DOI: 10.1111/cdev.13753

CHILD DEVELOPMENT

EMPIRICAL REPORT

Nap effects on preschool children's learning of letter-sound mappings

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Funding information
This work was supported by the Australian Research Council [DP150100419]

Abstract

This study explored whether a daytime nap aids children's acquisition of letter-sound knowledge, which is a fundamental component for learning to read. Thirty-two preschool children in Sydney, Australia (M_{age} = 4 years;3 months) were taught letter-sound mappings in two sessions: one followed by a nap and the other by a wakeful period. Learning was assessed by explicit letter-sound mappings ("Which sound does this letter make?") and knowledge generalization tasks ("Here's *Tav* and *Cav*, which one is /kav/?"). Results from the knowledge generalization task showed better performance after a nap than after wake. However, no nap benefit was found for explicit letter-sound knowledge. This study provides initial evidence that naps could be beneficial for preschool children's learning of letter-sound mappings.

INTRODUCTION

Critical to learning to read in alphabetic writing systems is the ability to map letters onto sounds (Brady & Shankweiler, 2013; Byrne, 1998; Share, 1995; Share & Jorm, 1987). Theories of reading development consider this the cornerstone of reading acquisition because it provides a learning mechanism that allows children to sound out an unfamiliar word and, from this, link the pronunciation to its meaning and establish connections to its written form (Share, 1995). Many empirical studies have supported the importance of letter-sound knowledge. For example, the ability to make letter-sound mappings in kindergarten children is strongly associated with later reading success (e.g., Lonigan et al., 2000), and prospective longitudinal studies show that children who are later diagnosed as dyslexic have poor letter-sound knowledge in the preschool years (e.g., de Jong & van der Leij, 2003; Snowling et al., 2003). However, research on reading acquisition is rarely considered in the context of broader theories of memory consolidation (Nation & Castles, 2017). To bridge this gap we examined whether the initial manifestation of the reading system—the acquisition of letter-sound mappings—is influenced by a factor that is important in learning and memory consolidation, namely sleep. Specifically, we investigated whether a daytime nap supports preschool children's ability to learn letter sounds and to transfer this newly

Abbreviation: CVC, consonant vowel consonant

[Correction added on May 14, 2022, after first online publication: CAUL funding statement has been added.]

learned knowledge to the recognition of novel printed words.

Sleep has been proposed to benefit memory consolidation and the integration of new memories into the network of existing long-term memories (e.g., Diekelmann & Born, 2010; Walker & Stickgold, 2010). The active systems consolidation theory suggests that sleep is instrumental in integrating newly encoded information that is temporarily stored in the hippocampus into long-term memory in the neocortex (for review, see Klinzing et al., 2019). Sleep influences different types of memory including declarative memory and procedural memory (see Diekelmann & Born, 2010 for a review) and its effects are seen across domains including spatial memory, memory for motor movements (Sawangjit et al., 2020; Walker et al., 2003) and language learning (Dumay & Gaskell, 2007; Gaskell et al., 2014; Henderson et al., 2012; Wang et al., 2017).

Sleep, often in the context of a daytime nap, also benefits learning in preschool children and infants (Axelsson et al., 2018; Friedrich et al., 2015; Giganti et al., 2014; Gómez et al., 2006; Hupbach et al., 2009; Spanò et al., 2018). Kurdziel et al. (2013) examined whether a midday nap improved preschool children's learning of spatial locations. Using a within-child design, they required children who were habitual nappers to either take their usual nap (Nap condition) or undertake quiet activities (No-nap condition) after learning. More spatial locations were recalled following a nap, and this nap benefit remained the following day. However, given children who habitually nap were kept awake in the No-nap condition, it is possible that retention was compromised, resulting in better performance in the Nap condition.

In the language domain, Gómez et al. (2006) found that naps benefitted 15-month-old infants' acquisition of grammatical rules. Infants were familiarized with an artificial language. After either a nap or a wake period, the extent to which they could abstract patterns from the artificial language and apply them to unfamiliar stimuli was assessed. Infants who napped after familiarization were more able to do this. Turning to preschool children, Sandoval et al. (2017) examined whether naps helped 3-year-old habitual and nonhabitual nappers to learn novel verbs (e.g., "rooping" matches with a video clip of a whole-body action). Children either napped or stayed awake after learning about the novel verbs, and learning was assessed 24 h later, after overnight sleep, with a generalization task (with a different actor). Both habitual and nonhabitual nappers showed generalization but only in the Nap condition.

