RETENTION OF SOURCE MEMORIES IN PRESCHOOL-AGED CHILDREN

By

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Abstract

Children encounter varying challenges in retaining similar memories linked to specific sources. To distinguish between memories, they may make connections between specific contextual characteristics of a memory, which allow them to retrieve memories after longer delays. In the present study, we examine how naps influence long-term retention of similar and dissimilar source memories in regularly napping children and whether preschool-aged children who no longer nap retain long-term information. Children were exposed to a source memory task, where they identified learned associations between two similar objects and two dissimilar objects, assigned to two puppets, and were tested 24 hours later. To assess the influence of naps on their retention, children who regularly nap either stayed awake for at least four hours or napped within two hours following the initial task. We predicted that children who nap following the initial task will have greater perfect recall of the learned associations than children that stay awake, since children that nap have less mature cognitive networks, and must nap to retain learned information (Li et al., 2015). We found that children who napped after learning had significant retention of source memories 24-hours later; whereas children who stayed awake after learning performed no greater than chance following a 24-hour delay, suggesting that regularly napping children require naps to retain learned source information. To assess learning in children who do not regularly nap, children stayed awake for at least four hours following the initial task. We predicted that these children would not need to nap to sustain learning, since their cognitive networks have matured, not requiring them to nap soon after learning (Riggins & Spencer, 2020). We found that older children had significant retention of learned source information following a 24-hour delay; whereas younger children performed no greater than chance, suggesting that younger children who no longer nap, may still require a nap after learning.

Retention of Source Memories in Preschool-Aged Children

Episodic Memory

Episodic memory is the recollection of previous experiences, consisting of specific contextual features, such as spatial and temporal information. These features play a fundamental role in establishing the source of a memory to differentiate between similar experiences, determine the origin of a memory, and connect new stimuli with past information (Lee et al., 2016). It is a long-term memory subtype that falls under explicit (declarative) memory, which is the deliberate remembrance of previous experiences (Drummey & Newcombe, 1995). The source of a memory (e.g. a location, object, or person) and integration, or binding, of source-specific information are key factors in the formation of episodic memories (Raj & Bell, 2020). This binding of source memory occurs within the hippocampus, where this region of the brain receives information from other regions, such as the neocortex, thus allowing the brain to store this information long-term (Yonelinas et al., 2019).

Episodic-like memory emerges around 2- to 3-years of age (Bauer, 2005; Bauer, Wenner, & Dropik, 2000; Hayne et al., 2011, Tustin & Hayne, 2016). Few studies have examined the emergence of episodic memory in infancy and early childhood. It is difficult to establish an appropriate paradigm for this age group, since children are in early-verbal stages around this time. Prabhakar et al. (2018) established a paradigm that uses functional magnetic resonance imaging to observe the activity within the hippocampus of 2-year-olds when exposed to a learned song and a novel song. They identified significant hippocampal activation when children listened to the learned song compared to the new song, indicating the early role the hippocampus plays in episodic memory abilities. Hayne and Imuta (2011) had 3- and 4-year-old children explain the location of stuffed toys in the order the experimenter hid them and then search for the stuffed toys in the correct order. Four-year-olds reported more information about where each item was hidden, but the age groups performed similarly with finding the items in the correct order. While this study reflects the improvement of episodic memory with age, this is only true for the verbal recall portion, in which the 4-year-olds report more details. However, this could more so reflect the verbal abilities of 3-year-olds, instead of their episodic-memory abilities in comparison to 4-year-olds. In a similar experiment, Cuevas et al. (2015) had 3- and 4-year-old children watch an experimenter hide four toys in four separate rooms, and then asked them to identify the toy, which room and where in the room it was hidden, and the order they visited each room. Four-year-olds had greater recall, recognition, and binding of the task, compared to the 3-year-olds. The observed age-related differences in episodic memory components in this study accords with Hayne and Imuta (2011) and avoids the possible limitations in their paradigm. Moreover, episodic memory continues to develop in early childhood from 4- to 6-years of age (Canada, Hancock, & Riggins, 2022; Drummey & Newcombe, 2002; Newcombe et al, 2022). Benear et al. (2021) investigated episodic memory differences in 4-year-olds and 6-year-olds through an association task, in which they are exposed to similar and unique associative pairs and are asked to identify the correct associated item immediately after learning and 24-hours later. Overall, 6-year-olds perform better on the task than 4-year-olds, indicating the continued development from 4- to 6-years of age.

