DAP) only required ordinary drawing paper. Twenty-eight instruments cost between US\$26 and US\$74 per batch of 25 test papers. All other instruments ($n = 17$) cost more than US\$75 per class batch of test papers. Only five instruments had more than two variations of the test to use for multiple testing points, with 23 having at least two test variations while the remaining 20 had only one test version.

To summarise, the DAP was the only instrument found to have a good rating for all three materials criteria, while four instruments (Boehm-3, DAP:IQ, ROWVPT-4, SPAT-R) met all criteria with a mix of good and adequate rating and one instrument (AIST-2) achieved two good but one inadequate rating. A further eight instruments achieved adequate ratings across all three criteria, with all other instruments ($n = 33$) rated as not adequate for at least one materials criterion.

Qualification Level

Eleven instruments could be administered and interpreted by teachers (Level A), 11 were suitable for administration and interpretation by trained specialists (Level C) only, with the remainder ($n = 27$) requiring Level B (master's degree) qualification.

Summary

Psychometric Properties

Ten instruments (PTONI, Stanford-Binet Intelligence Scales for Early Childhood-5th ed. [Early SB-5], Wechsler Preschool and Primary Scale of Intelligence-4th ed. [WPPSI-IV], Young Children's Achievement Test [YCAT], Brigance Inventory of Early Development-3rd ed. Standardized [IED-III], WIAT-III, SSIS, MAVA, TOLD P:4, TTFC-2) met all nine psychometric criteria (good or adequate rating). A further 16 instruments met eight criteria, whereas another 15 instruments met seven criteria. Four instruments (DAP, QELI, AIST-2, CASL) failed the most psychometric criteria (four each), with another three instruments (T-CRS 2.1, Comprehensive Test of Phonological Processing-2nd ed. [CTOPP-2], Oral and Written Language Skills-2nd ed. [OWLS-II]) failing three criteria.

Usability Properties

Four instruments (DAP, DAP:IQ, PPVT-4, SPAT-R) adequately met all usability criteria (i.e., good or adequate rating). A further 12 instruments met five of the six criteria (good/adequate rating) (Boehm-3, RIST-2, T-CRS 2.1, AIST-2, OWLS-II, ROWPVT-4, Test of Early Language Development-3rd ed. [TELD-3], Test of Early Reading Ability-3rd ed. [TERA-3], Test of Early Written Language-3rd ed. [TEWL-3], TTFC-2, Wiig Assessment of Basic Concepts [WABC], TEMA-III), whereas another 13 met four of the six criteria. Of all these, four could be administered to a whole class at once (Boehm-3, DAP, AIST-2, SPAT-R) and were modestly priced, with only the Boehm-3 requiring an ongoing test paper cost. The DAP:IQ can be adapted for administration to a whole class and was modestly priced. One instrument (WPPSI-IV) did not meet (inadequate rating) five of the six usability criteria, and 10 instruments did not meet four of the criteria (Kaufman Assessment Battery for Children-2nd ed. [KABC-II], Reynolds Intellectual Assessment Scales-2nd ed. [RIAS-2], Early SB-5, WJIV Complete, WJIV Ach, WJIV Cog, Batelle Developmental Inventory-2nd ed. [BDI-2], IED-III, TOLD P:4, WJIV OL). Administration time, costs, and qualification requirement were the most common criteria that were met the least well.

Combined Psychometric and Usability Properties

None of the instruments met all psychometric and usability criteria. One instrument (TTFC-2) met all nine psychometric criteria and five of the six usability criteria but incurred a high cost for test papers. Four instruments (PTONI, YCAT, SSIS, MAVVA) met all psychometric plus four usability criteria, and four (RIST-2, TEWL-3, WABC, TEMA-III) met eight psychometric and five usability criteria. Two instruments (DAP:IQ, PPVT-4) met all usability and eight psychometric criteria and 12 met seven or more psychometric criteria and four or more usability criteria (Boehm-3, Kaufman Brief Intelligence Test-2nd ed. [KBIT-2], Pictorial Test of Intelligence-2nd ed. [PTI-2], SIT-R3, EOWPVT-4, Preschool Language Scales-5th ed. [PLS-5], ROWPVT-4, SPAT-R, TAACL-4, TELD-3, TERA-3, TEXTL). Of the 23 instruments above, only two (Boehm-3, SPAT-R) were able to be administered to a whole class at one time, whereas eight could be administered within 15 min per child.

Discussion

Our results are consistent with previous reviews, which have reported that many standardized instruments do not meet psychometric expectations (Bogue et al., 2014; DeThorne & Schaefer, 2004; Gokiert et al., 2014; Williams et al., 2014; Visser et al., 2012). To our knowledge, no other review has examined usability criteria in comparable detail with this review. In a review by Bogue et al. (2014), the MAVVA was found to meet the highest number of standardization criteria; in our review it achieved a good rating for eight of the nine psychometric criteria and met four of six usability

criteria. In the same review, the Boehm-3 met most psychometric criteria but in our review its recency criterion was rated lower due to its age. Bogue et al. (2014) judged the PPVT-4 less favourably than reported in our review but this was based on norm size (fewer children in older age groups). In contrast to Bogue et al., two instruments in our review (EOWPVT-4 and ROWPVT-4) were judged to perform fairly well across both sets of criteria. Similarly to our results, Williams et al. (2014) reviewed the PTI-2 and PTONI favourably; however, in their review, the BDI-2 and KABC-II were also viewed favourably, which is in contrast to our results. Partly this was because of recent lapse of norms not only for our review but also on the review purpose, including criteria related to tests for use with younger (non-verbal) children than for this review. This applies also to a review by Visser et al. (2012) who reported on the BDI-2 and KABC-II for use with young children with special needs, whereas earlier reviews of PTI-2, KABC-II and RIAS (DeThorne & Schaefer, 2004) also viewed norm recency more favourably and used a smaller sample size criterion. Other reviews relate to earlier versions of tests, for example WPPSI-III and WJ III tests (Visser et al., 2012), so are not comparable to the results of this review of the fourth edition of these. In relation to the results of this review, it is important to note that there is only a minor difference between categories for some reliability evaluative criteria based on coefficients; for example .80 is adequate but .79 is not adequate. However, this is graded according to published standards for evaluation (AERA, APA, & NCME, 2014). It is also important to check for any norm update of instruments where norms have been reviewed unfavourably here. This is especially so where a respected older instrument has been well used in a certain context; it is important to determine if there is a need to move on or to continue to build momentum from past usage.

Oakland, Douglas, and Kane (2016) point to a concern about 'lemming effect' of repeated instrument use, suggesting that education professionals may be selecting instruments either because they were taught at university or because they are familiar and popular as opposed to being valid and reliable (Gould, Martindale, & Flens, 2013). This review of standardized instruments for use in universal screening of very early school-age children has presented a rigorous evaluation that may be used to guide the selection of psychometrically sound instruments for this purpose. While all instruments included are suitable for use with very young school-age children, this review highlights those most suited for universal screening. Conversely, instruments with lower usability features but high psychometric properties may be highly suitable for second-tier assessment following initial screening.

Short-form screening versions of accepted measurement instruments go a long way to enhancing the usability properties of instruments while retaining the psychometric properties of the parent instrument. Purpura et al. (2015) reported on testing of a brief screening tool for early numeracy

skills and, as with our review, found only two instruments measuring early mathematical skills that met their review criteria. This fits with other research noting a dearth of available measures for this purpose, despite the need for broad mathematical screeners for this age group (Purpura et al., 2015). Individual differences in numeracy skill development in the early school years can be measured, with early intervention essential to prevent later problems (Clarke, Hammond, & Gersten, 2014; Purpura et al., 2015). Although some of the comprehensive instruments included in our review did include selected mathematical concepts, these were not always available for the younger age groups in our review.

It is significant to note that use of standardized instruments provides only one mode of assessment of very young school-age children. Education experts (e.g., Brassard & Boehm, 2007; Christ & Nelson, 2014; Ford et al., 2012; NAEYC, 2015) recommend using a variety of assessment methods in early childhood, including play-based and observational assessment related to daily activities. However, use of standardized instruments does provide a valid and reliable method of screening across a large group of children in the very early school years (Christ & Nelson, 2014; Ford, Kozey, & Negreios, 2012; Naglieri, 2013; Willis et al., 2013). Following the specified standardized administration procedures is critical to achieving valid and reliable outcomes from instrument use, as well as for maintaining ethical standards of education professionals (Gould et al., 2013; McCallum, 2013). For example, the Draw-A-Person test continues to receive much attention as both suitable (Arden, Trazakowski, Garfield, & Plomin, 2014; McCallum, 2013) and not suitable (Imuta, Scarf, Pharo, & Hayne, 2013) for assessing cognition, with particular suitability with assessing non-verbal intelligence in young children (McCallum, 2013). It continues to be one of the top 10 tests preferred by school psychologists internationally (Oakland et al., 2016), with its usability possibly being significant to its selection. However, there is a difference between using the test in the simplified original version and the more highly standardized version (DAP:IQ), in terms of reliable, comparable results.

Conclusion

Given the importance of universal screening for very early school-age children, it is important to select instruments that are standardized to ensure the validity and reliability of results that can be used with confidence. However, even using a standardized instrument is not sufficient to guarantee quality of assessment, given that several instruments did not adequately meet all psychometric property criteria. Therefore, the user should be sufficiently apprised of the standard reached for the instrument before selection. In a busy, sometimes under-resourced school setting, costs and other usability features of instruments should also be considered prior to instrument selection. This review highlights the variation in usability of instruments for this age group, where individual administration

with a cost-per-paper is the norm. Although individual assessment is the ideal for very young school-age children, the designers of some instruments have demonstrated that valid results can be obtained from group administration where a child's developmental characteristics are utilized (e.g., drawing, invented spelling). Screening of very early school-age children is not the only way to identify children with problems, so use of group-administered instrument with better usability can be validly used as a first step. Once children with potential learning problems have been identified, individualized assessments with more technically adequate instruments should follow.

Limitations

Many instruments did not meet the age criteria for this review, since the specified lower or upper age limit was five years, or the lower limit did not commence until 4 years and 6 months. However, these might be suitable where precise ages are known in the context of screening. This review did not evaluate reliability measures of test-retest sample characteristics, test floors, item gradients, standard errors of measurement and validity measures of response processes and consequences of testing, which relate to diagnosis of learning difficulty or developmental delay in individual children (Alfonso & Flanagan, 2009; Cancilla-Menasche, 2011) or to assessment of teaching adequacy (Ford et al., 2012), or adaptability for children with special needs (Visser et al., 2012), which was beyond the scope of this review. These concepts are well addressed by other reviews. Specific physical or motor development assessment instruments were not reviewed since adequate aspects are assessed through the included overall development/behavior and drawing task instruments. Instruments designed for health screening or diagnostic purposes or for use by parents or with computers were not evaluated, though these may be useful for universal screening procedures designed as a first tier approach where concerns are noted.

Chapter Conclusion

This review of measurement instruments identified many instruments suitable for use with a large research trial with very early school-age children. The final determination of instruments to use in the research trial undertaken as Phase 4 was based on various aspects of the results of this review and on the size of and setting for the trial. Usability was a significant aspect to consider, given the large sample size for the trial. Thus, particular usability criteria were considered, including cost of instrument and ease of administration, as well as feasibility, particularly time of administration, for using within the setting with a large sample of children and ease of scoring. Instruments selected after this consideration are shown in Appendix D (pp. 157-169) and reasons for their selection are provided here. The *Astronaut Invented Spelling Test* (2nd ed.) (AIST-2) (Neilson, 2003a) and the *Sutherland Phonological Awareness Test – Revised* (SPAT-R) (Neilson, 2003b) were selected for their Australian norms, low cost and high usability to measure early language skills. The *Draw a Person* test

(DAP) (Goodenough, 1926; Harris, 1963; Koppitz, 1968) met suitability requirements to measure cognition, with universal norms, use in international research, and high usability and low cost. The three instruments just specified are all able to be used as a whole-of-class assessment, providing high usability.

The *Behavior Assessment System for Children (2nd ed.) - Teacher Rating Scales* (BASC-2 TRS 2-5 years and 6-11 years) with sub-categories: Externalizing Behaviour (EB), Internalizing Behavior (IB), Behavioral Symptoms (BS), and Adaptive Skills (AS) (Reynolds & Kamphaus, 2004) was selected for its high technical adequacy, excellent computerised scoring and familiarity to members of the research team, with its key purpose being as a holistic measure of behavioural, developmental and functional measures.

Since no suitable mathematic screening instrument was identified in this review, two sets of brief, multiple-proficiency measures, *Early Mathematics Concepts A and B* (EMCA, EMCB), were specifically developed for this study. These included standardised, validated and reliable mathematical computation concepts (counting, addition, dot array etc.) suitable to the two age groups in the trial, as recommended (Clarke, Hammond, & Gersten, 2014; Mather & Abu-Hamour, 2013; Purpura et al., 2015). Thus, this chapter presents the finalisation of instrument selection, and, together with the results from Chapter Five, selection of a suitable intervention, prepares the way for a pilot study to pilot test the selected intervention and instruments. This is reported in the next chapter, Chapter Seven Pilot Study.

Chapter Seven Pilot Study

Introduction

In order to undertake a well-designed research study, various preparations must be undertaken. For a large trial, it is important to determine if the chosen intervention and methods of evaluation, including instrumentation, can be used appropriately, validly and reliably in the chosen setting. This is particularly important to avoid unforeseen problems. This chapter presents a report of a pilot study, Phase 5, undertaken in one school within the study setting to test the feasibility of implementation of the selected intervention and instruments, in order to confirm preparations for the main study. This chapter sets the scene for reporting of the results of a randomised controlled trial undertaken in Phase 6, reported in Chapter Eight in the form of a paper under review.

Phase 5 Pilot Study

Prior to undertaking Phase 6, it was deemed important to undertake a pilot study to determine the suitability of both the intervention and instruments selected for the randomised controlled trial. Suitability includes the ease by which the intervention and instruments could be used in the school setting, and whether there was any need for increased training or instructions. This determines the feasibility of conducting the study as planned (Polit, Beck & Hungler, 2001), which is a key purpose for undertaking pilot studies (Eldridge et al., 2016). A pilot study was undertaken for one month, November 2011, in a single school within the study setting, to pilot test the selected sensory and motor intervention, the *Learning Connections School Program*, and to pilot test the selected measurement instruments.

The purpose of the pilot study was to:

- Trial the delivery of the selected sensory and motor intervention, the *Learning Connections School Program*
- Ensure that teachers are properly prepared, through training, to deliver the *Learning Connections School Program*
- Identify the feasibility and needs of classroom teachers delivering the intervention in the classroom setting
- Trial the selected measurement instruments in order to determine the feasibility of use in the classroom setting and suitability for that age group of children, judged by:
 - the average amount of time required to administer each of the instruments,
 - the ease of administration in the classroom setting with that age group of children and
 - the reliability of administration according to provided administration instructions, *and*

- Identify any issues concerned with administering the intervention and/or instruments in order to address these prior to commencement of the main study.