In contrast, other research has indicated that toddlers generalize their knowledge better after a period of wakefulness instead of sleep. Werchan and Gómez (2014) presented novel object pictures paired with novel spoken words to 2.5-year-old habitual nappers. Generalization was then assessed by asking the children to identify the objects presented in a novel context. Children who did not nap showed better generalization, leading to the conclusion that wakefulness promotes forgetting, which in turn benefits knowledge generalization. However, as the study used a between-child design, it is possible that children's learning was moderated by their nap habits. Indeed, there is evidence that napping affects children differently, depending on their age, nap habits, and whether they are in the stage of transitioning out of nap habits (Sandoval et al., 2017). In a more recent study, Werchan et al. (2021) updated their view on this matter from their experimental finding and suggested that knowledge generalization is promoted by a daytime nap combined with night time sleep.

The current study investigated whether a daytime nap facilitates preschool children's learning of letter-sound mappings, and whether any learning transfers to the recognition of unfamiliar written words. The influence of sleep on this key skill has not been examined before. In adults, however, sleep facilitates the integration of newly learned written words into the lexicon (Wang et al., 2017) and supports generalization to new written words (Tamminen et al., 2012). It also boosts reading fluency in children (Torres et al., 2021) and, combined with recent evidence that sleep is associated with verbal learning in children more generally (James et al., 2017; Knowland et al., 2021), there is a strong basis to predict that sleep may impact learning at the foundation of literacy.

In our study, all children were 3- to 5-year-old habitual nappers and participated in both the nap and the No-nap conditions: Given that the benefits of sleep may vary in children who differ in age and nap habits (Sandoval et al., 2017), and that sleep effects may be compromised when habitual nappers are kept awake (Kurdziel et al., 2013), we used a within-child design but did not keep the children awake during nap time. In a training session, children participated in activities where they learned letter-sound mappings, once in the morning (No-nap condition), and once just before they had lunch and a nap (Nap condition). Subsequently, learning was assessed, either after a nap (Nap condition) or after a period of wakefulness (No-nap condition). We assessed both explicit learning and knowledge transfer. In the explicit learning task, children were asked to produce or recognize the letter-sound mappings they had learned earlier. In the transfer task, they were required to identify unfamiliar words containing the letter-sound mappings they had previously learned. We predicted that if a nap benefits the learning of letter-sound mappings, children who had napped would perform better on both the explicit learning and knowledge transfer tasks. The same assessments were carried out approximately one day later to examine whether any nap effect was retained after an overnight sleep.

METHOD

Participants

We recruited 32 three- to five-year-old children from two childcare centers in Sydney, Australia, metropolitan region (M_{age}: 4 years;3 months; range:

TABLE 1 Session times for the nap and no-nap conditions

	Day 1				Day 2
	Early morning	Late morning		Afternoon	Morning
Nap		Training	Nap	Posttest 1 (same day)	Posttest 2 (next day)
No-nap	Training	Posttest 1 (same day)	Nap		Posttest 2 (next day)

3 years;2-months–5 years;0 months). Sydney is highly diverse in cultures and ethnicities. As the current study implements a within-participants design and the research questions were not associated with children's sociodemographics, this information was not collected. Only children who were reported by their carers as napping habitually were recruited. Data collection was completed between 2016 and 2017. There was no formal teaching of the letter names or sounds in these two childcare centers.

Design

Each child participated in seven sessions over 2–4 weeks: one pretest, two training, and four posttest sessions. The pretest established baseline levels of letter-sound knowledge. Nap was manipulated as a within-child factor across two training sessions held a week apart. The order of Nap vs.-No-nap was counterbalanced across children and randomly assigned. For the No-nap condition (Table 1), training took place soon after the child arrived at childcare (somewhere between 9 and 10 a.m.) and the first posttest just before lunch time (somewhere between 11:30 a.m. and 12 p.m.). For the Nap condition, training took place later in the morning (somewhere between 10:30 and 11:30 a.m.) and the first posttest soon after nap time (somewhere between 2:30 and 3:30 p.m.). Nap time scheduled at the childcare centers was between 1 and 2:30 p.m. The second posttest took place in the morning on the following day (approximately 10 a.m.). Note that the gap between learning and the first posttest was longer for the Nap condition ($M = 242$ min, $SD = 29$ min) than for the No-nap condition ($M = 128$ min, $SD = 9$ min) due to constraints in the childcare center schedules. With the time gap for the Nap condition longer, however, this worked against our hypothesis.