Relational Binding

Relational-binding, an element of episodic memory, appears around 2-years of age and greatly improves by 6-years of age (Newcombe et al., 2022). There appears to be a strong improvement within this range, as indicated by research investigating inter-item binding (e.g., pairing a household item with a unique location in a house) (Lee et al., 2016; Lloyd, Doydum, &

Newcombe, 2009; Sluzenski, Newcombe, & Kovacs, 2006). This improvement is also observed in more complex pairings (e.g., dog paired with window in a red house, and dog paired with water in a blue house) (Benear et al., 2021; Ngo et al., 2019; Ngo, Newcombe, & Olson, 2018).

This development is marked by changes in neuroanatomy. From birth to 2-years, the hippocampus, a region located within the medial temporal lobe, which is important for memory development, experiences an increase in volume (Knickmeyer et al., 2008), supporting the initial presence of episodic memory capabilities. The hippocampus consists of multiple subfields arranged along the longitudinal subregions. These subfields are the cornu ammonis (CA1-4), dentate gyrus (DG), and presubiculum–subiculum complex. In young children, CA1 is associated with memory (Schlichting et al., 2017; Tamnes et al., 2014) and tends to be larger in younger children compared to older children (Riggins et al., 2018). Furthermore, the hippocampal subregions (head, body, and tail) increase in volume from early- to mid-childhood (Canada, Botdorf, Riggins, 2020) and decreases from mid-childhood to adulthood (Schlichting et al., 2017). Additionally, the entorhinal cortex (EC), a region within the medial temporal lobe that connects the neocortex and hippocampus, reaches its maximum volume between the ages of 2- and 4-years (Li et al., 2015), supporting the continued development of episodic memory. Moreover, there is a bidirectional relationship between these neurodevelopmental changes and the continued encoding and storage of source memories; where these changes predict the development of source memories and the development of source memories predicts these changes (Geng, Botdorf, & Riggins, 2020).

Pattern Separation

The ability to distinguish between similar details, or pattern separation, is important in mitigating overlap in stimuli that would otherwise not allow us to form accurate memories that we can differentiate from similar memories (Newcombe et al., 2022). Studies investigating this ability have used the Mnemonic Similarity Task to identify behavioral expressions of pattern separation. In this task, children are initially shown a list of objects and then later shown a test list of objects that include some of the same objects from the first list, some similar versions of the first set of objects, and some different objects from the first set. Four-year-olds are more likely to identify the similar objects as being part of the first list (Ngo et al., 2019; Ngo, Newcombe, & Olson, 2018) compared to 6-year-olds (Canada et al., 2019; Keresztes et al., 2018; Rollins & Cloude, 2018). Moreover, younger children's performance correlates with greater volume of hippocampal subfields; whereas, in older children, better performance correlates with a smaller volume, suggesting developmental differences in the hippocampus contribute to age-related improvements in specific memory formation (Canada et al., 2019).

Sleep and Memory

In early childhood, children's brains are constantly subjected to novel stimuli that require an overproduction of synapses within the areas that help with learning, the hippocampus and neocortex, in order to encode and store new information (Spencer & Riggins, 2022). During this period, children nap to avoid overworking their learning systems, thereby strengthening their storage of episodic memories. When children receive new information, this information is briefly stored in the hippocampus, until it can be consolidated during sleep (Moscovitch et al., 2016). When children nap, their memories are stabilized within the neocortex through communication between the hippocampus (sharp-wave ripples with reactivation) and neocortex (cortical slow waves and sleep spindles) (Berres & Erdfelder, 2021; Buzsáki, 1989; Rasch & Born, 2013; Schabus et al., 2006).

