CHAPTER SEVEN

The role of naps in memory and executive functioning in early childhood

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Contents

Abstract

While sleep, including naps, has been shown to benefit many cognitive functions in adults, understanding whether naps are beneficial in early childhood has important translational implications. Here we review recent studies which, collectively, suggest that naps indeed benefit cognition at this age. Specifically, declarative, motor, and emotional memory are better if a nap follows learning. Executive functions such as attention and emotion processing are likewise better following sleep. However, a better understanding of the mechanism supporting these benefits and the generalizability to other forms of learning and executive functions is necessary. It is important for future research to extend such findings, which may promote the use of naps to support early education, particularly for learning-impaired children.

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1. Introduction

A common milestone in early childhood is the transition from a biphasic sleep pattern, characterized by two naps per day, to a monophasic sleep pattern in which sleep is consolidated to a single overnight sleep bout. Although transitional during the preschool years (around 3–5 years of age), for some children it can be difficult or even impossible to be deprived of this mid-day sleep bout.

Moreover, most childcare providers will describe the napless child as giddy, grumpy, or wavering between these opposing states. This response to nap deprivation is consistent with studies of sleep deprivation in adults. As is the common perception, when sleep deprived, adults are emotionally dysregulated. Napless children may also seem inattentive, a feeling shared by sleep deprived adults. As adults, we also recognize that when we do sleep, we are less forgetful and more reasonable with our emotions.

Given this lay appreciation for both the benefits of sleep and the impairments from sleep deprivation, it may then seem obvious that naps should be supported in early childhood, particularly in daycare-type settings with routines and policies. However, casual observations suggest otherwise; often parents are too busy to allow a nap opportunity, school curriculums are too time demanding to allow a sufficient interval of time for napping, or parents discourage napping out of concern it will reduce overnight sleep. Although this area has long been understudied, here we review a wealth of recent studies on the role of naps in cognitive functions in early childhood.

2. Why study naps in early childhood?

2.1 Translational significance: Implications for early education settings

The study of naps in early childhood has important translational significance. Currently, a nap opportunity is required in accredited preschools by most governing bodies in the United States (45 C.F.R. § 1302.31; 606 C.M.R. § 7.11; 22 C.C.R. § 101230). However, as early education curriculum expands and time becomes constrained, it becomes critical to demonstrate a role of naps in meeting the objectives of early education. For example, if naps in early childhood support cognitive function, as has been demonstrated in adults (Lovato & Lack, 2010), this would favor maintaining naps as part of the preschool day.

Moreover, a positive demonstration of a role of naps in early education leads to further open questions: Exactly what cognitive functions benefit from naps? What is the ideal time and length of naps in early education settings? When is a child ready to transition out of naps? It is important to provide scientific answers to such questions to guide the development of appropriate policies and recommendations for early education settings.

2.2 Theoretical significance: An ideal protocol to assess sleep function

A common paradigm for studying sleep function in adults is to have a participant encode items in memory and then assess recall 12 h later, following an interval containing sleep (e.g., 8 p.m. to 8 a.m.) or wake (e.g., 8 a.m. to 8 p.m.). Greater recall following the sleep interval compared to recall following the wake interval is interpreted as support for a role of sleep in cognitive function. However, an alternative explanation is that recall could simply be better in the morning (when the sleep group is tested) than in the evening (when the wake group is tested). To address this, a number of studies have adopted a nap paradigm. Specifically, items are encoded mid-day (e.g., 1 p.m.) and, subsequently, the participant either takes a nap (sleep condition) or stays awake (wake condition). Recall is tested later in the afternoon following a fixed interval (e.g., 4 p.m.). In this way, performance changes over intervals with sleep and wake can still be compared, but time-of-day is controlled.

Few adults nap regularly (Nap Time | Pew Research Center, 2009). For this reason, this paradigm is not ideal in adult studies. Some adults fail to nap during the nap interval (Baran, Wilson, & Spencer, 2010) or do not reach a criterion nap length (Jones, Fitzroy, & Spencer, 2019) and are thus excluded. However, naps are routine for most preschoolers. Even those who have transitioned out of naps still nap intermittently and, thus, naps can be considered 'in the range of normal' (Ward, Gay, Anders, Alkon, & Lee, 2007).