All sessions were conducted individually in the childcare centers, either in the staff room or in a quiet corner of the room. Children napped together in the room during their routine nap time.

Materials and procedure

Pretest: Letter name and letter-sound knowledge

This was conducted 1–5 days before training to determine which (if any) letter name and letter-sound mappings the children already knew and from this to generate individualized training items for the study. Modeled on Castles et al.'s (2009) letter knowledge test, we created a story book containing 26 letters of the alphabet. Children were asked to find the letters in the book, say their names and their corresponding sounds. As anticipated, performance was low (letter name: $M = 10.39$, $SD = 9.32$; letter sound: $M = 1.94$, $SD = 3.93$).

Training: Letter-sound mappings

Based on the pretest results, we individualized training items for each child by allocating them to two of four training sets (Set 1: C, T; Set 2: W, D; Set 3: G, B; Set 4: Y, P). For each child, we allocated the two sets containing letters for which they were unable to produce the corresponding sound, and also the name in most cases. We also avoided the letters of the child's initials. When a number of sets fitting these criteria were available for a particular child, assignment of the sets was counter-balanced and randomized.

The training letters all had easy to produce sounds appropriate to this age group (Sander, 1972). One training letter in each set was acrophonic with a predictable sound from its letter name (e.g., T and /t/), and the other nonacrophonic (e.g., W and /wh/). Each child learned one set (i.e., 2 letter-sounds) per condition (Nap / No-nap) making a total of four trained letters across two training sessions.

Each training session took approximately 30 min and included five activities such as introducing the letter-sound mappings using flashcards, making letters using playdough, and a memory game (see Appendix A for details).

Sleep activity

Sleep activity for the Nap condition was recorded by both the experimenter's observation and Actiwatch (Mini-mitter, Respironics, Inc). Actiwatches measure sleep activity using accelerometers to detect movements. The experimenter stayed in the classroom where the children napped during nap time and recorded sleep and wake times of the naps.

Posttests

These tests were administered twice: on the same day approximately 2–3 h after learning (same day), and the following day (next day). Each testing session took about 20 min.

Explicit letter-sound mapping

Two tasks provided a direct assessment of the children's explicit knowledge of the trained letter-sound mappings. As there were only two target items for each set, two filler items were selected for each set, with a total of eight filler items (J, F, S, L, N, R, V, H). The same fillers were used for both tasks. In the *recognition* task, the experimenter presented four letters at a time, and the child was asked to “point to the letter that makes the ___ sound”. In the *production* task, the experimenter presented a flashcard that contained a letter and the child was asked to say its sound. Each trained letter was tested twice, resulting in an accuracy score out of 4 for each task.

Knowledge transfer

Learning transfer was assessed using simple CVC words and nonwords. For the trials with word targets, the children saw two printed word cards at once (e.g., “Here's *TAP* and *CAP*, which one is Tap?”). For nonword targets, the child was shown two “alien” pictures with printed nonword cards as their name tags in each trial, and was asked to identify the correct nonword (e.g., “Here's *TAV* and *CAV*, which one is Cav?”). For each target word, where the target letter is embedded (e.g., TAP or TAV), four distractors were created, two with words (e.g., CAP, JOY) and two with nonwords (e.g., CAV, FEB). The word and nonword distractors had initial letters that were both nontarget trained letters and filler letters. Each pair was tested twice, resulting in an accuracy score of 8 for each target letter. The experimenter shuffled the two cards for each trial so that the participants were not biased in choosing cards based on certain positions. Stimuli are provided in Appendix B.

RESULTS

Three children were excluded from the analyses as they did not complete all testing sessions. Data from the remaining 29 participants were included in the analyses. Sleep activity was highly similar between the experimenter's observation and the data recorded from the Actiwatches. The children slept for 70 min on average in the Nap condition based on Actiwatches (Actiwatch: M = 70.31 min, SD = 27.84 min, range = 15–145 min; manual observation: M = 74.03 min, SD = 29.31).