Studies investigating nap physiology and learning in children have found that naps primarily consist of stage 2 non-rapid eye movement sleep (nREM2) and slow-wave sleep (SWS), both of which promote memory stabilization within the neocortex and learning (Kurdziel, Duclos, & Spencer, 2013; Lokhandwala & Spencer, 2021; Noh et al., 2023; Prabhakar et al., 2018). NREM2 is characterized by short bursts of brain waves (neural oscillations), called sleep spindles. SWS is often referred to as deep sleep and is observed by a slowing of neural oscillations (Allard et al., 2019). Within these slow oscillations, sleep spindles and ripples from the hippocampus timed with the up-phase of the slow oscillation, result in strengthening of episodic memories in the neocortex (Rasch & Born, 2013; Schabus et al., 2006).

Kurdziel, Duclos, and Spencer (2013) tested the declarative memory of habitually napping and non-habitually napping preschool-aged children. They had the children encode new information through a visual-spatial task and then tested them three times. The first test was immediately after encoding, before children napped, the second test was after the children napped, and the third test was 24-hours later. Children performed similarly for the immediate recall test, regardless of nap status. Also, children’s recall was significantly greater when they napped compared to when they stayed awake after encoding. Furthermore, naps have no influence on children’s recall when they do not regularly nap. These results emphasize the importance of naps in retaining learned information. Consistent with these results, children who regularly nap have greater recall when they nap following learning, rather than stay awake, and naps have little to no influence on the recall of children that do not regularly nap (Esterline & Gómez, 2021), further aligning with the findings of Kurdziel, Duclos, and Spencer (2013).

Furthermore, Kurdziel, Duclos, and Spencer (2013) observed children’s nap physiology and memory through polysomnography. They found a positive correlation between sleep spindle density and memory performance indicating the importance of naps in improving memory performance in children. Moreover, Prabhakar et al. (2018) identified that children as young as 2-years have the ability to reactivate hippocampal-dependent memories during naps. Additionally, Allard et al. (2019), found a positive correlation between sleep spindle density and memory performance in a visual-spatial task in 3- to 5-year-olds. In line with these results, Lokhandwala & Spencer (2021) also found a positive correlation between sleep spindle density and memory performance in a storybook task in 3- to 6-year-olds. Overall, these findings further support the importance of naps in consolidating children's learning by demonstrating the positive relationship between nap physiology and memory performance.

Children between the ages of 3- to 5-years-old are transitioning from biphasic sleep (sleeping at night and napping during the day) to monophasic sleep (only sleeping at night). The aforementioned studies suggest that this transition occurs due to the full development of the cortex, as indicated by the mapping of slow waves, since slow waves show cortical connections (Allard et al., 2019; Kurdziel, Duclos, & Spencer, 2013; Lokhandwala & Spencer, 2021; Prabhakar et al., 2018). Lam et al. (2011) first suggested children may transition out of naps due to brain maturation. They found that the number of times preschool-aged children nap is negatively correlated with their performance on cognitive assessments, therefore, they speculate that children who nap regularly may have less mature cognitive networks than children who no longer nap. Expanding on this research, Riggins et al. (2018), assessed source memory in 4- to 8-year-old children, observing the relationship between memory performance and hippocampal volume. They determined that memory correlates with the volume of the hippocampal subfields (i.e., the cornu ammonis (CA1-4), dentate gyrus (DG), and presubiculum–subiculum complex). Overall, children with a smaller CA1 in the body of the hippocampus had better memory performance than children with a larger CA1. This means that a smaller CA1 in the body is representative of a more mature brain. Expanding on these findings, Riggins and Spencer (2020) found that children who regularly nap have a larger CA1 in the body, compared to children that no longer nap. Combined, Riggins and Spencer (2020) argue that habitually napping children rely more heavily on the transfer of episodic memories from the hippocampus to the neocortex during naps as a result of immature cognitive networks.