Methods

Sample

A set of six schools for which principals had previously, in the Phase 2 Scoping Study (pp. 23-31), expressed interest in being available for a pilot study were listed in an Excel database. School which met the inclusion and exclusion criteria, and for which the school principal and teachers of two Prep year classes consented to participate in the pilot study were eligible to participate.

Inclusion criteria

- All Brisbane Catholic Education primary schools with PREP year classes where the School Principal had previously expressed interest in participation as a pilot study school.

Exclusion criteria

- Schools with existing sensory and motor intervention programs
- Schools for which the Principal decides not to participate
- Schools for which the Principal does not provide written consent to participate.

Training

Following consent to participate being provided, the teachers were provided with two days of training about the *Learning Connections School Program* by Learning Connections Centre staff. Training was provided in October 2011 on site at the Australian Catholic University with two research team members present. Class teachers then implemented the *Learning Connections School Program* on a daily basis in their classroom for four weeks in the month of November 2011, with one visit provided by Learning Connections Centre staff to check validity and reliability of program implementation.

Intervention Feasibility

Teachers were asked to provide feedback on the feasibility of implementing the program in the classroom setting with that age group of children on a daily basis, including commenting on whether the classroom provided sufficient space to implement the program, if the children were able to participate in the activities of the program, and whether the daily implementation could be accommodated by the usual class scheduling. Feedback was sought both by telephone to research team members and via email. Learning Connections Centre staff also visited each Prep class during the one month trial to provide guidance on program implementation and receive verbal and observational feedback regarding implementation feasibility.

Instrument Feasibility

Class Teachers were also provided with information and administration instructions for the set of selected measurement instruments (Appendix D, pp. 157-169), during the two day *Learning Connections School Program* training. Teachers were requested to administer each instrument during the month of November 2011. Following this, teachers were requested to return the completed instruments to the researchers by mail, using a provided reply-paid, pre-addressed envelope. Teachers were also asked to provide feedback regarding the feasibility of using the instruments, including ease of administration and time of administration (in minutes) for each instrument, and the suitability of the instruments for use with that age group of children in the classroom setting. Feedback was sought both by telephone to research team members and via hand written notes.

Two members of the research team scored each completed measurement instrument to determine the feasibility of scoring for these instruments for the two year trial (Phase 6).

Results

Sample

A single school was randomly selected from the Excel database list of six schools for which principals had previously, in the Phase 2 Scoping Study, expressed interest in being available for a pilot study. A random number generator was used to determine which school was selected from the list. The school thus selected met the inclusion and exclusion criteria, and the school principal and teachers of two Prep year classes were invited to consent to participate in the pilot study.

One school principal and two Prep year classroom teachers provided consent to participate in the pilot study, producing a sample size of 58 children (Class 1, n=28; Class 2, n=30). The two teachers verbally reported implementing the *Learning Connections School Program* daily in the classroom during November 2011.

Intervention Feasibility

Teachers provided verbal reports in person to Learning Connections Centre staff and via telephone to two research team members about the feasibility of implementing the program in the classroom setting with that age group of children on a daily basis. The two teachers found that their typical classrooms provided sufficient space to implement the program, though it was noted that matting or such suitable surface was required to enable the children to safely and cleanly undertake the rolling and crawling activities on the floor. Each teacher noted that children of Prep year age were able to participate in all activities of the program and that the training provided to them was sufficient for them to feel confident in delivering the program on a daily basis. Any queries on activities and

program components or delivery were found to be able to be answered promptly by Learning Connections Centre staff. Learning Connections Centre staff observed both Teachers delivering the program in their classroom and reported that Teachers had no difficulty in directing the program activities. It was noted that some classrooms lacked an appropriate flooring surface for rolling and crawling activities. Learning Connections Centre staff provided further information to teachers regarding use of suitable, cleanable vinyl surfaces that they recommend during training. Teachers noted that the daily implementation of the *Learning Connections School Program* could be accommodated with usual class scheduling, particularly if implemented in the early morning.

Instrument Feasibility

Teachers provided feedback via telephone and handwritten notes regarding the feasibility of using the measurement instruments with their class of Prep year children. Both teachers found that three measurement instruments (AIST-2, DAP, SPAT-R) were able to be easily administered to the whole class (cluster) of children at once in the classroom setting, which was easy to achieve if using the provided administration instructions. These three instruments were able to be administered in less than fifteen minutes (< 15min) per group. The remaining two instruments (BASC-2 TRS, EMCA) required individual administration, with the EMCA administered with each child in less than fifteen minutes (< 15min) per child in the classroom, while the BASC-2 TRS could be completed in less than fifteen minutes (<15min) per child and did not require sitting with the child to complete. Teachers recommended that the BASC-2 TRS completion be done from the teacher's working knowledge and background observation of each child, at a time suitable to the teacher, and not necessarily with the child present. Teachers suggested altering the administration instructions for the BASC-2 TRS forms to recommend completing these during quiet times for children, when children were engaged in other activities in the classroom, or when the whole class was undertaking a lesson with another specialty teacher, such as physical education or music. Administration instructions for all other instruments were deemed suitable.

All measurement instruments were noted to be suitable for the age group of children in the Prep year; however, concern was expressed by both teachers about the use of the AIST-2 instrument at the beginning of the Prep year as it requires writing of alphabet letters for which many children are unprepared at the commencement of their schooling. For this reason, teachers recommended not using this instrument until after at least one month of schooling. Scoring for all completed measurement instruments was undertaken by two members of the research team. Two instruments (EMCA, SPAT-R) were noted to be readily scored in less than two minutes per form, while two other instruments (DAP, AIST-2) required more consideration in scoring (2-5 min per form). The BASC-2 TRS was noted to require more complex scoring. Whilst computer scoring software is available for scoring calculation and interpretation for this test, data entry for each form is tedious unless scannable test

pages and an electronic scanner are used. This was noted for consideration in relation to feasibility of scoring for the BASC-2 TRS instrument for the two year trial (Phase 4), with recommendations made for the use of research assistance for this task.

Conclusion

The results from the Phase 5 pilot study provided evidence that Phase 6 was feasible using the planned sensory and motor intervention and measurement instruments. The *Learning Connections School Program* training and support were deemed suitable for teacher preparation and delivery of the program. The training was modified to emphasise the need for a suitable surface for rolling and crawling activities in each classroom and to provide recommendations for type of surface and cheap sourcing of such. The pilot study also provided evidence that the measurement instruments were suitable for children of the target age group for Phase 6, and for use at the commencement of the Prep year, with one recommendation to use the AIST-2 in late February or early March, after all children had had some exposure to learning to read and write alphabet letters. Administration ease, time and scoring was found to be highly feasible for the AIST-2, DAP, SPAT-R instruments, and quite feasible for the EMCA instrument, with the BASC-2 TRS less feasible. However, teachers noted that the BASC-2 TRS instrument was highly useful for teachers in considering each child's behaviour and development and so would be useful in helping to identify children who would benefit from enhanced learning opportunities within the pragmatic, usual school setting – the context for Phase 6. The research team was tasked with identifying a feasible way to score the BASC-2 TRS instrument across the two year randomised controlled trial of Phase 6, which included sourcing research assistance for data entry to enable computerised scoring. Results from this Phase 5 pilot study were used to inform and guide implementation of Phase 6, which is presented in Chapter Eight.

Chapter Eight Phase 6 – A Cluster Pragmatic Un-blinded Randomised Controlled Trial

Chapter Overview

A program of research was designed, with the main study, Phase 6, being the conduct of a pragmatic cluster randomised controlled trial. Previous chapters have reported on the planning and preparations for this trial, including the undertaking of a pilot study to pilot test the selected intervention and measurement instruments within the study setting. Since the pilot study determined that using the selected intervention and instruments was feasible for the large trial, preparations were noted to be complete. This chapter reports on the actual conduct and outcomes of the randomised controlled trial, presented in the form of a manuscript currently under review for publication in a Q1 journal: *American Journal of Occupational Therapy*, 2016 Scimago Journal Rankings: Impact Factor 0.710, 2/15 Health Professions – Occupational Therapy; 438/1806 Medicine – Medicine Miscellaneous. Manuscript ID Number: AJOT/2017/030478. Journal selection was based on the relevance of results to the ongoing dialogue about sensory and motor interventions being progressed by authors and journal editors.

Additional materials for the thesis reader to review related to this chapter include: *Appendix D Measurement Instruments* (pp. 157-169), *Appendix E Flow Diagram* for recruitment process and sampling details (p.170), *Appendix F Table 21 Prediction of study outcomes over time by baseline variables: cluster-adjusted Generalized Estimating Equations multivariable regressions (complete results)* (p.171) [Table 21 to be submitted as supplemental material to journal publication].

Please note the following: This chapter contains minor differences in spelling and other details due to the requirements of the USA journal where this was submitted for possible publication. The BASC-3 instrument referred to in Chapter Six was not available at the time of commencement of the trial detailed in this chapter. The reader will note that the previous edition, the BASC-2, was used in the trial and is referred to in this chapter; with the instrument review in Chapter Six having been since updated for publication. Table numbers have been altered from the submitted manuscript to suit the sequential numbering of tables in this thesis.

Title: Two-year cluster randomized-controlled trial of a school-group sensorimotor early intervention

Abstract

Objective: To examine the effects of a daily sensorimotor group intervention on behavior, development and early academic skills of 480 school children using a two year cluster randomized controlled trial.

Method: School clusters of children (age 4 – 5 years) were randomly allocated to intervention and control groups. Five measures of behavior, development and academic skills were administered at study commencement and end of the first and second years, with outcomes modelled using the Generalized Estimating Equations approach.

Results: Children in the intervention arm were significantly more likely to have higher scores on mathematics, compared to those in the control arm ($p < 0.05$). Despite a relatively large incidence-rate ratio, the crude effect of the intervention on mathematics scores was small (Cohen's $d = 0.21$). No other effects were demonstrated.

Conclusion: Despite being low-cost and easy-to-implement, it is difficult to recommend this group intervention when individualized occupational therapist-led interventions have more demonstrated effect.

Introduction

There is a concerning level of developmental vulnerability in children commencing formal schooling, as revealed by national USA and Australian surveys (Australian Government, 2016; Child and Adolescent Health Measurement Initiative, 2017). Thus there is impetus for school-based interventions that aim to enhance children's development and school-readiness (Case-Smith, Frolek Clark & Schlabach, 2013). While pediatric occupational therapists use a variety of interventions individually for early school-aged children with specific impairment (Reynolds et al., 2017), other commercialized group developmental interventions are widely implemented for the general school population (Stephenson, Carter, & Wheldall, 2007). There is evidence of effect for occupational-therapist led individualized interventions, but a lack of evidence regarding any developmental benefit of commercial group interventions for the general early school population.

When examining evidence level of interventions used with children, reviews have noted evidence of moderate intervention effect for Ayres®/classic *sensory integration* (SI) interventions for children with developmental and learning difficulties or Autism (e.g. Ottenbacher, 1982; Watling & Hauer, 2015) with high use in schools by occupational therapists for individual developmental concerns (May-Benson & Koomar, 2010). There is evidence of some developmental effect for interventions that are said to be *using a SI frame of reference* (Polatajko & Cantin, 2010) when compared to no treatment, with small effect size (e.g. Leong, Carter, & Stephenson, 2015; May-Benson & Koomar, 2010). There are inconclusive results for most other intervention types, such as *sensory-based*, *sensorimotor* (Polatajko & Cantin, 2010), and *perceptual-motor* interventions (Hoehn & Baumeister, 1994; Stephenson, Carter, & Wheldall, 2007), yet these are typically being implemented in the school setting by commercial operators, usually without occupational therapist oversight. Interventions are aimed at improving children's academic achievement, development and participation in daily school activities.

Methodological limitations in intervention trials have been noted in reviews, including: lack of control group and/or randomization; small sample sizes; short study duration; inconsistency in measurement outcomes; variable intervention dosage; and lack of fidelity to intervention (Lang et al., 2012; Leong, Carter, & Stephenson, 2015; May-Benson & Koomar, 2010). To enable accurate comparison and evidence appraisal, clear descriptions of interventions and research methods are required (Leong, Carter, & Stephenson, 2015; Polatakjo & Cantin, 2010; Reynolds et al., 2017; Watling & Hauer, 2015), together with details of dosage and fidelity measures used (Schaaf et al., 2014).

Set against this context, we designed a trial of a group intervention typically conducted in the school setting; using long study duration, relatively large sample size, control group, random cluster allocation, consistent measures, and following CONSORT guidelines (Campbell et al., 2012), to address previous research limitations. The aim of this study was to determine any effect from a daily group sensorimotor intervention, on behavior, development and early academic skills of very early school-age children in the school setting, by using a two year, un-blinded, cluster pragmatic randomized controlled trial.

Methods

Study Sample, Recruitment and Setting

Schools within one largely city-based district in southeast Queensland, Australia, with at least one class of children (aged 4 ½ - 5 ½ years) in the first year of formal schooling, were eligible to participate (n = 116). Recruitment was by email invitation sent to each principal. Schools volunteered for participation by principals (n = 46) were screened against the inclusion and exclusion criteria, with eight excluded because they already offered an intervention in the first school year. The remaining schools (n = 38) were randomized in an Excel database, and a randomizing number generator used to allocate ten schools (clusters) to each of the intervention and control groups (n = 20), with a total of 972 children in the first year of schooling. The University Human Research Ethics Committee (reference Q2010 56) granted ethical approval with agreement provided by the schools directorate. Formal consent to participate was sought from principals, class teachers and parents of children. Assent from the children was sought as a form of respect and engagement (Ungar, Joffe, & Kodish, 2006).

Intervention

This trial tested a commercially available intervention (Hawke, 2011), widely implemented throughout Australia and other countries. The intervention was selected due to its popular use in schools and because its elements and training are well described. It utilises a set of activities with the stated aim to improve children's behavior, development and academic success. The intervention can be implemented in the classroom and is categorized as *very low cost*, being well below The Education Endowment Foundation (2016) criteria of <AUD\$4000 (<USD\$3050) per class of 25 per year. It is classifiable as a *sensorimotor* intervention, taking an *impairment-orientation* approach, as delineated by Polatajko and Cantin (2010), anticipating children with learning/developmental impairments in any general school class. It is further classifiable as a caregiver-focused (teacher-mediated) intervention (Reynolds et al., 2017), though intervention activities are not individually planned and directed by an occupational therapist.

Teachers from all classes in the intervention group received two days of training from intervention-program operator staff, with phone support and two six-hour (2 x 6) follow-up visits each year to monitor fidelity to intervention. The whole class undertook the intervention daily, directed by the teacher in the classroom, with a dosage of 20 minutes each morning. Children took turns to use floor mats where needed to complete a set of activities, with booster activities used during the day when class energy was notably flagging. Specific intervention activities include *flip flops* (prone, head/leg/arm flexion, flop side-to-side), *commando crawl* (flip flops with forward movement), *cross pattern flip flops with commando crawl* (alternate flexion), *cross pattern walking*, *creeping* (kneeling rhythmical creep), and also vision- and vestibular- stimulating *enhancing* activities (adding of sight words, photos, visualization, balance, rhythm, timing and tapping to movements) and *self-calming* activities (humming, self-smoothing, stretching) (Hawke, 2011).