We first checked whether training had been effective using performance in the production task after training (same day posttest). Accuracy for the production task was 53% combined across Nap and No-nap conditions (recall the items were selected for each individual child to have a baseline accuracy of 0%). Additionally, a binomial test indicated that performance was significantly above chance (25%) on the recognition task, with 70% (N = 163) correct trials ($p < .001$).

Posttest data were analyzed with logistic mixed-effect modeling using the lme4 package in R. All reported statistics to represent confirmatory tests of our hypotheses related to nap effects. Note that we chose the statistical approach over ANOVAs because in this dataset, the items and participants are crossed and are therefore not independent from one another. In addition, the small number of items per cell violates the assumption in ANOVA that data will be normally distributed. All analyses began with a maximal model structure (following Barr et al., 2013) with random intercepts and slopes. If the model failed to converge, the random effect structure was simplified until convergence was achieved. Nap condition (Nap/No-nap) and Delay (Same day/Next day) were entered into each model as fixed factors along with their interaction. However, Nap condition was the main effect of interest and we had no specific prediction for the interaction between the two factors. The final models with parameter estimates and statistics effects are included in Appendix C. Descriptive results are presented in Table 2 and the nap effect (the difference in performance by Nap condition) is visualized in Figures 1 and 2. Exploratory analyses are reported in Supplementary material.

Explicit letter-sound mapping

There was no significant effect of Nap condition on production performance (p = .478), no effect of Delay (p = .153) and interaction between Nap and Delay (p = .136). Likewise, for the recognition task, there was no significant effect of Nap (p = .125) nor interaction (p = .085). Children performed better on the second test, however, reflected in a significant effect of Delay (p = .015).

TABLE 2 Mean accuracy (standard deviations in parentheses) for the explicit learning and knowledge transfer tasks

	Explicit letter-sound mapping (max. = 4)				Knowledge transfer (max. = 8)	
	Same day		Next day			
Delay	Production	Recognition	Production	Recognition	Same day	Next day
Nap	2.07 (1.70)	2.79 (1.47)	2.54 (1.64)	3.36 (1.19)	5.72 (1.79)	6.24 (1.64)
No-nap	2.18 (1.61)	2.82 (1.28)	2.25 (1.69)	3.04 (1.37)	4.97 (1.99)	5.72 (1.75)

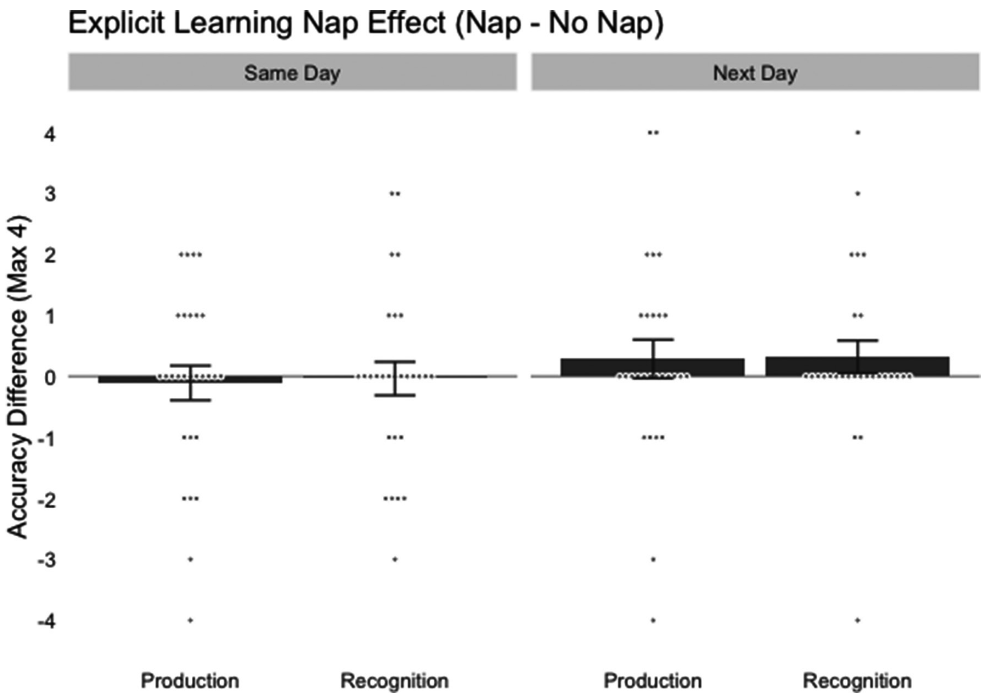

FIGURE 1 The difference in accuracy between nap and no nap conditions for the explicit learning measure