Naps are a microcosm of overnight sleep, further making them an ideal model for understanding sleep at this age. Sleep architecture, the sleep stage composition of a sleep bout, changes across the lifespan; decreases in slow wave sleep (SWS) and increases in non-REM stage 1 (nREM1) are dramatic across the lifespan. Other sleep stages (REM, nREM2) decrease across the lifespan but at a gradual rate. These same changes are seen when comparing nap architecture across the lifespan (Mantua & Spencer, 2017). As such, naps model the developmental- and age-related changes in overnight sleep.

3. Nap physiology and timing in early childhood

Nap length is variable at this age, with most studies reporting 70–90 min sleep bouts (Giganti et al., 2014; Kurdziel, Duclos, & Spencer, 2013; Ward et al., 2007). Although naps tend to get shorter with increasing age during this time, nap length does not always correlate with age. However, several factors contribute to the length of naps, including environmental factors (e.g., light, noise) and time of day (with later naps favoring more sleep as more sleep pressure has accumulated).

Classroom naps in early education settings are often scheduled for the afternoon, taking place shortly after lunch. Ideal timing reflects the accumulation of sufficient sleep pressure as well as timing at a local minimum in the circadian rhythm (Jenni & LeBourgeois, 2006). This timing may also take advantage of the post-prandial dip, the drowsiness that onsets following lunch and is attributed to blood flow or increased insulin presence (Afaghi, O'Connor, & Chow, 2007; but see Bazar, Yun, & Lee, 2004), or may reflect a mid-day circadian trough in alertness that may be greater during development (Carskadon & Dement, 1992).

Between 3–5 years of age, naps are largely composed of SWS (about 45%) and nREM2 sleep (about 45%), with nREM1 accounting for the remainder of the sleep bout (Kurdziel et al., 2013). As nap length is typically shorter than the length of a sleep cycle at this age (around 80 min; Montgomery-Downs, O'Brien, Gulliver, & Gozal, 2006), naps contain little-to-no REM.

4. Naps and memory in early childhood

The benefit of sleep, including naps, on cognition in young adults provided the impetus to consider whether naps support cognitive functioning in early childhood. A large corpus of work in adults has focused specifically on memory. Items learned before sleep are better remembered later than when recalled after an equivalent interval spent awake (e.g., Lahl, Wispel, Willigens, & Pietrowsky, 2008; Tucker et al., 2006; Wilson, Baran, Pace-Schott, Ivry, & Spencer, 2012). This benefit is thought to reflect memory consolidation. Memory consolidation refers to a process in which memories are strengthened offline (when not engaged in the task), which yields a memory that is more stable and more easily retrieved. Declarative memories, which initially engage the hippocampus, become less reliant on this structure and are stabilized in cortical regions (Born, Rasch, & Gais, 2006; Staresina et al., 2015). Supporting this hippocampal-neocortical 'transfer' is a series of embedded oscillations that primarily occur in sleep: ripples in the hippocampus occur in conjunction with nREM sleep spindles, which are often embedded in slow waves (Born & Wilhelm, 2012). The synchronous cortical activity, along with bursts of hippocampal activity reflecting memory replay, is an ideal mechanism for stabilizing short-term memories into long-term stores.

4.1 Declarative learning

To assess whether naps benefit memory in preschool children, we started with a visuo-spatial learning task (Fig. 1A). We chose to start with this task for three reasons. First, this visuo-spatial task was designed to mimic the children's game "Concentration" (also known as "Memory") so it would be engaging for children. Second, the task allowed for variation in difficulty (number of items encoded) to accommodate the varied abilities in this age range. Third, a similar task has been shown to engage the hippocampus at encoding in adults (Postma, Kessels, & van Asselen, 2008), a possible minimum condition necessary for sleep-dependent memory consolidation (Spencer, Gouw, & Ivry, 2007).

Preschool children (36–67 months) learned the task in the morning (typically between 10–11 a.m.; Fig. 1B). This was followed by an *immediate recall* phase in which each item was presented one at a time and children responded with the location of the matching item, but no feedback was given. This provided a baseline measure of learning. Subsequently, children went about their classroom routine (free play, lunch). During the regularly scheduled nap opportunity (typically between 1–3 p.m.), children were either nap promoted with back rubbing and soothing (nap condition) or were wake promoted by providing quiet, non-stimulating activities (such as wax sticks; wake condition). Children completed both the nap and wake conditions, one week apart, with the order of conditions counterbalanced. After the rest opportunity was over (typically around 3:30 p.m.), memory for the visuo-spatial task was probed again (*delayed recall*). Recall was also assessed the following morning (*24-h recall*).