The Current Study

The present study aims to understand how this period of changes in sleep habits and memory development influences long-term retention of associations between similar and dissimilar object pairs to a target in 3.5-, 4.5-, and 5.5-year-old children.

In Experiment 1, we explored the role naps play in the retention of learned associations between similar and dissimilar objects and their target pairs following a 24-hour delay in habitually napping 3.5-year-old children. Based on the existing literature supporting a greater retention of learned associations in regularly napping children that nap following a 4-hour delay (Esterline & Gómez, 2021), we are implementing a 24-hour delay to further determine the effect nighttime sleep has on consolidating learned information. To investigate this, we randomly assigned habitually napping children to either nap within two hours of learning or stay awake for at least four hours following training. If naps are necessary for retaining source memories at 3.5-years, then nappers that nap will have greater retention of learned associations than those that do not nap.

In Experiment 2, we investigated the recall of learned associations after a 24-hour delay in 3.5-, 4.5-, and 5.5-year-olds that no longer nap to determine if there are observable age-related differences in memory following a longer 24-hour delay. To investigate this, children who no longer nap are instructed to stay awake for at least four hours following training. If children who transition out of habitual napping no longer need to nap soon after learning, then there will be no significant difference in the retention of learned associations, as shown in previous studies that observed retention over a shorter delay (Allard et al.; 2019, Riggins & Spencer, 2020, Esterline & Gómez, 2021).

Experiment 1: The effects of a nap on long-term retention of similar and dissimilar source memories in regularly napping 3.5-year-olds.

Methods

Preschool-aged children that maintain biphasic sleep patterns have been shown to require naps after learning to retain learned information before further consolidation during nighttime sleep. This is because sleep spindles and cortical slow-waves are present during these naps, since children spend a majority of the nap in nREM2 and SWS (Kurdziel, Duclos, & Spencer, 2013; Lokhandwala & Spencer, 2021; Noh et al., 2023; Prabhakar et al., 2018). These physiological markers strengthen new memories in the neocortex through hippocampal-neocortical dialogue (Rasch & Born, 2013; Schabus et al., 2006).

In the present experiment, we asked if regularly napping preschool-aged children better retain source information 24-hours later when they nap or stay awake after learning, and the details they may retain. We had regularly napping 3.5-year-olds either nap or stay awake after learning source information and participate in a test 24-hours later. We hypothesized if naps are necessary for retaining source memory at 3.5-years, then the Nap group will show better retention than the Wakefulness group.

Participants

We recruited participants aged 3.5-years-old through social media and local events in Tucson, Arizona. After recruiting, we emailed parents to gather more information on their sleep schedule, birthweight, and gestational age, to verify children were more than 5.5lbs at birth, a gestational age of 36 to 42 weeks, and categorize them as habitual nappers (napping more than 4 days per week) or non-habitual nappers (napping 3 or fewer days a week). When 3.5-year-olds were within the appropriate age range (42 - 47 months), experimenters scheduled them when they were expected to be awake for at least four hours (Wakefulness condition) or when they were expected to nap within two hours of the training (Nap condition). The condition assignment (Nap or Wakefulness) is determined randomly before contacting parents. If children assigned to the Nap condition did not nap within two hours of training, or children assigned to the Wakefulness condition slept within four hours of training, their data were excluded from the study.

The final sample consisted of 17 children in the Nap group (M = 44.2 months, range = 42.8 - 46.4 months) and 18 in the Wakefulness group (M = 44.7 months, range = 41.8 - 47.3); $t(29.6) = -0.91$, $p = 0.35$. We discarded data from 26 children due to experimenter error (n = 9), changes in the experimental design/condition assignment (e.g., a child in the Wakefulness condition sleeping within four hours of the first appointment) (n = 11), refusal to participate (n = 5), and low birthweight (n = 1).