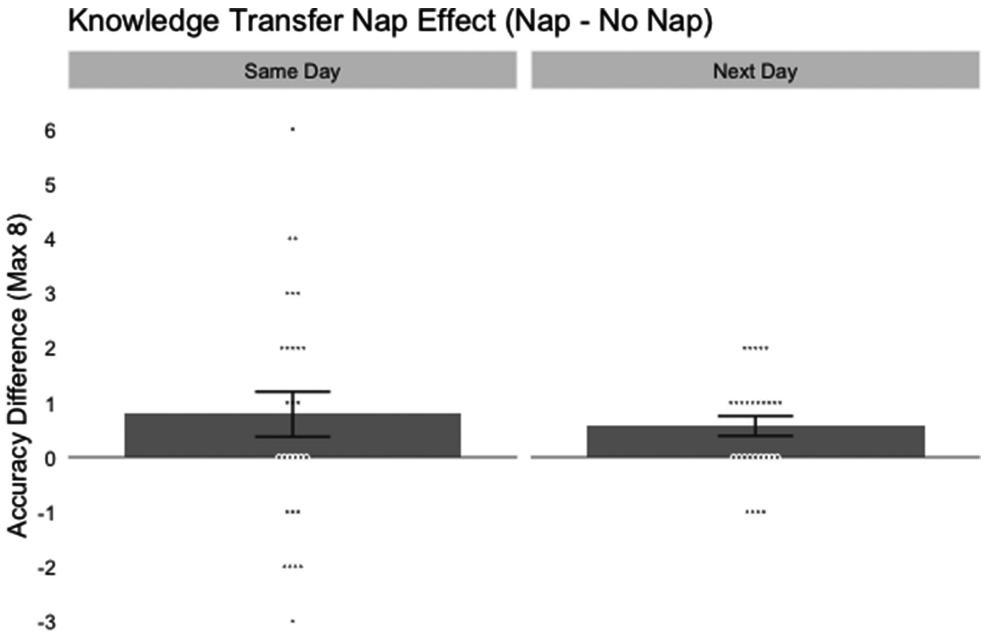

FIGURE 2 The difference in accuracy between nap and no nap conditions for the knowledge transfer measure

Knowledge transfer

We found a significant main effect of Nap condition, $p = .015$, indicating that performance was better after a nap. There was also the main effect of Delay, $p = .003$, indicating that performance was better on the next day than the same day. There was no interaction between Nap and Delay ($p = .922$).

DISCUSSION

This study explored the effect of daytime naps on children's learning of letter-sound mappings and the transfer of this to recognizing printed words. Preschool children aged 3- to 5-years-old were pretested on their letter-sound knowledge and were taught two sets of individualized letter-sound mappings. Subsequently, learning was assessed, once after a nap and once after a period of wakefulness. This within-child design provided a strong control for individual variation between children. To examine whether any effect of nap on learning was maintained, knowledge was reassessed one day later.

The training of letter-sound mappings was effective as children performed significantly better than chance at test. In terms of explicit letter-sound knowledge, there was no differential effect of nap: Children learned equivalently regardless of whether training was followed by a nap or a period of wakefulness. In contrast, napping did appear to affect performance on the knowledge transfer test: Children learned better when they napped after training than when they stayed awake, even though the amount of time between training and test was shorter in the No-nap condition. This nap benefit was maintained the following day.

The nap advantage for knowledge transfer is consistent with studies that have reported positive effects of naps on learning (e.g., Axelsson et al., 2018; Cabral et al., 2018; Gómez et al., 2006; Kurdziel et al., 2013). It also aligns with the negative correlation between nap latency and subsequent generalization reported by Werchan et al. (2021) and the suggestion that napping shortly after learning facilitates knowledge generalization.