Of interest is whether memories following the nap were superior to memories following an equal interval awake. To address this and account

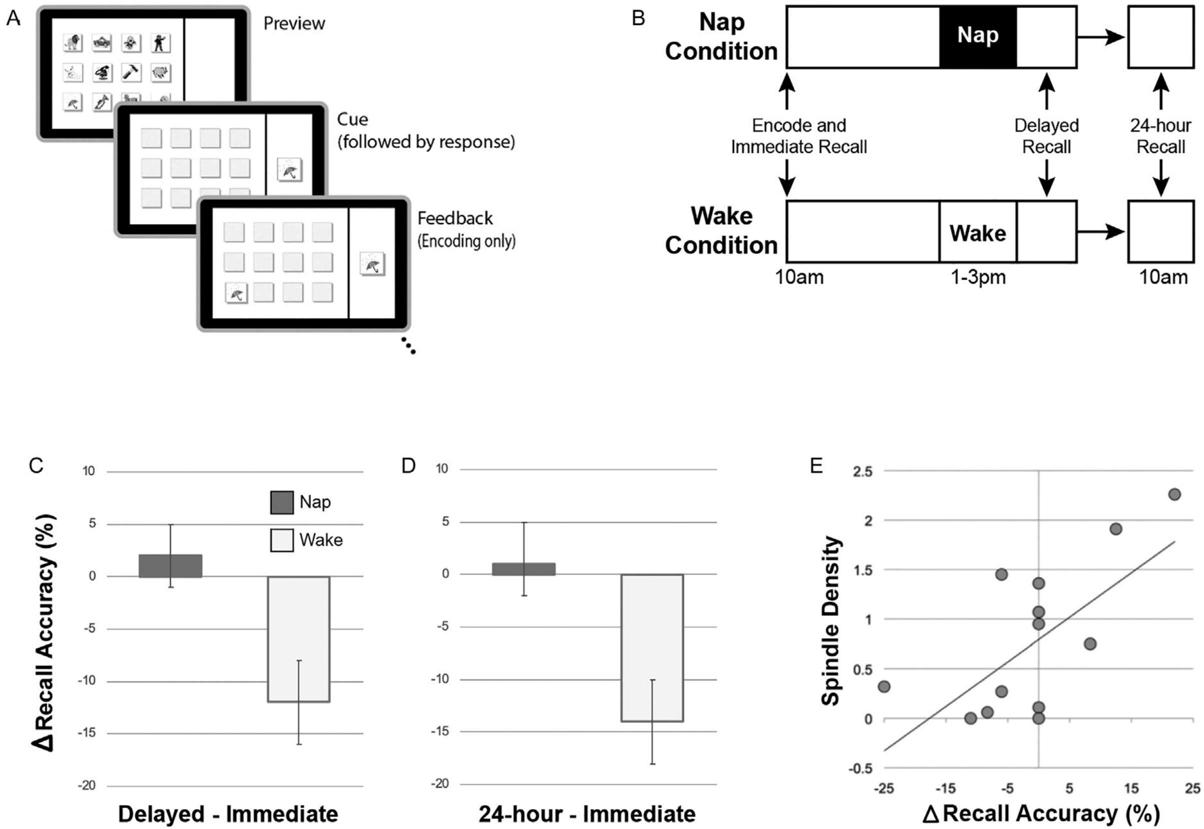

Fig. 1 (A) For a visuospatial declarative task, children learned and recalled the locations of several items on a grid. (B) On each testing day, children encoded the item locations in the morning, followed by immediate recall. Following the midday nap or wake period, delayed recall was probed. The next morning, 24-h recall was probed. (C) A comparison of the changes in recall accuracy from immediate to delayed recall across nap and wake conditions. (D) A comparison of the changes in recall accuracy from immediate to 24-h recall across nap and wake conditions. (E) The correlation between sleep spindle density and change in recall accuracy from immediate to delayed recall.

for baseline differences in learning, we calculated *ΔRecall* as delayed recall accuracy (percent correct) minus immediate recall accuracy. We found that ΔRecall was less for the wake interval, reflecting significant forgetting, compared to the nap interval. That is, when awake during the nap opportunity, children forgot approximately 12% of the items that were learned in the morning, whereas when they napped the memories were protected (no significant change; Fig. 1C).