The control group undertook schooling as usual (pragmatic) with no specific intervention. As teachers and children knew whether or not they were undertaking the intervention, the trial was un-blinded. The trial commenced at the beginning of the school year in 2012. Measures were undertaken for both intervention and control groups at three time points; early in the first school year (baseline: March, 2012), repeated at the end of the first year (end Year 1: November, 2012), and again at the end of the second year (end Year 2: November, 2013), with the same children for the two years of the study.

Instruments

An evaluative review (Miles, Fulbrook, & Mainwaring-Mägi, 2016) considering age-suitability, technical adequacy (psychometric properties: norms, validity, reliability) and usability properties (time/ ease of administration, cost), identified four suitable instruments to measure behavior, development and early academic skills, in line with the aim of the intervention program. The *Astronaut Invented Spelling Test* (2nd ed.) (AIST-2) (Neilson, 2003a) and the *Sutherland Phonological Awareness Test – Revised* (SPAT-R) (Neilson, 2003b) were selected for their Australian norms, low cost and high usability to measure early language skills. These two instruments use a test form for children to complete, either by writing letters to spell words (AIST-2) or circling the picture that rhymes with the word spoken by the teacher (SPAT-R). The *Draw A Person* test (DAP) (Goodenough, 1926; Harris, 1963; Koppitz, 1968) met suitability requirements to measure cognition, with universal norms, use in international research, high usability and low cost. A piece of paper is provided to each child to draw a drawing of a person, such as themselves or a family member. The *Behavior Assessment System for Children* (2nd ed.) - *Teacher Rating Scales* (BASC-2 TRS 2-5 years; 6-11 years) with sub-categories: Externalizing Behavior (EB), Internalizing Behavior (IB), Behavioral Symptoms (BS), and Adaptive Skills (AS) (Reynolds & Kamphaus, 2004) was selected for its high technical adequacy and excellent computerised scoring, with its key purpose as a holistic measure of school

readiness, including behavioral, developmental milestone and functional measures. A standardized test form is used.

No suitable mathematics screening instrument was identified in our review, as noted by other reviewers (Mather & Abu-Hamour, 2013; Purpura, Reid, Eiland, & Baroody, 2015). Two sets of brief, multiple-proficiency measures, *Early Mathematics Concepts A* and *B* (EMCA, EMCB), were specifically developed for our study using standardized, validated and reliable mathematics computation concepts (dot sets, quantity array, counting) suitable for the two age groups, as recommended (Clarke, Hammond, & Gersten, 2014; Mather & Abu-Hamour, 2013; Purpura et al., 2015).

Other variables measured included gender; school location, either metropolitan or provincial (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2012); and the *school's Index of Community Socio-Educational Advantage* (ICSEA) grouping, an ecological scale computed for each school relating to parental education / occupation and school characteristics, including location and socio-economic background (ACARA, 2012).

Standardized instructions were provided for teachers to complete all measures, with four measures (AIST-2, DAP, EMCB, SPAT-R) undertaken as a whole of class activity. Teachers completed the EMCA individually with children, while the BASC-2 TRS was completed by teachers from observation undertaken at any time. Two independent researchers scored all measures using standardized scoring, except the BASC-2 TRS which was computer scored after data entry by a research assistant; two research assistants entered all scores into a statistics program (SPSS Version 23) for analysis.

Data analysis

Baseline characteristics of the sample were analysed using cluster-adjusted Chi-square tests for independence. The mean outcomes *within* groups for each measure for the intervention and control groups over time (comparing end Year 1 with baseline, and end Year 2 with end Year 1) were compared using the cluster-adjusted t test. Mean outcomes for each measure were compared *between* intervention and control groups over time (at three time points: baseline, end Year 1, end Year 2) using cluster-adjusted t tests.

Given that this study involved grouped measurement results from clusters of children within the same classrooms, some degree of correlation of the within-cluster measurement results is to be expected, due to the influence of the teacher, and of the teaching methods, types of learning activities and interactions experienced in the classroom (Ghisletta & Spini, 2004). Therefore, multivariable analysis was undertaken using the Generalized Estimating Equations (GEE) approach. This is a marginal model in which the effect of covariates on each study outcome is averaged over

individuals at each point in time and compared over time, to account for both clustering and time (Ghisletta & Spini, 2004). An exchangeable working covariance matrix was used (Hin & Wang, 2009) and standard errors were adjusted for correlation within schools using the cluster Huber-White sandwich estimator of variance (Freedman, 2006). Effect sizes for crude mean differences of the intervention and control arms within the repeated measures were estimated, as described by Morris (2008), for measures with significant differences between the groups (based on the multivariable models). Analyses were conducted using SPSS and Stata statistical program (Version 14, Stata-Corp), with significance set at a p value of < 0.05 .

Results

Sample

Following randomization, eleven of the 20 school principals completed the required steps to participate; with one principal withdrawing consent when relocated to another school prior to commencement of data collection. This left a sample of ten participant schools, of which six were in the intervention arm, and a total of 480 children (Figure 2). Cluster-adjusted Chi-square tests for independence showed no significant difference between intervention and control groups by gender ($p = 0.15$). There were significantly more children from metropolitan schools in both intervention and control groups ($p < 0.001$) (in a city-based district), and more schools with a higher socioeconomic/educational advantage (ICSEA) score in both intervention and control groups ($p = 0.006$). Importantly, no significant differences in mean test scores between intervention and control groups and sub-groups were found at baseline. A post-hoc sample size calculation based on mean scores showed this study had sufficient power to detect statistically significant differences in outcomes for three instruments (AIST-2, DAP, EMCA), but not for the BASC-2 TRS.

Study Outcomes

Within-group cluster-adjusted comparisons demonstrate an increase in score for all outcome measures over time (Table 18). The BASC TRS (EB) (Outcome 2) is significantly higher at end Year 2 compared to end Year 1 in the intervention arm (Row 2, in bold), with no significant difference for other outcomes. Between-group comparisons in each of the three trial points in time showed no statistically significant difference between the intervention and control groups at baseline on any outcome (Table 19, Baseline columns). At end Year 1, statistically significant differences between intervention and control groups were seen only for one mathematics (EMCA) instrument (Outcome 7a), with the intervention group showing a greater increase in mean scores [mean 38.7 (SD 4.0) versus 36.1 (SD 6.3), $p = 0.018$]. The intervention and control groups differed at end Year 2 in the BASC-2 TRS EB (Outcome 2) only, with mean scores being higher (worse outcome) in the control arm [mean 135.5 (SD 25.0) for intervention versus mean 147.4 (SD 26.1) for control, $p = 0.027$].

Table 18. Within group comparisons by study outcomes over time: Baseline, Year 1 and Year 2

	Intervention			Control		
	<u>Baseline</u>	<u>End Year 1</u>	<u>End Year 2</u>	<u>Baseline</u>	<u>End Year 1</u>	<u>End Year 2</u>
Outcome 1 AIST-2, mean (SD)	10.7 (9.4)	24.1 (11.5)	39.3 (9.7)	9.8 (9.7)	21.8 (12.3)	39.4 (8.3)
Outcome 2 BASC-2 TRS EB, mean (SD)	93.6 (15.5)	93.5 (14.8)	135.5 (25.0)*	96.2 (17.1)	96.0 (14.4)	147.4 (26.1)
Outcome 3 BASC-2 TRS IB, mean (SD)	137.4 (20.3)	138.2 (16.5)	141.4 (25.9)	137.1 (18.7)	146.2 (22.9)	150.3 (29.2)
Outcome 4 BASC-2 TRS BS, mean (SD)	280.8 (39.7)	280.3 (38.9)	273.4 (47.9)	281.5 (43.1)	282.9 (37.6)	290.9 (48.5)
Outcome 5 BASC-2 TRS AS, mean (SD)	157.6 (29.7)	164.9 (27.8)	274.1 (45.1)	162.9 (27.2)	172.0 (24.5)	267.0 (42.7)
Outcome 6 DAP, mean (SD)	9.7 (3.2)	11.5 (2.4)	11.9 (2.1)	9.9 (3.0)	11.2 (2.3)	11.6 (1.8)
Outcome 7a EMCA, mean (SD)	34.2 (7.7)	38.7 (4.0)	-	33.2 (7.5)	36.1 (6.3)	-
Outcome 7b EMCB, mean (SD)	-	3.4 (3.8)	3.8 (0.5)	-	3.2 (1.0)	3.7 (0.7)
Outcome 8 SPAT-R, mean (SD)	4.9 (2.0)	4.8 (1.2)	5.0 (0.1)	4.7 (1.8)	4.7 (1.4)	5.0 (0.3)
<p><i>Note.</i> Year 1 values were compared with Baseline; Year 2 values were compared with Year 1 using cluster adjusted <i>t</i> tests.</p> <p>* <i>p</i> value < 0.05</p> <p><i>Abbreviations:</i> AIST-2, Astronaut Invented Spelling Test 2nd ed.; BASC-2 TRS EB, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Externalizing Behaviors; BASC-2 TRS IB, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Internalizing Behaviors; BASC-2 TRS BS, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Behavioral Symptoms; BASC-2 TRS AS, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Adaptive Skills; DAP, Draw a Person; EMCA, Early Mathematics Concepts A; EMCB, Early Mathematics Concepts B; SPAT-R, Sutherland Phonological Awareness Test – Revised.</p>						

Table 19. Between group comparisons by study outcomes over time: Baseline, Year 1 and Year 2

	Baseline			End Year 1			End Year 2		
	<u>Intervention</u>	<u>Control</u>	<i>P</i> ¹	<u>Intervention</u>	<u>Control</u>	<i>P</i> ¹	<u>Intervention</u>	<u>Control</u>	<i>P</i> ¹
Outcome 1 AIST-2, mean (SD)	10.7 (9.4)	9.8 (9.7)	0.7	24.1 (11.5)	21.8 (12.3)	0.3	39.3 (9.7)	39.4 (8.3)	0.9
Outcome 2 BASC-2 TRS EB, mean (SD)	93.6 (15.5)	96.2 (17.1)	0.3	93.5 (14.8)	96.0 (14.4)	0.3	135.5 (25.0)	147.4 (26.1)	0.027
Outcome 3 BASC-2 TRS IB, mean (SD)	137.4 (20.3)	137.1 (18.7)	0.9	138.2 (16.5)	146.2 (22.9)	0.2	141.4 (25.9)	150.3 (29.2)	0.3
Outcome 4 BASC-2 TRS BS, mean (SD)	280.8 (39.7)	281.5 (43.1)	0.9	280.3 (38.9)	282.9 (37.6)	0.7	273.4 (47.9)	290.9 (48.5)	0.06
Outcome 5 BASC-2 TRS AS, mean (SD)	157.6 (29.7)	162.9 (27.2)	0.6	164.9 (27.8)	172.0 (24.5)	0.5	274.1 (45.1)	266.97 (42.7)	0.5
Outcome 6 DAP, mean (SD)	9.7 (3.2)	9.9 (3.0)	0.8	11.5 (2.4)	11.2 (2.3)	0.5	11.9 (2.1)	11.6 (1.8)	0.7
Outcome 7a EMCA, mean (SD)	34.2 (7.7)	33.2 (7.5)	0.5	38.7 (4.0)	36.1 (6.3)	0.018	-	-	-
Outcome 7b EMCB, mean (SD)	-	-	-	3.4 (3.8)	3.2 (1.0)	0.6	3.8 (0.5)	3.7 (0.7)	0.2
Outcome 8 SPAT-R, mean (SD)	4.9 (2.0)	4.7 (1.8)	0.6	4.8 (1.2)	4.7 (1.4)	0.7	5.0 (0.1)	5.0 (0.3)	0.2
<p><i>Note.</i> ¹ Between-group comparisons were analysed using cluster-adjusted <i>t</i> tests. Statistical significance was determined at <i>p</i> value = < 0.05.</p> <p><i>Abbreviations:</i> AIST-2, Astronaut Invented Spelling Test 2nd ed.; BASC-2 TRS EB, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Externalizing Behaviors; BASC-2 TRS IB, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Internalizing Behaviors; BASC-2 TRS BS, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Behavioral Symptoms; BASC-2 TRS AS, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Adaptive Skills; DAP, Draw a Person; EMCA, Early Mathematics Concepts A; EMCB, Early Mathematics Concepts B; SPAT-R, Sutherland Phonological Awareness Test – Revised.</p>									

Results of GEE regressions, modelled for each outcome and represented by respective β regression coefficient, Wald confidence intervals and significance (*p*), are shown in Table 20. Effects for each of the independent variables can be read across rows, while Visit in the final row represents the three study time points, baseline, end Year 1 and end Year 2. The only statistically significant difference between the intervention and control groups (Table 20, first row, in bold) is noted for both mathematics measurement outcomes; EMCA ($\beta = 1.36$, Wald = 0.37, 95% CI = 2.4, *p* = 0.012;

incidence-rate ratio of 3.9, 95% CI 1.45-11.02) and EMCB ($\beta = 0.30$, Wald = 0.07, 95% CI = 0.5, $p = 0.010$; incidence-rate ratio 1.35, 95% CI 1.07-1.65) (Model 7a, Model 7b), with higher (better) scores shown in the intervention arm. Despite the relatively large incidence-rate ratio, the crude effect of the intervention on the EMCA test was small (Cohen's $d = 0.21$).

In respect to independent variables, GEE regression modelling results show females (Table 20, second row) were significantly more likely to score higher than males for drawing (DAP, $\beta = 0.43$, Wald = 0.1, 95% CI = 0.8, $p = 0.019$) and phonological awareness (SPAT-R, $\beta = 0.14$, Wald = 0.06, 95% CI = 0.22, $p = 0.001$) and less likely to exhibit externalizing behaviors (e.g., bullying, aggression) (BASC-2 TRS EB). Time (Visit) (Table 20, final row) had a positive effect on six outcome variables; invented spelling (AIST-2, $\beta = 13.7$, Wald = 12.4, 95% CI = 5.2, $p < 0.001$); two aspects of behavioral development – externalizing behaviors and adaptive skills (BASC-2 TRS EB, $\beta = 17.7$, Wald = 13.2, 95% CI = 22.2, $p < 0.001$; BASC-2 TRS AS, $\beta = 44.7$, Wald = 36.3, 95% CI = 53.2, $p < 0.001$); drawing (DAP, $\beta = 1.1$, Wald = 0.48, 95% CI = 1.64, $p < 0.001$); and early mathematics skills (two measures: EMCA, $\beta = 4.19$, Wald = 3.59, 95% CI = 4.79, $p < 0.001$; EMCB, $\beta = 0.28$, Wald = 0.04, 95% CI = 0.53, $p = 0.023$). No effects were shown for school location (Table 20, third row) or for socioeconomic/ educational advantage score (ICSEA) (fourth row).