Materials

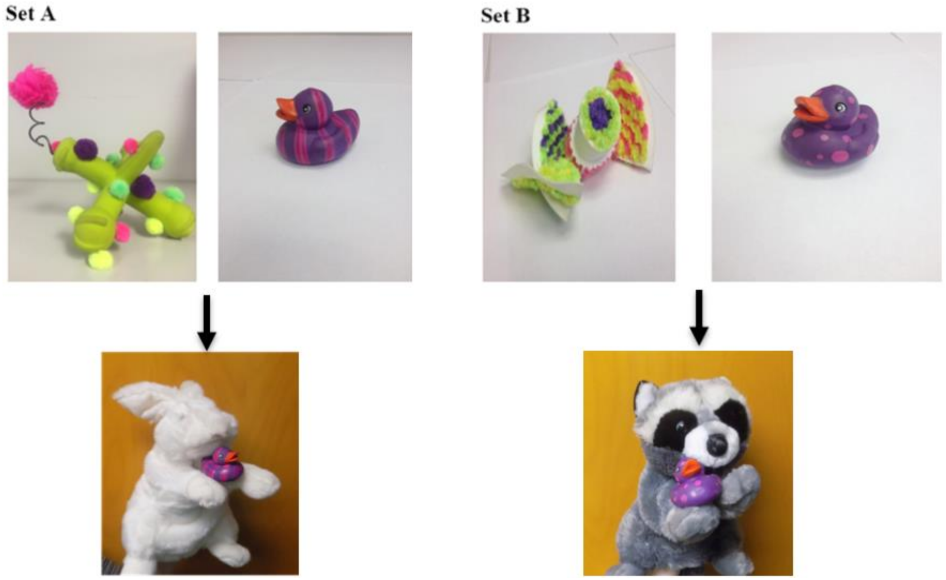
To assess source memory, we assigned one of two similar objects and one of two dissimilar objects to Set A or B, each comprising one similar object and one dissimilar object, then randomly assigned these sets to two puppets, Mr. Bunny and Mr. Raccoon (see Figure 1) placed in either a red or yellow box to assist children in remembering the object-source associations. Similar objects share the same color, shape, and size, differing in pattern, whereas, the dissimilar objects are similar in color and size, differing only in shape and pattern. We used a third puppet, Mr. Owl, to test children's retention of object assignments.

Source memory retention was categorized as either a perfect learner, dissimilar-pair learner, similar-pair learner, or non-learner. Children who correctly identified all object assignments are considered perfect learners. Children who correctly identified the assignments of both dissimilar objects but one or fewer similar objects are dissimilar-pair learners. Children who correctly identified the assignments of both similar objects but one or fewer dissimilar objects are similar-pair learners. Finally, children who correctly identified one or fewer similar objects and one or fewer dissimilar objects are non-learners.

To monitor sleep, we asked participants to wear sleep-monitoring watches, called Actiwatches, during the 24-hour delay. We also asked parents to fill out two sleep questionnaires, the first asking about the child’s typical sleep patterns, and the second asking about the child’s sleep during the 24-hour delay.

Figure 1

Object Pair Assignments Example



Procedures

Each appointment took place over two consecutive days. On Day 1, children completed a practice session at home to ensure their ability to participate in the task, followed by criterion training. On Day 2, children came to the lab to complete the test.

Day 1: Practice and Training. During practice, we presented children with a pointing task where they identified two common objects: an apple and a cup. Then we asked them to point to each item to ensure their understanding of the task. Following this, the experimenter took out Mr. Bunny and introduced the puppet by saying, “This is Mr. Bunny.” Then the experimenter picked up the apple using the puppet and in a deeper voice said, “Hi, this is my apple.” Then, the experimenter pulled Mr. Raccoon out and repeated the previous step in a distinct, high-pitched voice. Next, the experimenter set the puppets on their assigned boxes, mixed the two objects up behind their back, and then asked the children to point to the owner of the cup. If the child pointed correctly, the experimenter asked them to point to the owner of the apple. If the child did not correctly identify the owners in either case, the experimenter provided the correct assignments and repeated while holding the correct puppet “This is my apple/cup” in the appropriate voice. Then the experimenter will ask the child to point again till they correctly identify the object assignments or until four iterations. If the child did not complete the practice within four iterations, the experimenter moved onto criterion training and delay test, and the data was discarded.