While this finding is consistent with the hypothesis that memories are consolidated to a greater extent during the nap than during wake, there are important alternative explanations of these results that were considered. First, when nap deprived, children are likely to be inattentive, experiencing sleepiness, and emotionally dysregulated (either grumpy or giddy). This may explain why performance is superior following the nap. This consideration motivated the inclusion of the 24-h recall assessment. We found that 24-h recall, when subtracting out baseline encoding, was again significant when a nap followed learning the prior day compared to when children stayed awake following learning (Fig. 1D). If acute effects of nap deprivation accounted for worse delayed recall performance, then those performance differences should be mitigated following overnight sleep when children are sufficiently rested. Thus, the benefit of the nap does not reflect performance impairments from nap deprivation.

A second alternative account is that naps may provide passive protection from the interference that occurs during wake. In other words, naps may not be beneficial per se; rather, being awake may be damaging to memories as memories are interfered with by ongoing learning experiences. Although we attempt to minimize such concerns by providing a limited number of activities for the child to engage in during the wake condition, and activities that do not seemingly interact with the visuo-spatial task, we cannot be certain that interference did not occur. Thus, to consider whether naps played an active role in memory consolidation, we replicated the initial finding in the sleep laboratory where sleep physiology could be recorded during the nap. Sleep physiology is measured using polysomnography, a montage of physiological recordings (see Allard et al., 2019). If naps play a passive role, protecting memories from waking interference, then the longer the child naps, the more memories would be protected from interference. In other words, a significant correlation between nap length and ΔRecall for the nap interval ($\Delta\text{Recall}_{nap}$) would be expected. Alternatively, if naps benefit memories via embedded oscillations, then a relationship between measures of those sleep features and the nap benefit on memory ($\Delta\text{Recall}_{nap}$) would be expected.

We found that the correlation between $\Delta\text{Recall}_{nap}$ and nap length was not significant. However, there was a significant correlation between $\Delta\text{Recall}_{nap}$ and sleep spindle density (Fig. 1E). More sleep spindles present in nREM2 sleep was associated with greater protection of the memories learned prior to the nap. This supports an active role of naps in visuo-spatial learning.

It is possible that visuo-spatial learning is unique with respect to sleep's role in memory. Studies in animals have found that recently encoded memories are replayed in the hippocampus during nREM sleep. Replay is measured by recording hippocampal place cells during task exposure, typically while navigating a maze, and continuing to record these place cells during subsequent sleep. There is a higher correlation between the pattern of cell firing during maze exposure and firing during subsequent nREM sleep than the correlation for the pattern of cell firing during maze exposure and firing during sleep the prior night. This suggests that there is replay of recent spatial memories during nREM sleep. Given this known mechanism, it is possible that spatial memories are unique.

Yet, a study of episodic learning suggests that these results are generalizable to non-spatial tasks. Specifically, Williams and Horst (2014) demonstrated a benefit of naps on a task in which novel words were learned through a storybook task. In this study, children (around 36 months of age) were read either one 10-page storybook three times or three 10-page storybooks once. Each storybook contained two novel objects which were each named four times. Memory for the novel words was tested immediately after the storybooks were read and again following a 2.5-h delay. Children who regularly napped slept during this interval, while children who no longer napped stayed awake during this interval. Regardless of how many storybooks were used for encoding of the new words, performance was consistently better when children napped following learning. In fact, those who napped showed enhanced recall (more likely to identify the new word following the nap compared to immediate recall) while those who stayed awake had worse memory following the delay. Importantly, as with Kurdziel et al. (2013), this difference was maintained when recall was probed the next day. Strikingly, this difference even persisted when probed 1 week after learning.

An important caveat on this finding is that the sleep and wake comparison was between subjects, comparing habitual nappers (nap group) to non-habitual nappers (wake group). Lam, Mahone, Mason, and Scharf (2011) proposed that children who transitioned out of naps may have greater brain development (even when controlling for age) and may no longer 'need' naps to maintain memories (see Kurdziel et al., 2013). This point will be discussed further later in this chapter.

Yet, Giganti et al. (2014) lends further credence to the fact that naps may benefit declarative memories. They considered whether implicit aspects of memories would likewise benefit from a nap using a priming task. In this study, children (38–70 months) were presented with blurred images to identify. Images (objects or animals) were either foils or "old," having been presented in an earlier study phase (implicit priming). There was no benefit of the nap on children's performance on the priming task. However, on a basic recognition memory task for the same objects versus foils, there was a nap benefit. These results further support the role of naps on explicit declarative memories but suggest that such a benefit may not extend to implicit memory.