[Please note: For the thesis reader - Complete GEE results are shown in Appendix F - Table 21, p.171. However, no further relevant results are shown.]

Table 20. Prediction of individual study outcomes over time by baseline variables: cluster-adjusted Generalized Estimating Equations multivariable regressions

Model →	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7a	Model 7b	Model 8
Outcome variable ↓	AIST-2 β (Wald 95% CI), p	BASC-2 TRS EB β (Wald 95% CI), p	BASC-2 TRS IB β (Wald 95% CI), p	BASC-2 TRS BS β (Wald 95% CI), p	BASC-2 TRS AS β (Wald 95% CI), p	DAP β (Wald 95% CI), p	EMCA β (Wald 95% CI), p	EMCB β (Wald 95% CI), p	SPAT-R β (Wald 95% CI), p
Intervention vs control	-0.40 (-2.9,2.1), 0.8	-2.61 (-9.1,3.9), 0.4	-5.2 (-10.4, 0.05), 0.1	0.45 (-5.2,6.1), 0.9	-2.0 (-12.9, 8.9), 0.7	0.04 (-0.6, 0.7), 0.9	1.36 (0.37, 2.4), 0.012	0.30 (0.07, 0.5), 0.010	0.04 (-0.23, 0.31), 0.8
Female sex	0.39 (-1.2, 2.0), 0.6	-2.68 (-4.2,-1.1), 0.001	1.68 (-0.9,4.3), 0.2	-2.1 (-5.1,1.0), 0.2	2.1 (-1.3, 5.5), 0.2	0.43 (0.1, 0.8), 0.019	0.06 (-0.74, 0.86), 0.9	-0.01 (-0.17, 0.15), 0.9	0.14 (0.06, 0.22), 0.001
Provincial school (Metropolitan as reference)	0.43 (-2.0,2.8), 0.7	6.6 (-0.51, 13.7), 0.1	-1.2 (-10.8, 8.3), 0.8	-1.5 (-8.5, 5.4), 0.7	-1.9(-22.3, 18.4), 0.9	0.05 (-0.7,0.8), 0.9	-0.26 (-1.1, 0.6), 0.5	-0.05 (-0.37, 0.27), 0.8	-0.14 (-0.45, 0.16), 0.4
ICSEA (Socioeconomic- Educational advantage)	0.1 (-3.6,3.8), 0.9	4.0 (-1.92, 11.8), 0.2	1.2 (-3.3, 5.6), 0.6	1.3 (-3.1, 5.7), 0.6	-11.6 (-33.1, 9.9), 0.3	0.4 (-0.3,1.1), 0.3	0.33 (-0.59, 1.25), 0.5	-0.09 (-0.39, 0.22), 0.6	0.08 (-0.34, 0.49), 0.7
Visit ¹	13.7 (12.4,15.2), <0.001	17.7 (13.2, 22.2), <0.001	4.2 (-1.1,9.4), 0.1	1.6(-1.2,4.4), 0.3	44.7 (36.3, 53.2), <0.001	1.1 (0.48, 1.64), <0.001	4.19 (3.59, 4.79), <0.001	0.28 (0.04, 0.53), 0.023	0.14 (-0.17, 0.45), 0.4

Note. ¹ Visit constituted of the three study points in time: Baseline, Year 1, and Year 2

Abbreviations: AIST-2, Astronaut Invented Spelling Test 2nd ed.; BASC-2 TRS EB, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Externalizing Behaviors; BASC-2 TRS IB, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Internalizing Behaviors; BASC-2 TRS BS, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Behavioral Symptoms; BASC-2 TRS AS, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Adaptive Skills; DAP, Draw a Person; EMCA, Early Mathematics Concepts A; EMCB, Early Mathematics Concepts B; SPAT-R, Sutherland Phonological Awareness Test – Revised.

Discussion

Multivariable GEE analyses show that, compared to children in the control arm, those in the intervention arm were significantly more likely to score higher in mathematical tests at both the end of study Year 1 and Year 2; however, effect size is small. This pragmatic study fits with previous reviews that have found a small or limited effect for interventions when compared to no treatment (Leong, Carter, & Stephenson, 2015a; May-Benson & Koomar, 2010). When comparing mean scores in this study, the absolute difference between intervention and control groups on the EMCA was 2.6 points (6.5%) at end Year 1; and, on the EMCB, 0.1 points (2%) at end Year 1 and 0.2 points (4%) at end Year 2. Given the limitations of our non-standardized measurement instrument, the practical importance of such small differences needs to be considered by education professionals.

Nonetheless, effect sizes of between 0.19 and 0.26 for education interventions are considered moderate by The Education Endowment Foundation (2016) with three months impact; meaning children that undertake such interventions could gain three months developmental improvement from an intervention with this effect size.

The relationship between early and later mathematics proficiency is stronger than for reading proficiency (Anders et al., 2012), with early mathematics ability in kindergarten a better predictor of later reading achievement than early literacy skills (Clements, Sarama, & Germeroth, 2016). So, any intervention that can enhance early mathematics skills is important (Anders et al., 2012; Clarke et al., 2014). Mathematic achievement is strongly related to visual-motor/visual-spatial integration skills (e.g. Carlson, Rowe & Curby, 2013; Clements et al., 2016; Son & Meisels, 2006), so it is possible that intervention effect on mathematics in this trial relates to vision-enhancing activities undertaken concurrently with motor activities in the intervention studied. Future intervention trials should measure visual-motor skills and sensory-processing at study commencement and completion.

Two measures of school socioeconomic/educational advantage, ICSEA and location, were shown to have no significant effect on any outcome measures in GEE modelling. Other studies have shown significance in relation to socioeconomic status (e.g. Anders et al., 2012).

GEE modelling results demonstrate considerable effect over time on six outcome variables. This likely reflects age-related improvements in test scores. In a review of eight SI studies, Hoehn and Baumeister (1994) concluded the source of improvements to be maturation. Age has been demonstrated as the largest predictor of scores on tests of academic achievement (Anders et al., 2012). This does not relate to intervention effect.

Limitations

As with other studies of this type of intervention, this study has some limitations. Teachers, children and parents were not blinded to which group (control or intervention) they were assigned. While the mathematics instrument used was not standardized through testing, the early mathematics concepts incorporated have been standardized and tested for validity and reliability for the age groups of children (Clarke, Hammond, & Gersten, 2014; Mather & Abu-Hamour, 2013; Purpura et al., 2015). It is, nonetheless, important to exercise caution in inferring a causal relationship between the intervention and mathematics.

This study was not compared to an alternate or placebo intervention, as recommended by some reviewers (e.g. May-Benson & Koomar, 2010; Watling & Hauer, 2015). However, there is a general call for pragmatic studies which compare an intervention to 'usual conditions' (e.g. usual schooling), under flexible conditions (Zwarenstein & Treweek, 2009).

Direct measurement of functional behavioral and developmental outcomes related to the theoretical basis of an intervention is a priority (Leong, Carter, & Stephenson, 2015a; May-Benson & Koomar, 2010). This means that the instruments used may not have measured what the program is actually affecting (Lane & Schaaf, 2010) despite the BASC-2 TRS being a comprehensive measure of functional behavior and development that could be expected to show change linked to intervention effect; though this study lacked power for this instrument.

Since the majority of schools were located in a metropolitan area, the results of this trial may be less generalizable to schools in provincial/rural locations; while comparison to another district may have reduced any clustering effects.

Implications for Occupational Therapy Practice

Study findings have the following implications for occupational therapy practice:

- Occupational therapist-led individualized interventions for children with learning or developmental disorders/conditions have demonstrated effect.
- Group sensorimotor interventions without occupational therapist oversight in school settings cannot be recommended due to limited evidence of effect.
- Further research is needed to determine if group intervention effect can be enhanced with oversight by an occupational therapist.

Conclusion

This study demonstrates evidence of statistically significant improvement, but with a small effect size, from a group sensorimotor intervention on early mathematics skills in early school-age children. However, no other behavioral, developmental or academic learning outcomes from intervention were seen. This type of commercial group intervention cannot be recommended above individualized occupational therapist-led interventions or other early education interventions with more proven effect, particularly where school resourcing is limited. Future research should specifically examine any effect of such interventions on children's behavior and development with suitable power for the measurement instruments used.

The final chapter, Chapter Nine, fits the results from this research trial within the whole program of research and within the wider literature.

Chapter Nine Discussion and Conclusions

Introduction/Overview

A program of research has been undertaken to examine the effect of sensory and motor interventions on very early school-age children's development, behaviour and early academic skills; with a particular research focus on one specific intervention, *The Learning Connections School Program*. This chapter situates the findings from this program of research within the broader literature and highlights the value of the research program and results in contributing new knowledge to this topic area. Strengths and limitations of the research are discussed in the context of the type of research previously undertaken in this field of research and practice. Finally, recommendations are made for future research and practice, with these drawn from the experience of reviewing and researching in this field of specialty.

Value of this research

Level of Evidence

This program of research utilised an experimental design, collecting and analysing quantitative data, which is considered to be the highest level of design for studying effectiveness (Joanna Briggs Institute, 2014). The main research method used in this program of research was a cluster, pragmatic randomised controlled trial. Randomised controlled trials provide Level 1.c evidence for effectiveness of interventions (Joanna Briggs Institute, 2014), and are considered to be the 'gold standard' (Schultz, Altman & Moher, 2010) of research evidence for a single study to determine the effectiveness of practice interventions (Solomon, Cavanaugh & Draine, 2009).

The results of the randomised controlled trial have added to the evidence of effect for sensory and motor interventions, in particular those that use a group sensorimotor approach, such as *The Learning Connections School Program*. The results demonstrate evidence of statistically significant improvement from this intervention after the first year, with 4 – 7 year old children in the intervention arm being more likely to have higher scores for early mathematics concepts skills than those in the control arm ($p < 0.05$), albeit with a relatively small effect size (Cohen's $d = 0.21$). This effect is further reduced after the second year of intervention. On all other measures, no statistically significant effect was seen for the intervention. Given the limitations of a pragmatic study and clustering effect (Campbell, Piaggio, Elbourne, & Altman, 2012), the limitations of the non-standardised mathematics instrument, and that this study is underpowered for some measures used, it may be that such an intervention can effect a significant change but that this was unable to be demonstrated in this study. It may also be that this type of intervention has more effect at an earlier age in childhood, since effect was reduced in the second year of this study. Conversely, it is most

likely that this study adds to the current evidence that there is limited or negligible evidence of effect from such interventions. This level of evidence needs to be considered by health and education professionals in practical terms of resourcing. While these interventions may be very low cost, easy-to-implement and require a relatively small investment of time, implementing these interventions may take funding and time away from other interventions with proven effect.

Strengths

This program of research specifically addressed the stated research problem: *Is there evidence of any beneficial effect for young children from the implementation of sensory and motor interventions in mainstream early schooling?* This problem was addressed by answering the research question derived from the research problem: *What is the evidence of effect from sensory and motor interventions on the development, behaviour, and early academic skills of very young school-age children in the school setting?* As determined from this program of research, there is evidence of some effect of such interventions. The six phases of research addressed the stated research aim: *To examine the evidence of effect from sensory and motor interventions implemented in the school setting for young children in the transition to formal schooling.* Each research objective was specifically addressed in the following way:

- *Identifying the nature and extent of sensory and motor intervention use with the identified school district context.*
 - A scoping study, undertaken in Phase 1, determined there is widespread use of interventions in the school diocese study setting, as detailed in Chapter Two.
- *Appraising the literature for research evidence of the effect of sensory and motor interventions and identify any gap in research evidence related to intervention use in the school setting.*
 - A systematic review of literature, undertaken in Phase 2, identified that the evidence for sensory and motor intervention effect is generally mixed and inconclusive and that the program of research is justified, as detailed in Chapter Three.
- *Designing a program of research to address the research question and any identified gap in research evidence.*
 - A program of research was undertaken to address this gap in research evidence, with Phase 3 undertaken to identify a suitable intervention to trial and Phase 4 undertaken to identify suitable instruments to use in such a trial, as detailed in Chapters Five and Six.

- Phase 5, reported in Chapter Seven, pilot tested the feasibility of using these instruments and intervention in a large research trial, while Phase 6 saw the conduct of a randomised controlled trial using the selected intervention and measurement instruments, as detailed in Chapter Eight, with methods justified in Chapter Four.

The randomised controlled trial conducted in this study adhered closely to the conduct and reporting of cluster and pragmatic trials, as listed in the Consolidated Standards of Reporting Trials (CONSORT) checklists for cluster randomised controlled trials (Campbell, Piaggio, Elbourne & Altman, 2012) [Appendix A pp. 146-150] and for pragmatic randomised controlled trials (Zwarenstein et al., 2008) [Appendix B pp. 151-153]. It is critical to report how well each trial followed the guidelines to better describe applicability and generalisability of the study to other settings and groups (Campbell, Elbourne, & Altman, 2004).

This trial addressed some methodological limitations noted in other research trials of sensory and motor interventions. A relatively large sample size was used for a longer duration than most studies. A control group was used and school clusters were randomly allocated to *intervention* or *no intervention* arms of the study. Schools were randomly selected to participate in the study, after school principals initially volunteered the participation of the school. Teachers were fully informed of the study and trained in the use of the intervention. Follow-up ensured fidelity to intervention. Standardised instructions were provided for use with measurement instruments. Four standardised instruments were selected for use in the study. Both intervention and instruments were pilot-tested for feasibility and suitability within the school setting. Measures were scored by the researchers, not the teachers, and only teachers knew the identity of the children in the trial.

Use of the Generalized Estimating Equations modelling approach is of particular strength with a cluster trial, as the model adjusts for the effect of both clustering and time. This takes data analysis a step beyond most other research trials of sensory and motor interventions. As noted from the reviews reported in Chapters Three and Five, generally more simplified statistical analysis has been used in previous trials, with some use of multiple regression. Accounting for clustering presents a more robust source of evidence for this trial. Use of traditional regression without flexible modelling for intra-cluster correlation could result in Type I errors (Muth et al., 2016).

The Generalized Estimating Equations modelling approach is particularly suitable for longitudinal data with repeated measures; in order to account for difference in measurement outcomes (mean scores) over time (Muth et al., 2016). The greatest disadvantage of traditional analysis for this type of data is the assumption of a linear relationship between the outcome measures and time, assuming

equal variance between measures, which can lead to inflated Type I errors (Muth et al., 2016; Twisk, 2003). This is not the case for Generalized Estimating Equations modelling, which takes account of clustering effect and the effect of time, using marginal modelling that estimates the average response of the population rather than prediction of response or effect (Twisk, 2003). As well, Generalized Estimating Equations modelling is able to accommodate missing data (Muth et al., 2016). Traditional regression modelling methods tend to diminish data sets by performing list-wise deletion of any individual with incomplete data records (Muth et al., 2016). As with data set in this study, some children were absent from school on the day when an instrument measure was implemented for the class; meaning that outcome measure would be missing from their case in the study database. Where data are missing at random, Generalized Estimating Equations modelling uses a sandwich variance estimator approach, to reduce standard errors relating to missing data (Twisk, 2003). The use of a Generalized Estimating Equations modelling approach enabled us to demonstrate the effect of time as the main source of increased mean scores in this study. This means that developmental maturation was the main source of improvements in children's developmental, behavioural and academic learning outcomes.