Our findings are inconsistent with the results of Werchan and Gómez (2014) who found a period of wakefulness after learning was more beneficial for knowledge transfer than a nap. Werchan and Gómez argued that wakefulness promotes forgetting of unimportant information (the background color of an object in their study), which in turn contributes to knowledge generalization. In our experiment, however, this might not apply. While knowledge did need to transfer from isolated letters to printed words (and nonwords), no "irrelevant details" needed to be forgotten to recognize the written words. It is possible that nap effects on knowledge transfer might be context and domain specific, and this requires further investigation.

It is important to consider why there was no nap effect on the explicit learning measures. One possibility is that the consolidation needed for letter-sound learning, as assessed by our explicit learning tasks, is less dependent on sleep. These tests were similar to the procedures used during training, whereas the task used to assess knowledge transfer was quite different. Having a nap after learning might facilitate the capacity to utilize newly learned information in a new task. While speculative, this explanation is in line with the view that sleep might be more helpful in reconstructing memory rather than strengthening rote memory (Conte & Ficca, 2013). In addition, Giganti et al. (2014) found that preschool children's learning of object names benefited from a daytime nap when the outcome measure required children to judge whether each picture is old or new (dissimilar to the training activity), but not when object had to be named (similar to the training activity).

Another possibility for the lack of nap effect on the explicit learning measure could be that the benefit is delayed. Werchan et al. (2021) found that the nap benefit is observed only after an overnight sleep. Our data showed a marginal interaction between delay and Nap in the recognition task of the explicit learning measure (p = .085) and was more evident when the data from both recognition and production tasks were combined (p = .040). The interaction reflected better performance the next day (but not on the same day of learning) when training was shortly followed by a nap compared to a period of wakefulness. This result is consistent with the positive nap effect in combination of overnight sleep observed by Werchan et al. (2021). Caution is needed, however: We saw no interaction in the knowledge transfer measure, and the analysis combining the recognition and production tasks was post hoc and not planned. Further study is needed to examine the effects of nap plus overnight sleep in letter-sound learning more specifically. It is also important for future research to explore nap effects and individual learning differences with a larger sample size.

Unfortunately, we were not able to equate the time gap between training and testing perfectly across Nap condition due to constraints within the daycare center's schedule, and the nature of the within-child manipulation. We note, however, the gap was longer on average in the Nap condition meaning that the nap benefits seen in knowledge transfer cannot be due to a shorter retention interval. Also, the difference in this gap did not affect the results consistently, which is supported by the fact that a nap effect was only evident in the knowledge transfer measure and not the explicit knowledge measures. Nevertheless, future studies should seek to replicate the current findings with a more well-controlled time gap. Another possible limitation concerns time of day: Training took place in late morning for the Nap condition but early morning for the No-nap condition. To explore whether this affected learning, we looked at the performance of letter-sound production and recognition (these tasks were conducted as a part of the training activities) at the end of the training session. There was no significant difference in learning between the two conditions (Nap: M = 5.11; No Nap: M = 5.13, p = .870),[1] which would suggest that the different timing of training did not affect children's learning. Lastly, as the study was conducted in the childcare center, we were not able to examine the important physiological features of sleep such as rapid eye movement or slow wave sleep and how they are related to the sleep benefits. This would also be an important direction for future research (Lokhandwala & Spencer, 2021).

In summary, this study combines in a novel way two disparate research strands: the foundations of reading acquisition in preschool children and the extensive literature on memory and sleep. The findings provide initial evidence that naps facilitate the acquisition and

[1]The performance was out of total of 6 marks. Note that the accuracy was quite high as the task was a part of the training session and feedback was provided after each response.

application of letter-sound mappings, abilities that are crucial to early reading development. These findings are consistent with the growing evidence base showing learning benefits following naps and extend these findings to the learning of cross-modal associations between printed letters and sounds in daycare contexts. As such, the findings also provide broad support for the active systems consolidation theory of memory consolidation, in which the process of transition from hippocampal to neocortical memory system is facilitated by sleep (e.g., Klinzing et al., 2019). More practically, the finding may have implications for creating the optimal conditions for learning letter-sound mappings in preschool children.