4.2 Motor learning

Motor learning is unique from non-motor declarative learning both in terms of encoding and consolidation. Regarding encoding, motor tasks often engage subcortical regions (cerebellum, striatum) initially, with the hippocampus possibly becoming engaged later, reflecting contextualization of the motor task with the episode or greater awareness of the sequence or strategy use. It has also been suggested that the relevant sleep mechanism for motor learning may differ from that of declarative learning. While declarative learning has been associated with SWS in young adults (Gais & Born, 2004; Rasch, Büchel, Gais, & Born, 2007), motor procedural learning is most frequently associated with nREM2 sleep (Laventure et al., 2016; Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002).

We used a similar nap paradigm as described above to examine whether motor sequence learning was benefited by a nap in early childhood (Desrochers, Kurdziel, & Spencer, 2016). Children (33–71 months) learned a 5-item sequence of keypresses in the morning followed by an immediate test. Performance was assessed following a nap and equivalent interval awake (delayed test) and again the following morning (24-h test). Performance improvements following a nap did not differ from those following wake. However, when assessed the following morning (24-h test), performance was superior if children napped (compared to staying wake) after learning the prior day (Fig. 2). Moreover, we found a significant correlation between the performance improvement over the nap and performance improvement across overnight sleep. Specifically, those who had the least over-nap

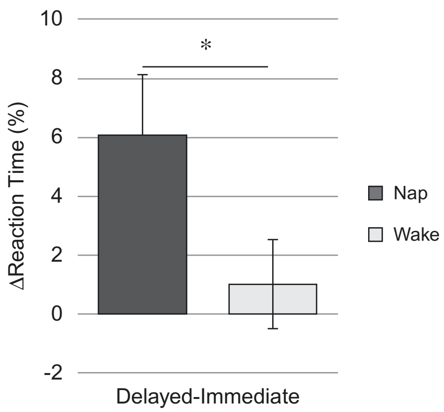

Fig. 2 A comparison of the changes in reaction time on a motor sequence task from immediate to 24-h recall across nap and wake conditions.

improvement (post-nap performance was slower than pre-nap performance), had the greatest improvement overall when probed the following day. We interpret this result to suggest that for a procedural learning task, mechanisms of plasticity (e.g., protein synthesis, dendritic spine formation) may initially impede behavioral benefits but ultimately facilitate successful consolidation. Notably, a similar result was reported in studies of song learning in juvenile zebra finches (Derégnaucourt, Mitra, Fehér, Pytte, & Tchernichovski, 2005).

Using a similar motor sequence learning task to that of Desrochers et al. (2016), Wilhelm, Metzkow-Mészàros, Knapp, and Born (2012) found that the nap benefit in early childhood may depend on initial learning. When children (4–6 years) learned the task over 10 blocks (8-item sequence repeated 5 times), they too found no nap benefit. However, if learning was enhanced by providing additional learning the prior day, performance benefits were observed at delayed recall, immediately following the nap. For comparison, they also tested adults on the same task. In adults, a nap benefit was found for the training condition, but when overtrained with initial learning the prior day, the nap did not benefit performance. This suggests that memories that are too weak (children in the "train" condition) or too strong (adults in the "overtrained" condition) are not consolidated over a nap.

Consistent with work on overnight sleep in this age group (Wilhelm et al., 2013), these studies support a role of naps in motor memory consolidation in early childhood. However, unlike the processing of declarative memories, motor learning may not show a post-nap benefit unless learning is sufficiently strong. To date, the specific mechanism underlying this benefit is unknown. Studies in adults largely support a role of nREM2 sleep (Walker et al., 2002) and sleep spindles (Tamaki, Matsuoka, Nittono, & Hori, 2008), both of which are rich in naps at this age (Kurdziel et al., 2013).

4.3 Emotional learning

Emotional learning is also a unique form of declarative learning. Amygdala activation during encoding is thought to prioritize negative memories over neutral memories in studies in young adults (Canli & Gabrieli, 2000; Dolcos, LaBar, & Cabeza, 2004). Children likewise show better recall of negative over neutral memories (Kinzler & Shutts, 2008).

Emotional memory consolidation is also distinct from consolidation of declarative memories. Amygdala reactivation during REM sleep (Maquet et al., 1996) is thought to underlie the prioritization of emotional memories for consolidation during sleep (Payne, Stickgold, Swanberg, & Kensinger, 2008). Others have suggested that SWS contributes to emotional memory consolidation in adults (Jones, Schultz, Adams, Baran, & Spencer, 2016), particularly for naps (Alger, Kensinger, & Payne, 2018), which typically lack REM in adults as well (Mantua & Spencer, 2017).