In relation to the hypotheses for this randomised controlled trial, the alternate hypothesis was supported - that the means are not equal across the groups. Nonetheless, this was only able to be demonstrated for one measurement outcome. This randomised controlled trial has been classified correctly with regard to hypothesis, that of superiority, whereby the intervention (the sensory and motor intervention) was hypothesised as superior to usual conditions (no sensory and motor intervention) in a statistically significant way (Piaggio et al., 2012). It has been demonstrated that using this sensory and motor intervention would be better than not using it for children's early mathematic skills; though caution is expressed regarding the causality and strength of this relationship and that no effect was seen for other measures of development, behaviour and early academic skills. This study and trial has highlighted why there is widespread use of sensory and motor interventions in the school setting, though it has justified this to a very limited degree. Further research building on the outcomes of this study, appropriately powered with a larger sample, and implemented with an earlier age group of children, would progress the level of evidence.

Limitations

As with any research trial, there are a number of limitations to this research. There was no blinding of participants, as previously explained in Chapter Four. Dosage of intervention was not closely monitored, which fits with a pragmatic trial. This study could have used a placebo or alternate intervention for comparison in a randomised controlled trial, as recommended by reviewers (e.g. Lang et al., 2012; Leong, Carter, & Stephenson, 2015a; Leong, Carter, & Stephenson, 2015b);

however, this pragmatic trial, which compared the intervention to usual schooling, is an accepted practical trial method, providing this is reported (Thorpe et al., 2009; Zwarenstein & Treweek, 2009).

An important limitation is that the measurement instrument used for measuring early mathematics skills in very early school-age children was not a standardised instrument. As noted from a review of instruments, no standardised instrument suitable for the age groups of children in the study was identified. The instruments devised did use standardised, valid and reliable early mathematical concepts suitable for the age groups of children in the study, in a manner recommended by specialists in this field of education. It is important to exercise caution in regard to inferring a causal relationship between the intervention and mathematics (Tabachnick & Fidell, 2013) until further studies are undertaken.

In regards to recruitment, of the 38 eligible schools (of 46) where the principal volunteered for their school to participate in this study, only ten principals ultimately provided consent for their school to be part of this trial. This resulted in a smaller than planned sample size, with more schools in the intervention arm than the control arm. This is beyond the control of the researcher, as all efforts were made toward effective recruitment in order to commence the study at the beginning of the 2012 school year. A larger sample, more evenly balanced between intervention and control arms, may have provided stronger evidence of effect for intervention, given that clustered analysis reduces power if there are not sufficient clusters ((Campbell, Piaggio, Elbourne, & Altman, 2012; Hedge, 2011; Wears, 2002). Nonetheless, retrospective power of sample size calculations (reported in Chapter Four) demonstrated the sample to be large enough to detect statistically significant differences in three instruments (AIST-2, DAP, EMCA). The sample size (> 50000) required for one other comprehensive behavioural and developmental instrument (BASC-2 TRS IB) was unachievable in a small, localised study. In this study, the sample may have been too homogeneous, given the likelihood of clustering effect across one school district, in this case an Archdiocese, due to the same policies and requirements across all schools within the diocese. Further studies comparing clusters from different districts may be relevant for furthering evidence.

A further limitation pertains to the age of children experiencing an 'early' intervention. There is strong recommendation from within the literature that intervention should occur much earlier than school age (e.g. Case-Smith, Frolek Clark, & Schlabach, 2013; Frolek Clark & Schlabach, 2013), so it is possible that more effect may be noted from sensory and motor interventions implemented in kindergarten or perhaps even earlier in a child's life. This recommendation fits with the results from this study where more effect was noted in the first year of the study with the children when they were younger. Future research may be well placed to examine earlier larger effect of intervention.

Anecdotal evidence

During the course of this program of research, teachers provided anecdotal feedback to the researchers and to staff from The Learning Connections Centre. This feedback related to their observations noted from prior to the commencement of the randomised controlled trial to the end of the first or second year (not every teacher was involved for the two years). Teachers from clusters in the intervention arm noted that children in their classes were not well prepared for schooling at the beginning of the Prep Year. Many children had diagnosed conditions, such as autism or attention deficit hyperactivity disorder, or recognised developmental delay or noted learning difficulties. Indeed, teachers noted that these problems were becoming more prevalent with each school year commencement. In other words, school readiness was becoming less apparent each year, with classes being disrupted by children who could not settle or sit still at their desks. Teachers noted that there was a marked difference, an improvement, to school readiness once the *Learning Connections School Program* was commenced in their class. Ten teachers wrote personal emails and notes to the research candidate to comment on the apparent improvement in settled behaviour that they observed in their classes during the first few months of the study. Five other teachers verbally expressed these observations in phone calls and personal conversations. Therefore, this may be an important aspect of functional outcomes to be assessed in future research.

Relationship of results to other literature and theoretical framework

The evidence from this trial fits with several previous research studies of sensory and motor interventions (reviewed in Chapter Five), for which, many have shown some/limited statistically significant effects among mostly non-significant effects (Callcott, 2008; McPhillips, Hepper & Mulhern, 2000; Paul et al., 2003; Peens, Pienaar, Nienaber, 2008; Pienaar, van Rensburg & Smit, 2011; The Learning Connections Centre, 2000). A mixed result also fits with conclusions drawn from various meta-analyses and systematic reviews of research evidence for sensory and motor interventions (reviewed in Chapter Three) (Armstrong, 2012; Baranek, 2002; Blauw-Hospers & Hadders-Algra, 2005; Case-Smith, Frolek Clark & Schlabach, 2013; Frolek Clark & Schlabach, 2013; Griffer, 1999; Krieder, Bendixen, Huang & Lim, 2014; Lang et al., 2012; Mauer, 1999; Patel, 2005; Polatajko & Cantin, 2010; Tinderholt Myrhaug, Østensjø, Larun, Odgaard-Jensen, & Jahnsen, 2014; Watling et al., 1999; Watling & Hauer, 2015; Weaver, 2015).

In regard to sensory and motor interventions that use a sensory integration framework of reference, (discussed in Chapter One and reviewed in Chapter Three) the results of this research trial fit with results from two systematic reviews (May-Benson & Koomar, 2010; Polatajko & Cantin, 2010). These

reviewers determined that there was evidence that this approach to intervention may have some positive outcomes for children, and that intervention is shown to have more effect than no treatment or compared to nothing (May-Benson & Koomar, 2010), which fits with results from this trial. For sensory and motor interventions using a mixed approach to intervention, such as a sensorimotor approach (discussed in Chapter One) like the *Learning Connections School Program*, reviewers found that children with impairments, such as sensory processing disorder, may benefit from these interventions; though the results from studies are still mixed and inconclusive (Polatajko & Cantin, 2010; Watling & Hauer, 2015) (presented in Chapter Three). This fits with anecdotal feedback from teachers, presenting a reason why these interventions are widely implemented in schools, as established in Chapter One and in the findings of the scoping study, presented in Chapter Two.

Some evidence has been provided, from this trial, that there is some likelihood that children in mainstream schooling may show an improvement in their early mathematics skills as a result of participation in a mixed sensorimotor approach sensory and motor intervention. These results fit somewhat with Parham's (1998) study of sensory integration, where a significant relationship was found between mathematics and sensory integration scores for 6 – 8 year old children with and without learning difficulties; however, a direct sensory-processing measure was used in Parham's study. As with research by Callcott, Hammond and Hill (2015), who studied a sensory and motor intervention synergistically with a phonological awareness intervention, in order to more fully understand the benefit of this type of intervention, studying this intervention simultaneously, comparatively and synergistically with a specific mathematics skill intervention would prove of interest in advancing evidence for this type of sensory and motor intervention. A multivariable analysis by Duncan et al. (2007), determined that early mathematic concepts, such as knowledge of numbers and ordinality were the most powerful predictors of later learning. Therefore, it is worth pursuing this possible intervention effect in future research.

There is no evidence advanced from this study in regard to the effect of intervention for children with specific impairments, as this was not the focus of this research. This study did not have sufficient power to detect a statistically significant effect for the BASC-2 TRS, which is the main measure of children's development and behaviour and, subsequently, of any impairments of such in this study. Nonetheless, as was previously established in Chapter One, many children in mainstream schooling will experience some type of impairment and, anecdotally, the teachers reported so for this study. So it is still possible that a sensory and motor intervention using a mixed sensorimotor approach may have some effect on improving or reducing impairments for children in mainstream

schooling. A research study replicating the methods used here, but with sufficient power for the BASC-2 TRS instrument or other appropriate impairment measure may determine such evidence.

Given the level of developmental vulnerability with which children present to school, as evidenced by results from the 2015 national Australian Early Development Census (Australian Government, 2016) (detailed in Chapter One), further research into early interventions, such as the one studied here, is recommended. Particular focus for future research should be directed toward the transition to formal schooling, as many children are unprepared for the requirements of school (Fox & Geddes, 2016). It would be appropriate to use specific measures of school-readiness, such as the ability to sit and settle, since these are the developmental behaviours expected of very early school-age children (Fox & Geddes, 2016; Kettler et al., 2014). While the BASC-2 TRS tool used in this study is a very comprehensive developmental and behavioural assessment measure, with high psychometric properties, it may be more appropriate to use measures with higher usability properties, as detailed in Chapter Six, in any future research.

Implications for Health and Education Professionals

This program of research has implications for various groups of health and education professionals.

Child Health / School Health Nurses

This research helps to inform nurses working with the school setting, or those working with children and families in clinic or home settings, about this type of early intervention. A background literature review confirms that children develop at different rates, with some requiring early intervention to address developmental vulnerability and enhance developmental progress. Given the evidence of some effect of this specific intervention on children's academic achievement, specifically mathematics skills achievement, albeit with small effect, together with the anecdotal support from teachers for enhanced school-readiness among Prep year children following intervention, school health nurses could cautiously advise parents/caregivers and education professionals that such an intervention may be worth implementing in the school setting. The caution applied is that funding and resources would be better directed to interventions with more proven effect (Stephenson, Carter, & Wheldall, 2007). So, any recommendation would be for extra intervention, rather than for using this type of intervention as a replacement intervention. This would also be time-dependent, i.e. if there is time in the school day or before or after school for such an intervention, without encroaching on usual curriculum.

There was no obvious effect on children's behavioural and developmental outcomes in this research trial, as assessed by teachers completing the BASC-2 TRS, although this study was underpowered for

studying effect from this outcome. There was noted anecdotal support from teachers for this intervention in enhancing school-readiness in Prep Year children. So, it is not clear if child health nurses should recommend such an intervention, based on this research. However, given that this intervention uses activities that promote physical activity and fun, there may be benefits beyond those tested in this program of research, especially for young children prior to or just commencing formal schooling. For developmentally vulnerable children, this type of early intervention might be recommended to parents for their children in a community setting, as an extra intervention, rather than as a replacement for any schooling interventions with more proven benefit. This would be especially so for younger children displaying signs of developmental delay, as noted by child health nurses and other health care professionals.

Occupational Therapists

As previously noted, sensory integration interventions are widely implemented by occupational therapists. However, these interventions are generally implemented individually for children with specific impairments. As identified from literature review, there is evidence of moderate effect of such interventions (Watling & Hauer, 2015). It is therefore clear that occupational therapists would not recommend an early intervention, such as the one tested, instead of an individualised approach to intervention.

Education Professionals

Since early intervention is critical within the education setting (Kettler et al., 2014), education professionals seek programs that are low-cost and easy-to-implement. The intervention trialled in this research program meets those criteria, and, with evidence noted of some effect from intervention, as well as positive anecdotal feedback from teachers, education professionals could cautiously consider using this intervention in the early school setting. This would be in particular for a setting with a play-based curriculum, such as kindergarten or Prep, and where a focus on mathematics skills achievement would be of benefit. It may also be of benefit where impairment is evident for children within a particular class. However, this intervention should not be recommended above other interventions with more proven effect, particularly where resourcing is limited (Stephenson, Carter, & Wheldall, 2007). This information has implications for teacher education and training. It is important for education professionals to improve their knowledge in this area and understand the limited evidence of effect for sensory and motor interventions and to be judicious in the selection and implementation of such interventions.

A particular strength of this program of research for education professionals is a critical review of measurement instruments suitable for very early school-age children, undertaken as Phase 4 and reported in Chapter Six. This published paper presents a method of instrument selection for this age group of children by education professionals for use in the school setting. Education professionals have the option to select instruments based on their reported psychometric properties, focusing on technical adequacy, or on usability properties to focus on the feasibility of instrument use in the school setting. Alternatively, looking for instruments with a blend of both properties that are most suitable for the purpose of their use within the particular school setting would be the recommendation from this program of research.

Exercise Scientists and Physical Education Professionals

The intervention trialled in this program of research is classifiable in the impairment-orientation approach to intervention, as clarified by Polatajko and Cantin (2010). Interventions used by exercise scientists and physical education professionals tend to focus on a performance-orientation approach to intervention. Therefore, this intervention may be of limited use for exercise scientists.

Nonetheless, as it does present an opportunity for group activity, it may be use for exercise scientists or physical education professionals working with groups of children in the school setting or an associated capacity. It should not be used as a replacement for usual physical education classes and sporting activities with proven benefit, but could supplement such classes.

Recommendations

From this program of research, a number of recommendations can be made for practice and further research. These include the following:

- Publication of a systematic review appraising research evidence of effect of sensory and motor interventions specifically in the early school setting is required to address an identified gap in the literature.
- Further research of sensory and motor interventions could use an alternate intervention for comparison, as recommended (Hillier, 2007; Leong, Carter, & Stephenson, 2015a), though this would not be a pragmatic trial like the one undertaken here.
- Consideration could be given to examining the effects of a sensory motor intervention for children with a diagnosed learning or behavioural difficulty, and to using instruments that specifically measure more functional developmental and behavioural outcomes in future research, such as ones that initially measure retained primitive reflexes, as recommended (e.g. Callcott 2008; Callcott, Hammond, & Hill, 2015), or measure sensory processing (e.g. Lane & Schaaf, 2010; Leong, Carter, & Stephenson, 2015a; May-Benson & Koomar, 2010;

Watling & Hauer, 2015), and/or school-readiness attributes as recommended (e.g. Kettler et al., 2014), in an effort to determine the effects that a sensory and motor intervention has on young children's behaviour and development.