ACKNOWLEDGMENTS

We thank the reviewers for their very helpful comments on an earlier version of the paper. We are also very grateful to the staff and children at Gumnut Cottage and Banksia Cottage for participating in the study, to Julianne Pascoe, Cheryl Quek, and Chloe Garrett for the assistance in collecting data, and to Chin Moi Chow for the technical support on Actiwatch. Open access publishing facilitated by Macquarie University, as part of the Wiley - Macquarie University agreement via the Council of Australian University Librarians.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Wang, H.-C., Nation, K., Gaskell, M. G., Robidoux, S., Weighall, A., & Castles, A. (2022). Nap effects on preschool children's learning of letter-sound mappings. *Child Development*, 93, 1145–1153. https://doi.org/10.1111/cdev.13753

APPENDIX A

Task 1: *Letter-sound flashcards*. The experimenter introduced the letter-sound by saying: "This letter has [describe the visual features]. This letter makes the sound /…../, can you repeat after me?"

Task 2: *Find the Letter*. The experiment placed flashcard with letters and cueing pictures (e.g., C with a cat picture next to it) on the wall, and said "This letter makes the sound /y/, 'yoghurt' begins with the sound /y/, run to /y/."

Task 3: *Playdough*. The child made the letters using playdough. "Lets make the letter which makes the sound /m/"

Task 4: *Memory game*. The experimenter placed flashcards face down and the child flipped them. After each card was flipped, the child was asked to say what sound they found in the cards.

Task 5: *Find the Letter*. The experiment placed flashcards with letters (but no cueing pictures) on the wall, and said "This letter makes the sound /y/, run to /y/."

APPENDIX B

STIMULI USED FOR THE LETTER-SOUND KNOWLEDGE TRANSFER TASK

	Set 1		Set 2		Set 3		Set 4	
	T, C		W, D		G, B		Y, P	
Words	Targets	Distractors	Targets	Distractors	Targets	Distractors	Targets	Distractors
Nonwords	TAP	CAP	WIG	DIG	GOO	BOO	YET	PET
	TOY	JOY	WON	SON	GAP	NAP	YUM	HUM
	CRY	TRY	DAY	WAY	BUN	GUN	PAY	YAY
	CAR	FAR	DOT	LOT	BED	RED	PAN	VAN
	TAV	CAV	WOY	DOY	GUP	BUP	YAZ	PAZ
	TEB	FEB	WAN	LAN	GOP	ROP	YIG	VIG
	CAM	TAM	DAP	WAP	BOZ	GOZ	PAB	YAB
	CUX	JUX	DUT	SUT	BAV	NAV	PUD	HUD

APPENDIX C

MIXED EFFECT MODELING RESULTS FROM THE PRODUCTION TASK IN THE EXPLICIT LETTER-SOUND TEST

Note

Maximal model = glmer(ProductionAcc~Nap*Delay (1 + Delay|subject) + (1||item))

Fix effects:	**Estimate**	***SE***	***z***	**Pr(>|*t*|)**
(Intercept)	0.513	.506	1.013	.311
Nap	−0.179	.252	−0.709	.478
Delay	−0.476	.333	−1.428	.153
Nap:Delay	0.753	.505	1.492	.136

To improve interpretability of the parameters, all variables were mean-centered. Nap is coded as 0.5, No Nap −0.5; Delay is coded as S1 −0.5; S2: 0.5.

MIXED EFFECT MODELING RESULTS FROM THE RECOGNITION TASK IN THE EXPLICIT LETTER-SOUND TEST

Note

Maximal model = glmer(RecognitionAcc~Nap*Delay (1 + Delay|subject) + (1|item))

Fix effects:	**Estimate**	***SE***	***z***	**Pr(>|*t*|)**
(Intercept)	2.443	.684	3.573	.000***
Nap	0.470	.306	1.535	.125
Delay	1.717	.708	2.426	.015*
Nap:Delay	1.022	.593	1.724	.085+

To improve interpretability of the parameters, all variables were mean-centered.
* $p < .05$. *** $p < .001$.
+ $p < .10$.

MIXED EFFECT MODELING RESULTS FROM THE KNOWLEDGE TRANSFER TEST

Note

Maximal model = glmer(KTransferAcc~Nap*Delay* + (1 + Delay|subject) +(1 + Nap|item))

Fix effects:	**Estimate**	***SE***	***z***	**Pr(>|*t*|)**
(Intercept)	1.115	.220	5.061	4.18e-07***
Nap	0.528	.219	2.410	.015*
Delay	0.618	.210	2.943	.003**
Nap:Delay	−0.031	.320	−0.097	.922

To improve interpretability of the parameters, all variables were mean-centered.
* $p < .05$. ** $p < .01$. *** $p < .001$.