This motivated us to separately consider whether naps consolidate emotional memories in early childhood, using an emotional memory task previously used in this age group (Kinzler & Shutts, 2008; Kurdziel, Kent, & Spencer, 2018). Children (34–64 months) encoded neutral faces paired with statements that were either mean or nice. Recognition of a subset of the items was probed immediately after encoding, after a nap or equivalent interval awake, and again the following morning. There was no significant benefit of the nap compared to wake. That is, the change in memory from immediate to delayed recall, ΔRecall, did not differ for the nap and wake conditions. However, performance changes over 24 h were greatest in the nap condition. Thus, we see a delayed benefit of the naps on emotional memories similar to that reported for motor learning (Desrochers et al., 2016).

Note that we did not find a significant benefit of negative items over nice items, which may seem problematic. However, we recently reported that neutral and even mildly positive items 'behave' like negative items when encoded in that context (Jones et al., 2016).

Nonetheless, the nap must prepare the memory for overnight processing given that no behavioral changes were observed following overnight sleep in the wake condition. We posit that there is an interaction of the memory processing over the nap and overnight sleep bouts. To examine this, polysomnography was recorded on a subset of children in the sleep laboratory. We found that nap slow wave activity (SWA; the primary frequency of the EEG in slow wave sleep) was associated with greater memory decay during the nap. Yet nap SWA also predicted greater overnight improvement in memory. We interpret this to suggest that SWA in naps may yield an initially destabilized memory that is most labile to plastic processes in overnight SWS. While high SWA during the nap was associated with short-term memory decay, it was advantageous to long-term memory consolidation, potentially via the enhancement of overnight SWS. Greater plasticity over the nap, as indicated by greater SWA (Tononi & Cirelli, 2014) may allow nocturnal SWS to be more effective at consolidating and preserving the memories learned earlier in the day. In contrast, with the lack of processing and remodeling directly following learning, information is forgotten across the 24-h period in the wake condition. Newly formed memories may be more susceptible to daytime waking interference (Diekelmann, Büchel, Born, & Rasch, 2011) without plastic changes across the nap.

Although no other studies of naps and emotional memory processing have been reported in young children, these results are consistent with the reported role of SWA in emotional memory consolidation during naps in adults (Alger et al., 2018). Moreover, studies of overnight sleep in older children (10–13 years) found that overnight sleep is beneficial to emotional memories (negative scene images; Prehn-Kristensen et al., 2009). Additional studies verifying the generalizability of the delayed nap benefit and the physiological findings are needed.

5. Naps and executive functions in early childhood

Recent studies suggest that the benefit of naps on cognition may extend to executive functions as well. For instance, when children are presented with unsolvable puzzles (that included one incorrect piece which prevented completion of the puzzle), children (30–36 months) were more frustrated and exhibited more negative emotions when nap deprived compared to when they were presented with the same task following a routine nap. Moreover, positive emotions were dampened when nap deprived compared to the nap condition (Berger, Miller, Seifer, Cares, & LeBourgeois, 2012). These results suggest that naps may promote healthy emotion regulation and inhibitory control in early childhood.

To more specifically assess whether naps influence one specific aspect of emotion regulation, we used the Dot Probe task (Cremone, Kurdziel, Fraticelli-Torres, McDermott, & Spencer, 2017). The Dot Probe task provides a measure of emotional attention bias (Pérez-Edgar et al., 2011). In this task, children (37–69 months) were shown pairs of faces, one of which was emotional (happy or angry) and the other of which was neutral. Those faces were removed, and a cue (a star) was placed in the position of one of the two face images. If attention is biased towards emotional stimuli, then response times are expected to be quicker when the star is in the place of the emotional face compared to response times when the star is in the place of the neutral face. The task was performed before and after the afternoon nap, and again one week prior or after the nap condition, before and after an equivalent afternoon interval spent awake.

The emotional attention bias was measured as the difference in response time when the star was behind emotional faces compared to response time when the star was behind the neutral faces. There was no significant bias following the nap. That is, reaction times to the cue behind emotional faces did not differ from reaction times when the cue was behind neutral faces. This implies that following the nap the child was calm, or what we might call "cool as a cucumber". However, when children stayed awake during nap time, there was a significant bias towards emotional stimuli. Children responded more quickly when the star was in the place of emotional faces, suggesting a bias in attention towards emotional stimuli. This may present as a child that is over-reactive to emotional stimuli in the environment.