- Given that there is great anecdotal support for sensory and motor interventions, a qualitative study exploring the nature of this support and any evidentiary data for such support could highlight functional outcomes or other benefits not yet well recognised for such interventions.
- Increased funding would enable a future research study to better monitor adherence to treatment, treatment fidelity and dosing, as recommended (Roley et al., 2007; Schaaf et al., 2014).
- Further funding of future research would also enable independent assessment of children for impairments to replace the teacher-assessed BASC-2 TRS instrument assessment used in this study, or to recruit a larger sample size, given the large sample size required to have the power to determine a statistically significant effect from this instrument.

Conclusion

The overall aim of this program of research was to determine the effect of sensory and motor interventions on young children's development, behaviour and early academic skills. This aim was achieved by systematically searching and appraising the existing literature, determining that the evidence for effect was mixed. It was identified that part of the reason for this mixed result was due to the methodological limitations in previous research trials designed to determine evidence for intervention effect. Furthermore, this area of literature was found to be characterised by heterogeneity, with unlike interventions being compared, thereby lacking the quality and quantity of research evidence for specific interventions. Subsequently, the design of a research trial provided evidence for limited effect of one such intervention on a likely improvement in early mathematics skills in very early school-age children.

Following on from the recommendations produced by this research study, a program of post-doctoral research is planned to continue on with the development of research evidence in this field. Future research would be well placed to examine intervention effect on other functional outcomes and less well-recognised benefits of sensory and motor interventions. A program of systematic review, qualitative and quantitative research, potentially using a mixed methods design, would be well placed to address this gap in research evidence.

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Appendices

Appendix A. CONSORT 2010 checklist of information to include when reporting a cluster randomised trial

Section/Topic	Item No	Standard Checklist item	Extension for cluster designs	Page No *
Title and abstract				
	1a	Identification as a randomised trial in the title	Identification as a cluster randomised trial in the title	Thesis title page; Ch.8 p.109
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	See table 2	Ch.8 results paper abstract pp.109
Introduction				
Background and objectives	2a	Scientific background and explanation of rationale	Rationale for using a cluster design	Ch.4 p.49; Ch.8 p.113
	2b	Specific objectives or hypotheses	Whether objectives pertain to the cluster level, the individual participant level or both	Ch.4 p.49; Ch.8 aim pp.111
Methods				
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	Definition of cluster and description of how the design features apply to the clusters	Ch.4 p.49, 53-56; Ch.8 p.111, 113
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons		N/A
Participants	4a	Eligibility criteria for participants	Eligibility criteria for clusters	Ch.4 p.49; Ch.8 p.111
	4b	Settings and locations where the data were collected		Ch.1 p.18; Ch.2 p.23; Ch.4 p.52; Ch.8 p.111
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	Whether interventions pertain to the cluster level, the individual participant level or both	Ch.4 p.49, 52, 56; Ch.8 p.111, 113
Outcomes	6a	Completely defined pre-specified primary and	Whether outcome measures pertain to the cluster level, the	Ch.4 pp.57-60; Ch.8 pp.113-119

		secondary outcome measures, including how and when they were assessed	individual participant level or both	
	6b	Any changes to trial outcomes after the trial commenced, with reasons		N/A
Sample size	7a	How sample size was determined	Method of calculation, number of clusters(s) (and whether equal or unequal cluster sizes are assumed), cluster size, a coefficient of intracluster correlation (ICC or <i>k</i>), and an indication of its uncertainty	Ch.4 pp.53-56; Ch.8 p.114
	7b	When applicable, explanation of any interim analyses and stopping guidelines		N/A
Randomisation:				
Sequence generation	8a	Method used to generate the random allocation sequence		Ch.4 p.49; Ch.8 p.111; Flow Diagram p.170
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	Details of stratification or matching if used	Ch.4 p.49
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	Specification that allocation was based on clusters rather than individuals and whether allocation concealment (if any) was at the cluster level, the individual participant level or both	Ch.4 p.49; Ch.8 p.111
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	Replace by 10a, 10b and 10c	See below
	10a		Who generated the random allocation sequence, who enrolled clusters, and who	Ch.4 p.49; Ch.8 p.111

			assigned clusters to interventions	
	10b		Mechanism by which individual participants were included in clusters for the purposes of the trial (such as complete enumeration, random sampling)	Pre-existing clusters Ch.4 p.49; Ch.8 p.111
	10c		From whom consent was sought (representatives of the cluster, or individual cluster members, or both), and whether consent was sought before or after randomisation	Ch.4 p.49, 60; Ch.8 p.111
Blinding				
	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how		N/A
	11b	If relevant, description of the similarity of interventions		N/A
Statistical methods				
	12a	Statistical methods used to compare groups for primary and secondary outcomes	How clustering was taken into account	Ch.4, p.43, pp.57-60; Ch.8 p.106
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses		Ch.4, p.40, pp.53-56; Ch.8 p.111
Results				
Participant flow (a diagram is strongly recommended)				
	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	For each group, the numbers of clusters that were randomly assigned, received intended treatment, and were analysed for the primary outcome	Flow diagram p.170; Ch.8 p.111, 114
	13b	For each group, losses and exclusions after randomisation, together with reasons	For each group, losses and exclusions for both clusters and individual cluster members	Flow diagram p.170; Ch.8 p.114, 126

Recruitment	14a	Dates defining the periods of recruitment and follow-up		Flow diagram p.170; Ch.8 p.112
	14b	Why the trial ended or was stopped		Trial completed, Ch.8 p.112
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Baseline characteristics for the individual and cluster levels as applicable for each group	Ch.8 pp.114-116, Tables 18,19,20
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	For each group, number of clusters included in each analysis	Flow diagram p.170; Ch.8 p.114
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	Results at the individual or cluster level as applicable and a coefficient of intracluster correlation (ICC or k) for each primary outcome	Ch.8 pp.114-116
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended		Ch.8 p.116
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory		Ch.8 pp.114-116
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)		N/A
Discussion				
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses		Ch.8 pp.120; Ch.9 pp.125-129
Generalisability	21	Generalisability (external	Generalisability to clusters and/or	Ch.8 p.120; Ch.9

		validity, applicability) of the trial findings	individual participants (as relevant)	p.125-126
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence		Ch.8. pp.116-118; Ch.9 pp.122-126
Other information				
Registration	23	Registration number and name of trial registry		Ch.4, p.62
Protocol	24	Where the full trial protocol can be accessed, if available		Ch.4, p.62
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders		Acknowledgements

* Note: page numbers optional depending on journal requirements

Appendix B. Checklist of items for reporting pragmatic trials

Section	Item	Standard CONSORT description	Extension for pragmatic trials	Included in reporting for this trial, page
Title and abstract	1	How participants were allocated to interventions (eg, “random allocation,” “randomised,” or “randomly assigned”)		Thesis title page; Abstract p.xix; Ch.8 Abstract p.109
Introduction				
Background	2	Scientific background and explanation of rationale	Describe the health or health service problem that the intervention is intended to address and other interventions that may commonly be aimed at this problem	Ch.1 pp.1-22; Ch.8 pp.110-111
Methods				
Participants	3	Eligibility criteria for participants; settings and locations where the data were collected	Eligibility criteria should be explicitly framed to show the degree to which they include typical participants and/or, where applicable, typical providers (eg, nurses), institutions (eg, hospitals), communities (or localities eg, towns) and settings of care (eg, different healthcare financing systems)	Ch.1 pp.18-20; Ch.2 p.23; Ch.4 p.52; Ch.8 pp.110-111, 114
Interventions	4	Precise details of the interventions intended for each group and how and when they were actually administered	Describe extra resources added to (or resources removed from) usual settings in order to implement intervention. Indicate if efforts were made to standardise the intervention or if the intervention and its delivery were allowed to vary between participants, practitioners, or study sites	Ch.5 pp.79-81; Ch.8 pp.111-112
			Describe the comparator in similar detail to the intervention	Ch.8 p.112
Objectives	5	Specific objectives and hypotheses		Ch.1 p.21; Ch.4 pp.52; Ch.8 pp.110-110
Outcomes	6	Clearly defined primary and secondary outcome measures and, when applicable, any methods used to enhance the quality of measurements (eg, multiple observations, training of assessors)	Explain why the chosen outcomes and, when relevant, the length of follow-up are considered important to those who will use the results of the trial	Ch.1 pp.18-20; Ch.4 pp.56-59; Ch.8 pp.110, 112-114
Sample size	7	How sample size was determined; explanation of any interim analyses and stopping rules when applicable	If calculated using the smallest difference considered important by the target decision maker audience (the minimally important difference) then report where this difference was obtained	Ch.4 pp.52-56; Ch.8 p.114
Randomisation—sequence generation	8	Method used to generate the random allocation sequence, including details of any restriction (eg, blocking, stratification)		Ch.4 p.49; Ch.8 p.111; Flow Diagram p.170

Randomisation— allocation concealment	9	Method used to implement the random allocation sequence (eg, numbered containers or central telephone), clarifying whether the sequence was concealed until interventions were assigned		Ch.4 p.49; Ch.8 p.110; Flow Diagram p.170
Randomisation— implementation	10	Who generated the allocation sequence, who enrolled participants, and who assigned participants to their groups		Ch.4 p.49-51; Ch.8 p.111
Blinding (masking)	11	Whether participants, those administering the interventions, and those assessing the outcomes were blinded to group assignment	If blinding was not done, or was not possible, explain why	Ch.4 pp.50-51; Ch.8 p.112
Statistical methods	12	Statistical methods used to compare groups for primary outcomes; methods for additional analyses, such as subgroup analyses and adjusted analyses		Ch.4 pp.40, 57-60; Ch.8 pp.113-114
Results				
Participant flow	13	Flow of participants through each stage (a diagram is strongly recommended)—specifically, for each group, report the numbers of participants randomly assigned, receiving intended treatment, completing the study protocol, and analysed for the primary outcome; describe deviations from planned study protocol, together with reasons	The number of participants or units approached to take part in the trial, the number which were eligible, and reasons for non-participation should be reported	Ch.8 p.111, 114; Flow Diagram p.170
Recruitment	14	Dates defining the periods of recruitment and follow-up		Ch.8 p.112; Flow Diagram p.170
Baseline data	15	Baseline demographic and clinical characteristics of each group		Ch.8 p.114-116, Tables 18, 19
Numbers analysed	16	Number of participants (denominator) in each group included in each analysis and whether analysis was by “intention-to-treat”; state the results in absolute numbers when feasible (eg, 10/20, not 50%)		N/A
Outcomes and estimation	17	For each primary and secondary outcome, a summary of results for		Ch.8 pp.114-116, 118

		each group and the estimated effect size and its precision (eg, 95% CI)		
Ancillary analyses	18	Address multiplicity by reporting any other analyses performed, including subgroup analyses and adjusted analyses, indicating which are prespecified and which are exploratory		N/A
Adverse events	19	All important adverse events or side effects in each intervention group		N/A
Discussion				
Interpretation	20	Interpretation of the results, taking into account study hypotheses, sources of potential bias or imprecision, and the dangers associated with multiplicity of analyses and outcomes		Ch.8 pp.118-120; Ch.9 pp.121-129
Generalisability	21	Generalisability (external validity) of the trial findings	Describe key aspects of the setting which determined the trial results. Discuss possible differences in other settings where clinical traditions, health service organisation, staffing, or resources may vary from those of the trial	Ch.8 p.120; Ch.9 p.121, 125
Overall evidence	22	General interpretation of the results in the context of current evidence		Ch.8 pp.118-120; Ch.9 pp.126-131

Appendix C. Human Research Ethics Committee Approvals

Human Research Ethics Committee

Committee Approval Form

Principal Investigator/Supervisor: Professor Paul Fulbrook Brisbane Campus

Co-Investigators:

Student Researcher: Ms Sandra Miles Brisbane Campus

Ethics approval has been granted for the following project:

Able-bodied children: development and exercise (ABCDE) project. (ABCDE project) PHASE 2 OF PROJECT ONLY

for the period: 21 May 2010 to 31 August 2010

Human Research Ethics Committee (HREC) Register Number: Q2010 28

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: 21.05.2010

(Research Services Officer, McAuley Campus)

Human Research Ethics Committee
Committee Approval Form

Principal Investigator/Supervisor: Paul Fulbrook

Co-Investigators:

Student Researcher: : Sandra Miles

Ethics approval has been granted for the following project:

Able-bodied children: development and exercise (ABCDE) project. (ABCDE project) PHASE 3

for the period: 28 October 2011 to 31 December 2012

Human Research Ethics Committee (HREC) Register Number: Q2010 55

Special Condition/s of Approval

Prior to commencement of your research, the following permissions are required to be submitted to the ACU HREC:

Catholic Education Office

Principal permission

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:

(Research Services Officer, McAuley Campus)

Date: 28.10.2011.....

Appendix D. Measurement Instruments

Examples of Measurement Instruments and Standardised Administration instructions

Astronaut Invented Spelling Test (2nd ed.) (AIST-2) (Neilson, 2003a) [Test page and standardised administration instructions]

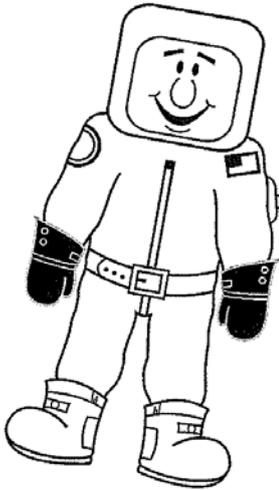
Behavior Assessment System for Children (2nd ed.) - Teacher Rating Scales (BASC-2 TRS 2-5 years and 6-11 years) [Instrument pages and standardised administration instructions]

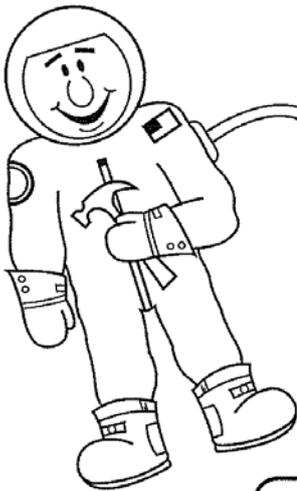
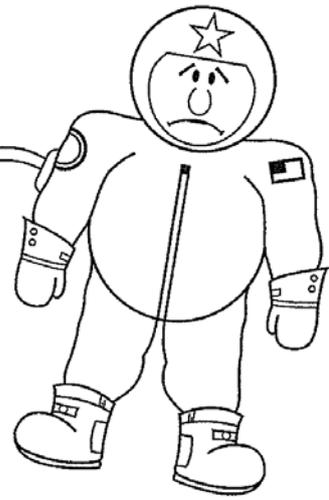
Draw-A-Person test (DAP) (Goodenough, 1926; Harris, 1963; Koppitz, 1968) [Standardised administration instructions and sample drawings for the age groups studied]

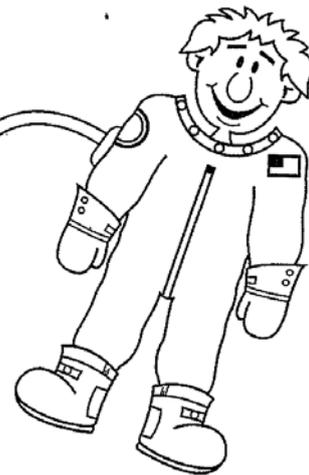
Early Mathematics Concepts A (EMCA) [Test pages and standardised administration instructions]

Sutherland Phonological Awareness Test – Revised (SPAT-R) (Neilson, 2003b) [Test page and standardised administration instructions]

Name: _____ Class: _____ Date: _____







Astronaut Invented Spelling Test ©
Roslyn Neilson (2003)

ABCDE Research Project

4) Assessment Four: Astronaut Invented Spelling Test Form A

The Astronaut Invented Spelling Test (AIST) is an instrument for assessing children's ability to write words for which they do not necessarily know the conventional spelling (a process often referred to as 'invented spelling'). When children invent spelling, they can reveal interesting insights into their phonological awareness, or their ability to attend to and analyse the separate sounds in words. The ABCDE Research team wish to implement the AIST as it is inferred that the relationship between phonological awareness and invented spelling best explains the development of spelling skills.

How to Administer: (Please familiarise yourself with the instructions **before** administering the test)

- This assessment is to be completed as a whole class activity. **The assessment should take approximately 10 minutes to complete.**
- Each student is to be allocated a response form.
- Please ensure that each form is coded and handed to the correct corresponding student.
- The teacher is to stand at the front of the class and say the following:

These astronauts went for a space walk and got lost. Someone attached name tags to their sleeves, so if you write their names, they might get found again. I'll tell you what their names are. (Pause). You probably won't know how to spell the names, but have a go at writing them anyway. It doesn't matter if you aren't sure – just listen to how the names sound, and have a try. (Pause). I want to see how YOU try to spell the names. Don't copy from anyone else, and cover up each name as soon as you have written it so no one can copy from you. I'll be checking that no one is copying.

- The assessment is to commence at the completion of these instructions.
- The teacher is then to say the following script in numerical order. Please note that the astronaut names may be repeated if required.
 - 1) **If you look carefully, you'll see that one of the astronauts is walking around with a hammer in his hand. Can you find him? His name is Fred Fix-it.**
 - 2) **Now find the fat little astronaut with a sad face and a star on his helmet. His name is Tubby Twinkle.**
 - 3) **One of the astronauts looks happy because he has taken off his helmet and he's feeling comfortable. His name is Smiley Sam.**
 - 4) **The last astronaut, with black gloves and a belt, is the only one with a square helmet. His name is Bobby Blockhead.**
- **Please pause long enough each student to finish attempting one name before proceeding to the next. Students who have finished their spelling may colour in the figures while they are waiting for the next instructions. If it is obvious that a particular student is experiencing significant difficulty completing the task, it is okay to continue.**

- This assessment piece is now complete. Please collect the forms and return them to the research team. We can collect these or supply a replied paid envelope for this purpose.

BASC-2

Teacher Rating Scales— Preschool Computer-Entry Form

TRS-P
Ages
2-5

Behavior Assessment System for Children, Second Edition
Cecil R. Reynolds and Randy W. Kamphaus

Child's Name _____
First Middle Last
 Date _____ Birth Date _____ Age _____
Month Day Year Month Day Year
 School/Center _____ Grade/Class _____
 Sex: Female Male Other Data _____

Your Name _____
First Middle Last
 Position _____
 What type of class do you teach? _____
 How long have you known this child? _____

Instructions:

On both sides of this form are phrases that describe how children may act. Please read each phrase, and mark the response that describes how this child has behaved recently (in the last several months).

- Circle **N** if the behavior **never** occurs.
- Circle **S** if the behavior **sometimes** occurs.
- Circle **O** if the behavior **often** occurs.
- Circle **A** if the behavior **almost always** occurs.

Please mark every item. If you don't know or are unsure of your response to an item, give your best estimate. A "Never" response does not mean that the child "never" engages in a

behavior, only that you have not observed the child to behave that way.

How to Mark Your Responses

Be certain to circle completely the letter you choose, like this:

N S **(O)** A

If you wish to change a response, mark an X through it, and circle your new choice, like this:

N **(S)** ~~(O)~~ A

Before starting, be sure to complete the information above these instructions.

- | | | | |
|--|---------|--|---------|
| 1. Tries new things. | N S O A | 23. Bullies others. | N S O A |
| 2. Says all letters of the alphabet when asked. | N S O A | 24. Has a hearing problem. | N S O A |
| 3. Has a short attention span. | N S O A | 25. Is negative about things. | N S O A |
| 4. Teases others. | N S O A | 26. Is easily soothed when angry. | N S O A |
| 5. Has eye problems. | N S O A | 27. Communicates clearly. | N S O A |
| 6. Is sad. | N S O A | 28. Listens carefully. | N S O A |
| 7. Gets colds. | N S O A | 29. Argues when denied own way. | N S O A |
| 8. Worries. | N S O A | 30. Gets very upset when things are lost. | N S O A |
| 9. Disrupts the play of other children. | N S O A | 31. Pouts. | N S O A |
| 10. Does strange things. | N S O A | 32. Complains of pain. | N S O A |
| 11. Has trouble staying seated. | N S O A | 33. Is nervous. | N S O A |
| 12. Refuses to join group activities. | N S O A | 34. Hits other children. | N S O A |
| 13. Says, "please" and "thank you." | N S O A | 35. Seems unaware of others. | N S O A |
| 14. Misses school or daycare because of sickness. | N S O A | 36. Has poor self-control. | N S O A |
| 15. Acts out of control. | N S O A | 37. Refuses to talk. | N S O A |
| 16. Is easily upset. | N S O A | 38. Offers help to other children. | N S O A |
| 17. Provides full name when asked. | N S O A | 39. Complains about health. | N S O A |
| 18. Screams. | N S O A | 40. Bothers other children when they are working. | N S O A |
| 19. Complains of being cold. | N S O A | 41. Says, "Nobody likes me." | N S O A |
| 20. Has trouble making new friends. | N S O A | 42. Provides own telephone number when asked. | N S O A |
| 21. Seems to take setbacks in stride. | N S O A | 43. Throws tantrums. | N S O A |

Continue on the back ►

ABCDE Research Project

2) Assessment Two: *Behaviour Assessment Systems for Children - 2nd Edition*

Dear Teachers,

In addition to assessing a range of curriculum based competencies, the ABCDE research team also aim to consider behavioural functioning and readiness to learn across the two year study. The concept of readiness to learn has been re-defined over the years, however, many sources don the term to explain both the level of development at which children have the capacity to learn specific competencies, in addition to a set of social, linguistic and cognitive skills that enable children to assimilate school based tasks.

We have chosen the *Behaviour System Assessment for Children – 2nd Edition (BASC-2)* as an effective tool for measuring students' readiness to learn. The *BASC-2* is a popular screening tool used within many areas of Psychology, Counselling and Education. Using a multi-dimensional approach, scored responses are used to evaluate behaviour of children and adolescents alike.

At the completion of each form, the results will be score and tabulated against standard scales using norms. Computer software will highlight any developmental delays across adaptive skills, behaviour functions, internalizing processes and externalizing behaviours. With follow up assessments to occur towards the end of the year, this data will allow us to examine any change in readiness to learn, in relation to the functions of this research study.

How to Administer:

- The forms are to be completed for each student in your class. **Each form should not take more than a couple of minutes to complete.**
- The forms do not have to be completed at the simultaneously, so please take your time. They can be completed before your students arrive of a morning, during non contact time, or during any free time of an afternoon or evening. We do not expect you to relinquish your lunch hour to complete these forms. We do, however, prefer all forms to be completed within a two-week period.
- Please return all completed forms using the replied paid envelope.

ABCDE Research Project

1) Assessment One: 'Draw A Person'

The Draw A Person assessment is a well validated cognitive test used to evaluate children and adolescents for a variety of reasons. For the purpose of this research study, we are asking you to implement this assessment in order to gain a greater understanding of your students' visual spatial awareness, shape comprehension and hand-eye motor control. To evaluate this, the research team will use a recognised scoring system. This system analyzes fourteen different aspects of the drawings (such as specific body parts and clothing) for various criteria, including presence or absence, detail, and proportion. In all, there are 64 scoring items for each drawing.

How to Administer:

- This assessment is to be completed as a whole class activity.
- Each child is to be allocated a plain white piece of paper.
- Prior to commencing the assessment, ensure each piece of paper is coded.
- Once the students are ready to complete the assessment, hand out each piece of paper to the corresponding student.
- The teacher is to stand at the front of the class and say the following:

On your piece of paper, I want you to draw a person you know. I want you to draw the whole person. I will tell you when to stop

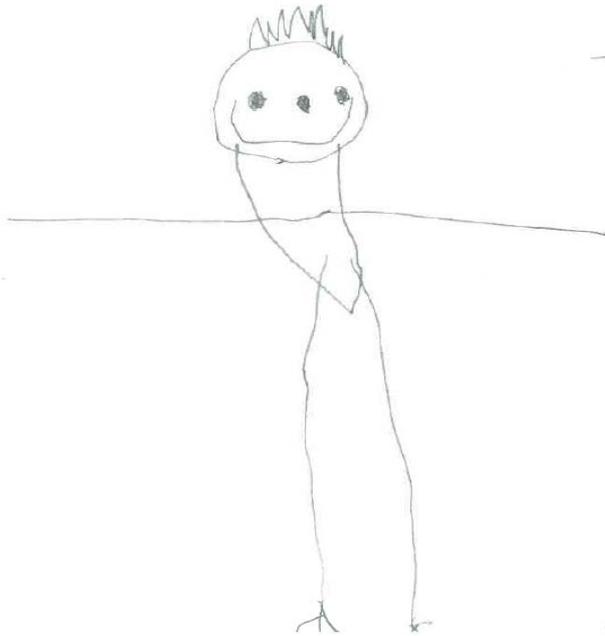
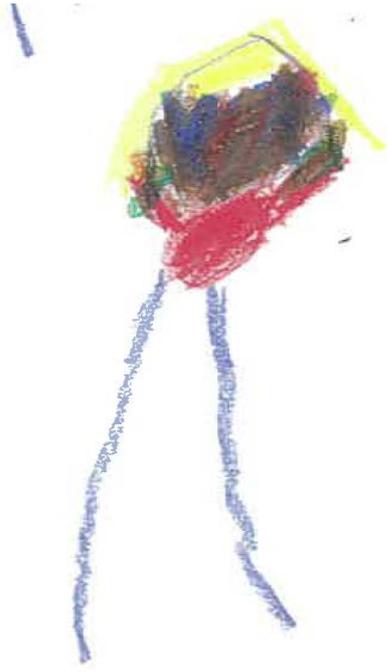
- The class is to be given 10 minutes to complete this task.
- At the end of the time limit, please say the following:

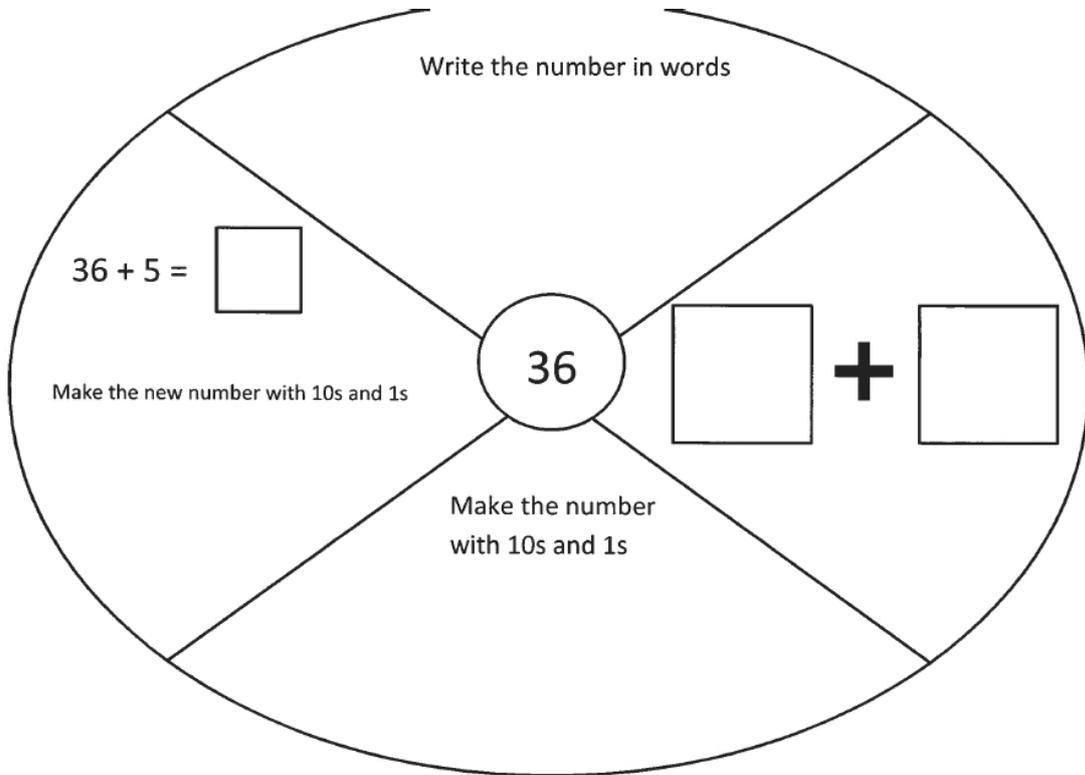
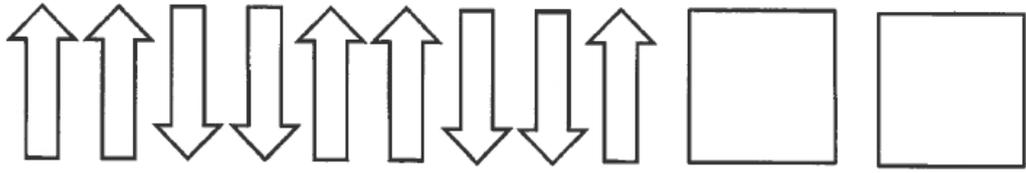
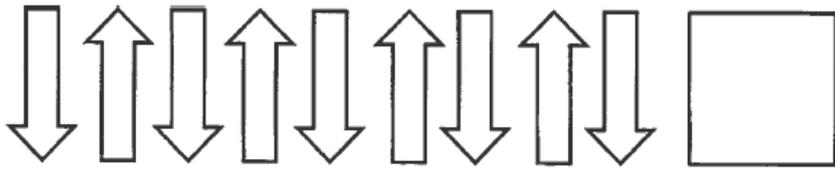
Okay, time is up. Please stop drawing your person. I now wish for you to name this person. This person can have any name you chose.

- Allow approximately one minute for the students to write a name. At the end of this time limit, please say the following:

Excellent. Can you please return your pieces of paper to me?

- This assessment piece is now complete. Please collect the forms and return them to the research team. We can collect these or supply a replied paid envelope for this purpose.