Is it that sleep was beneficial or that sleep (nap) deprivation was harmful? To assess whether naps serve an active role in modifying the subsequent emotional attention bias (as opposed to a detriment in responding following nap deprivation), we assessed sleep physiology. We predicted that the reduced emotional attention bias following a nap was the result of the emotional memory processing described above. That is, we posited that by consolidating emotional memories from the morning during the nap, children are able to handle new emotional challenges in a more 'even keel' way. If this is the case, then we would expect a correlation between Dot Probe performance after a nap and SWA, the physiological feature of sleep which we showed to support emotional memory consolidation (Kurdziel, Kent, & Spencer, 2018). Indeed, we found a significant correlation between these measures, suggesting that SWA in the nap may support emotional memory processing (even though no immediate performance benefits are observed), which, in turn, reduces emotional reactivity. Notably, a more direct assessment of this relationship is needed.

We also examined acute effects of naps on attention. Executive attention is the ability to regulate attention in the presence of conflicting information (Rueda, Posner, & Rothbart, 2005). A common task used to assess this function is the flanker task, in which a central stimuli is either consistent (congruent) with the orientation of flanking stimuli or inconsistent (incongruent) with the orientation of flanking stimuli (Cremone, McDermott, & Spencer, 2017). Children (35–70 months) performed the flanker task in the afternoon, following a nap. A week before or after, children performed the flanker task at the same time of day but were kept awake prior to the task, during their regular nap opportunity. Although reaction time did not differ for the nap and wake conditions, children were significantly more accurate when the flanker task was performed after a nap. Notably, this nap benefit was present for both congruent and incongruent trials, suggesting a general benefit of sleep on attention, including executive attention needed for incongruent trials.

6. What is the role of nap habituality?

Collectively, these studies provide strong support for naps in preschool age children as they provide broad cognitive benefits. This may be taken to suggest that children should continue napping. Yet children seem to "grow out of naps," no longer able to fall asleep during nap time, typically between 3–5 years of age (Weissbluth, 1995). Alternatively, naps may become less functional at the point of the biphasic to monophasic sleep transition. In consideration of this, Kurdziel et al. (2013), when reporting the declarative memory consolidation benefit of naps, separately considered habitual and non-habitual nappers. Habitual napping was defined as napping 5 or more days per week. Non-habitual napping was defined as napping fewer than 2 days per week. We found that naps were equally beneficial for habitual and non-habitual nappers. What differed is how damaging staying awake during nap time was. For habitually napping children, we found extensive forgetting when the children stayed awake. For non-habitually napping children, those that had largely "outgrown" napping, there was no significant forgetting over wake, similar to the nap condition.

Similarly, for the delayed benefit of the nap on emotional memory consolidation (Kurdziel, Kent, & Spencer, 2018), the benefit of having napped prior to learning of the emotional faces the previous day was significant for the habitually napping children. Emotional memories were protected if a nap followed learning the prior day, but emotional memories were forgotten when the habitually napping children stayed awake during naptime. However, there was no difference in memory for the nap and wake conditions (either immediately after the nap or the next day) for the habitually napping children. For these children, the memories were unchanged from the prior day whether or not they napped following learning. Thus, the nap was beneficial to both habitually and non-habitually napping children. What differed is how damaging wake was. Wake caused forgetting of memories for the children who habitually napped but not for the children who were non-habitual nappers.

We proposed that children who are non-habitual nappers have sufficiently developed memory stores to hold memories for longer without interference (Kurdziel et al., 2013). A more developed hippocampus, for instance, would allow more memories to be collected throughout the day without harm to the memories acquired in the morning. Those with a less mature hippocampus may need to nap to prevent catastrophic interference as more learning occurs throughout the day.

Consistent with this prediction, frequent naps were found to predict *lower* attention and working memory. Lam et al. (2011) used actigraphy to monitor sleep of children (3–5 years) over a 7-day period. From a battery of neurocognitive tasks, napping frequency was negatively correlated with performance on the Peabody Picture Vocabulary Test and a Number Recall test (from the Kaufman Assessment Battery). The latter measure requires attention as well as working memory. Thus, those children that napped most frequently had the poorest working memory and attention abilities. One interpretation of such a result is that napping may impair working memory and attention span. Alternatively, and consistent with the hypothesis in Kurdziel et al. (2013), nap frequency may reflect brain development such that those who are non-habitual nappers have more developed brains and a correspondingly greater working memory and attention capacity.

We likewise found a difference between habitual and non-habitual nappers in performance of an executive function task, the Dot Probe task (Cremone, Kurdziel, et al., 2017). Habitually napping children had an attention bias towards the emotional stimuli when kept awake during nap time. Napping actually reversed this bias a little, giving the children a bias away from the emotional stimuli. Conversely, whether the non-habitually napping children were kept awake or napped, there was no difference. In both conditions, the children showed no bias, either towards or away from the emotional stimuli.

However, it is worth noting that there are studies that failed to find a difference in the nap benefit for habitual and non-habitual nappers. For instance, there was similar performance following the nap and wake conditions for habitual and non-habitual nappers on the flanker task, the test of executive attention (Cremone, McDermott, et al., 2017). Likewise, in a study of language learning, Sandoval, Leclerc, and Gómez (2017) found a benefit of nap on performance, but this did not differ for habitually and non-habitually napping children (35–41 months). Children were presented with videos depicting an action which was paired with a novel word. To test generalization of the learned verbs, children were shown the action performed by a new actor and a new actor performing a novel action. Children were shown the test stimuli following a nap or equivalent time awake and were to point to the screen with the studied action. Habitually napping children were defined as those who napped four or more days per week while non-habitually napping children were defined as those napping three or fewer days per week. Performance for both groups was at chance when they stayed awake during the nap interval, while both groups were equivalently able to generalize the learned actions to new actors.

Understanding the role of nap habituality across conditions may provide insight into underlying mechanisms for the benefit of naps at this age. It will also provide necessary guidance for caregivers in supporting the nap transition.

7. Conclusions

As in adults (e.g., Mednick, Nakayama, & Stickgold, 2003; Milner & Cote, 2009), naps provide a broad benefit to cognition in early childhood. Multiple forms of memory are better the next day if a nap followed learning. These naps also benefit executive functions including attention and emotional regulation. Together, this corpus of work supports the maintenance of naps in early childcare settings. Although naps may take time away from education opportunities (70–90 min; Kurdziel et al., 2013), naps support learning goals by consolidating memories encoded in the morning and enhancing attention important for afternoon learning.

However, how long naps should be and when children no longer need to nap ("grow out of napping") are areas for additional research. For studies that reported nap length (Cremone, Kurdziel, et al., 2017; Kurdziel et al., 2013), nap length was not a significant predictor of the cognitive benefit. Rather, studies using polysomnography provide evidence that nap quality is more important than nap quantity. Consolidation of declarative memories over an interval with a nap has been associated with sleep spindles in the nap (Kurdziel et al., 2013). However, consolidation of emotional memories (Kurdziel, Kent, & Spencer, 2018) and nap-dependent improvements in the Dot Probe task (Cremone, Kurdziel, et al., 2017) correlate with slow wave activity.

Although this may seem conflicting, we propose a single underlying mechanism for the benefit of naps on memory and other emotional processes. Specifically, the part of the memory that reflects the episode (location, people) we posit to be consolidated in non-REM sleep with the support of sleep spindles and slow oscillations. While these sleep features are found in conjunction with one another, and indeed alignment might provide the most optimal conditions (Niethard, Ngo, Ehrlich, & Born, 2018), it seems they have the ability to function in isolation (Oyanedel et al., 2014; van der Helm, Gujar, Nishida, & Walker, 2011). By this view, nREM sleep would support memories regardless of their emotional tone (see Jones, Fitzroy, & Spencer, 2019).

Consolidation of memories from the morning, particularly emotional memories, would provide a proverbial 'clean slate' for taking on new memories or when faced with emotional challenges in the afternoon. Note that by this view, we posit that even though there was no visible immediate benefit to performance following the nap for the emotional memory task, we predict that those memories have been nonetheless processed even if that processing leaves the memory unstable in the short term (see Kurdziel, Kent, & Spencer, 2018).

Admittedly, there are many aspects of this integrative view that are speculative and many avenues for further research on the cognitive benefits of naps in early childhood. The most pressing need is to understand whether the proposed findings are generalizable. Most forms of memory and executive functions have been probed with a single task. Examining whether these findings and their implicated sleep stages hold up to new task probes is essential for theoretical and translational impact.

Translating these findings to recommendations and policies around napping, as might be of interest to pediatricians and early education policies, will require answers to many obvious questions. If naps benefit learning, when is it reasonable for a child to transition to monophasic sleep? Is it possible to identify this transition point with behavioral measures? How long should naps be to maximize cognitive processing while minimizing impact on overnight sleep? These questions provide a rich research agenda for the field that will have broad theoretical and translational impact.

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