ABCDE Research Project

3) Assessment Three: Early Mathematical Concepts Set A

We are interested in assessing mathematic concepts as we believe that they are the foundation for success in a variety of areas during a child's educational experience. We are asking you to implement the Early Mathematical Concepts Set A in order to gain a greater understanding of your students' level of basic mathematic concepts.

During the Pilot Phase of this study (Phase 3), a number of standardised assessment tools were implemented, reviewed and critiqued. Despite their strong empirical presence, a number of concerns were raised in relation to completing the said tools with students this age, in addition to completing the assessments with larger classes. To attend to these concerns, the research team devised a short screening tool.

This screening tool is based on similar questions found in a number of published and commonly used assessments. These include: the Curriculum Associates' *Brigance Early Preschool Screen – 2nd Edition*, the *Woodcock-Johnson III Edition - Australian Adaptation* and the *Assessing Math Concepts* textbook series. The aim of the tool is to assess counting abilities, visual spatial processing and shape recognition. To evaluate class responses, the research team will use a recognised scoring system. Please read through the questions before commencing the test to familiarise yourself with the requirements.

How to Administer:

- This assessment is to be completed one-on-one with the student.
- Prior to commencing the assessment, please ensure each coded form is allocated to the correct corresponding student.
- Some questions require the teacher to circle responses on behalf of the child. Please refer to the notes of each question.
- When you are ready to commence the test, please start at question one. Read the bold text aloud to the student. Continue the questions at you own pace.
- There is no time limit on this test. **The test should not take more than a couple of minutes per child.**
- The completion of question three marks the end of this assessment. Please collect the forms and return them to the research team. We can collect these or supply a replied paid envelope for this purpose.

Subtest 2A: Rhyme Detection

ABCDE Research Project

5) Assessment Five: Sutherland Phonetic Awareness Test, Revised Form A

The Sutherland Phonetic Awareness Test, Revised (SPAT-R) is to be used in conjunction with the AIST in order to gain greater insight into students' phonological awareness. As you may be aware, phonological awareness has received an increasing amount of attention in the past decade in relation to its implications for children experiencing reading difficulties. Measures of phonological awareness correlate with concurrent reading and spelling skills and also predict later reading and spelling ability.

Because phonological awareness is considered to be the one of the primary stages of reading and spelling, the SPAT-R has been used extensively to assess prep-aged children. This factor, along with its successful completion during the ABCDE Research Phase 3, suggests that the SPAT-R is suitable for the students in your class.

How to Administer: (Please familiarise yourself with the instructions **before** administering the test)

- This assessment is to be completed as a whole class activity. **The assessment should take approximately 10 minutes to complete.**
- Each student is to be allocated a response form.
- Please ensure that each form is coded and handed to the correct corresponding student.
- The teacher is to stand at the front of the class with their own copy of the response form. The teacher will be required to point to their copy during the assessment.
- Once ready to commence the assessment, the teacher is to stand at the front of the class and say the following:

These pictures are about words that rhyme. This one is cat (point to the cat). ***You circle the word that rhymes with cat...ring*** (point to the ring) ***or hat*** (point to the hat). ***The answer is hat...cat, hat.***

- On completing the first practise question, please say the following:

This picture is wet (point to wet). ***Which one rhymes with wet...net or lick?***

- On subsequent items, just provide the labels. Say the following:

1) Dive Teeth Five

2) Fin Bin Thumb

3) Patch Match Bush

4) Lamb Run Jamb

- **Please pause long enough for everyone in the class to attempt to circle the correct picture. If it is obvious that a particular student is experiencing significant difficulty completing the task, it is okay to continue.**

- This assessment piece is now complete. Please collect the forms and return them to the research team. We can collect these or supply a replied paid envelope for this purpose.

Appendix E. Flow Diagram

CONSORT 2010 Flow Diagram

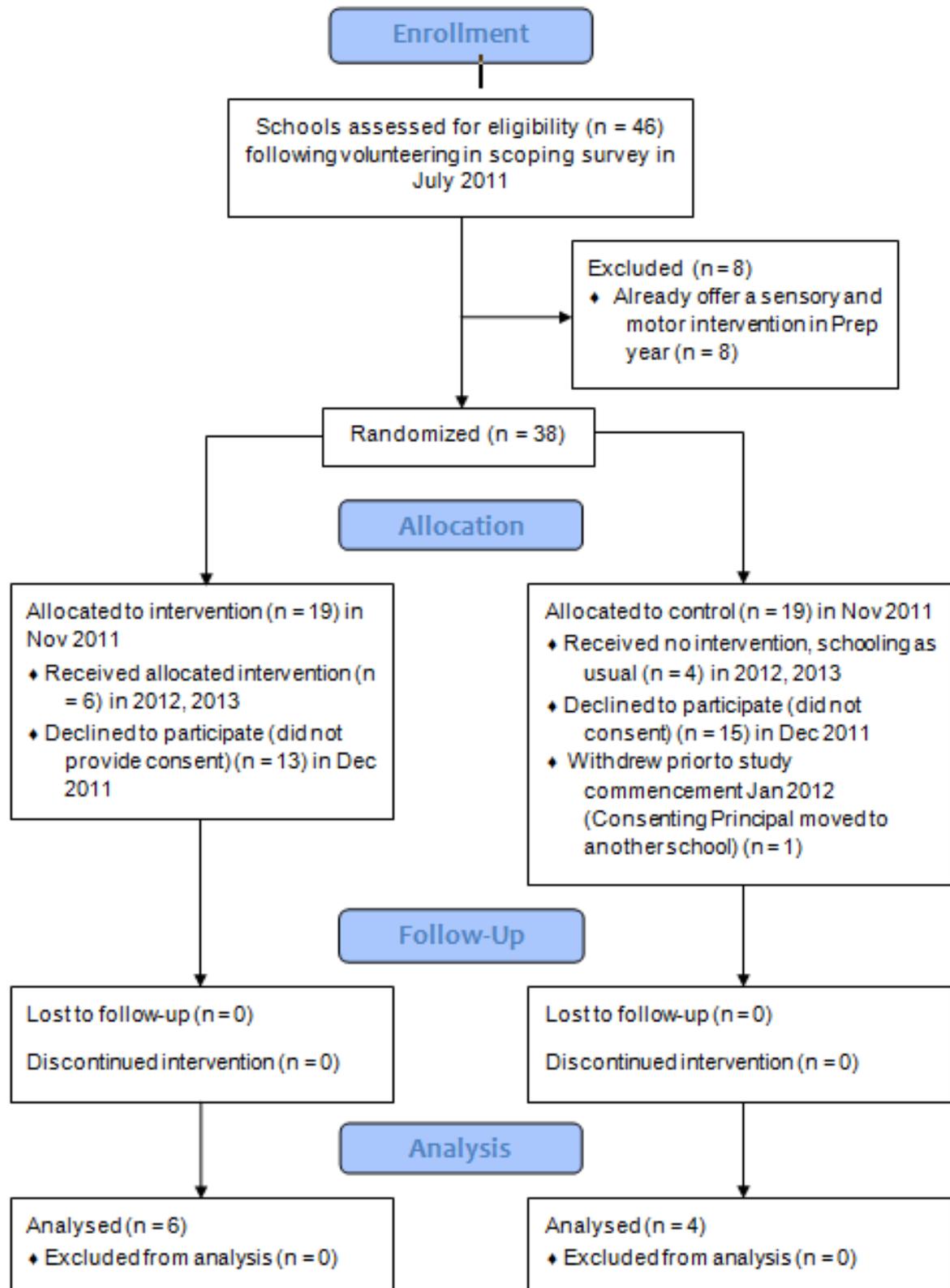


Figure 2. Consort 2010 Flow Diagram

Appendix F. Complete Results

Table 21. Prediction of study outcomes over time by baseline variables: cluster-adjusted GEE multivariable regressions (complete results)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7a	Model 7b	Model 8
	AIST-2 β (Wald 95% CI), p	BASC-2 TRS EB β (Wald 95% CI), p	BASC-2 TRS IB β (Wald 95% CI), p	BASC-2 TRS BS β (Wald 95% CI), p	BASC-2 TRS AS β (Wald 95% CI), p	DAP β (Wald 95% CI), p	EMCA β (Wald 95% CI), p	EMCB β (Wald 95% CI), p	SPAT-R β (Wald 95% CI), p
Intervention vs control	-0.40(-2.9,2.1), 0.8	-2.61(-9.1,3.9), 0.4	-5.2(-10.4, 0.05), 0.1	0.45 (-5.2,6.1), 0.9	-2.0 (-12.9, 8.9), 0.7	0.04 (-0.6, 0.7), 0.9	1.36 (0.37, 2.4), 0.012	0.30 (0.07, 0.5), 0.010	0.04 (-0.23, 0.31), 0.8
Female sex	0.39 (-1.2, 2.0), 0.6	-2.68(-4.2,-1.1), 0.001	1.68 (-0.9,4.3), 0.2	-2.1(-5.1,1.0), 0.2	2.1 (-1.3, 5.5), 0.2	0.43 (0.1, 0.8), 0.019	0.06(-0.74, 0.86), 0.9	-0.01 (-0.17, 0.15), 0.9	0.14 (0.06, 0.22), 0.001
Provincial school (Metropolitan as reference)	0.43(-2.0,2.8), 0.7	6.6 (-0.51, 13.7), 0.1	-1.2(-10.8, 8.3), 0.8	-1.5 (-8.5, 5.4), 0.7	-1.9(-22.3, 18.4), 0.9	0.05 (-0.7,0.8), 0.9	-0.26 (-1.1, 0.6), 0.5	-0.05 (-0.37, 0.27), 0.8	-0.14(-0.45, 0.16), 0.4
ICSEA	0.1 (-3.6,3.8), 0.9	4.0 (-1.92, 11.8), 0.2	1.2(-3.3, 5.6), 0.6	1.3 (-3.1, 5.7), 0.6	-11.6(-33.1, 9.9), 0.3	0.4(-0.3,1.1), 0.3	0.33 (-0.59, 1.25), 0.5	-0.09 (-0.39, 0.22), 0.6	0.08 (-0.34, 0.49), 0.7
AIST-2 baseline	-	0.01(-0.08,0.1), 0.9	-0.11(-0.3, 0.1), 0.2	-0.19(-0.5, 0.1), 0.2	0.18(-0.1,0.4), 0.2	0.02 (0.01, 0.03), <0.001	0.11 (0.07, 0.15), <0.001	0.01 (-0.002, 0.02), 0.1	0.01 (0.004, 0.02), 0.001
BASC-2 TRS EB baseline	0.05(-0.05,0.2), 0.3	-	-0.66(-0.9,-0.4), <0.001	1.42 (1.2, 1.6), <0.001	0.77 (0.5,1.0), <0.001	-0.01(-0.05, 0.03), 0.6	0.02(-0.05, 0.09), 0.5	0.01 (-0.01, 0.03), 0.3	0.01(0.001, 0.03), 0.029
BASC-2 TRS IB baseline	-0.004(-0.03, 0.02), 0.8	-0.18(-0.24,-0.11), <0.001	-	0.30 (0.15, 0.45), <0.001	0.14 (-0.06, 0.3), 0.2	-0.00(-0.01, 0.01), 0.6	0.01(-0.01, 0.03), 0.4	0.00 (-0.00, 0.01), 0.2	0.003 (-0.00, 0.00), 0.053
BASC-2 TRS BS baseline	-0.05(-0.13, 0.03), 0.2	0.39 (0.34, 0.45), <0.001	0.46(0.3, 0.6), <0.001	-	-0.68 (-0.8,-0.5), <0.001	-0.00(-0.02 ,0.02), 0.9	-0.03(-0.07, 0.01), 0.2	-0.00 (-0.01, 0.03), 0.3	-0.01(-0.01, - 0.004), <0.001
BASC-2 TRS AS baseline	0.02(-0.05,0.1), 0.5	0.13(0.1,0.2), 0.001	0.1(-0.02, 0.2), 0.1	-0.35(-0.44, - 0.26), <0.001	-	0.01(-0.01, 0.05), 0.4	0.03 (0.004, 0.06), 0.024	0.01 (0.001, 0.01), 0.008	-0.003(-0.01, 0.00), 0.06
DAP baseline	0.26 (0.11, 0.41), 0.001	-0.19(-0.5,0.2), 0.3	0.2 (-0.4, 0.8), 0.5	0.19(-0.9,0.5), 0.6	0.3(-0.4,1.0), 0.4	-	0.15 (-0.04, 0.25), 0.1	0.012 (-0.01, 0.05), 0.2	0.05 (0.03, 0.06), <0.001
EMCA baseline	0.38 (0.2, 0.6), <0.001	0.01(-0.08, 0.1), 0.9	0.08(-0.1, 0.3), 0.5	-0.1(-0.3,0.1), 0.4	0.35 (0.16, 0.54), <0.001	0.02(-0.01, 0.05), 0.1	-	0.01 (-0.01, 0.02), 0.4	0.001 (-0.02, 0.02), 0.9
EMCB first measure	0.91 (0.35, 1.46), 0.001	0.60 (-0.22, 1.42), 0.2	-0.14 (-1.1, 0.8), 0.8	-1.1 (-2.7, 0.6), 0.2	1.75 (0.36, 3.13), 0.013	0.11 (-0.04, 0.24), 0.1	0.15 (-0.37, 0.66), 0.6	-	0.16 (0.06, 0.26), 0.001
SPAT-R baseline	0.48 (0.2, 0.8), 0.002	0.19(-0.59,1.0), 0.6	-0.01(-0.9, 0.9), 0.9	-1.65 (-2.9,-0.35), 0.013	-0.81(-1.7,0.1), 0.1	0.29 (0.18, 0.41), <0.001	-0.03 (-0.54, 0.47), 0.9	0.06 (0.01, 0.1), 0.008	-
Visit ¹	13.7(12.4,15.2), <0.001	17.7 (13.2, 22.2), <0.001	4.2 (-1.1,9.4), 0.1	1.6(-1.2,4.4), 0.3	44.7 (36.3, 53.2), <0.001	1.1 (0.48, 1.64), <0.001	4.19 (3.59, 4.79), <0.001	0.28 (0.04, 0.53), 0.023	0.14(-0.17, 0.45), 0.4

Note. ¹Visit constituted the three study points in time: Baseline (beginning of Prep Year), end Year 1 (end of Prep Year), and end Year 2 (end of Grade 1)
Abbreviations: AIST-2, Astronaut Invented Spelling Test 2nd ed.; BASC-2 TRS EB, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Externalizing Behaviors; BASC-2 TRS IB, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Internalizing Behaviors; BASC-2 TRS BS, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Behavioral Symptoms; BASC-2 TRS AS, Behavior Assessment System for Children 2nd ed. Teacher Rating Scale Adaptive Skills; DAP, Draw a Person; EMCA, Early Mathematics Concepts A; EMCB, Early Mathematics Concepts B; SPAT-R, Sutherland Phonological Awareness Test – Revised.