Prior to the start of criterion training, the experimenter explained to the child they would be introduced to toys, some belonging to Mr. Bunny and some belonging to Mr. Raccoon, and they need to remember which toy belongs to which puppet.

Following the set assignment and order specified in the condition, the experimenter introduced the similar and dissimilar objects using the appropriate puppet. The experimenter held up each object with the assigned puppet and repeated three times in the appropriate voice, “This is Mr. Bunny’s/Mr. Raccoon’s toy,” tilting the puppet to each side, showing the sides of the object. After all four objects were presented, the experimenter separated the boxes and mixed up the objects with the puppets, while exclaiming, “Wee,” to pretend the puppets are playing. Then, the experimenter yawned and said, “They’re so tired from all that playing, they’re going to take a nap,’ placing the two puppets placed on their boxes while using two distinct snores for each puppet. Next, the experimenter introduced the control puppet, Mr. Owl, for the test by saying, “Hoo! Hoo! Here comes Mr. Owl! Can you help him?”

Following the test object order, the experimenter held each object in front of the child using Mr. Owl, and in a third distinct voice, asked participants to point to the owner of each object. Since Mr. Bunny and Mr. Raccoon were sleeping during this portion, Mr. Owl requires the child's assistance in putting the toys away. If the child correctly identified the assignment of all four objects, the test was complete. If the child did not correctly identify the assignment of all four objects, the experimenter repeated the criterion training, either until they correctly completed the task or until they completed four iterations of the task.

After the completion of practice and training, we attached the Actiwatch and asked parents to complete the first sleep survey.

Day 2: Test. 24-hours after criterion training, the child came into the lab. The experimenter repeated the final portion of the training procedure, starting with mixing the toys up on the ground with Mr. Bunny and Mr. Raccoon. Since this is the test, the procedure is only done once to assess the child's retention.

After the completion of the test, the experimenter retrieved the Actiwatch and asked parents to complete the second sleep survey.

Results

Learning Trials to Criterion

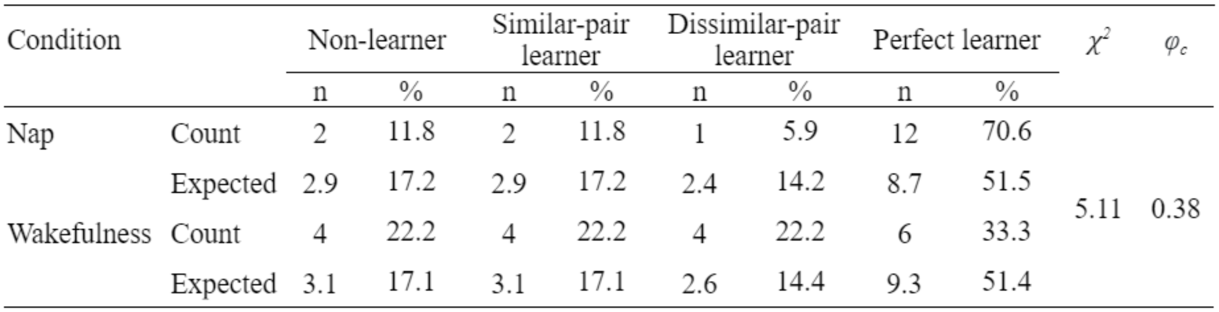
We conducted an independent means t-test to determine if there is a significant difference in the average number of trials it takes habitually napping children in the Nap condition to reach criterion compared to the children in the Wakefulness condition. Criterion is met when the child correctly identifies all four objects' assignments. We observed that children in the Nap group ($M = 1.9$, $SE = 0.3$) demonstrated no significant difference in the average number of trials to criterion compared to children in the wakefulness group ($M = 2.2$, $SE = 0.3$) $t(32.9) = -0.64$, $p = 0.53$. This is supported by Kurdziel, Duclos, and Spencer (2013), where they found that habitually napping children have similar immediate recall, regardless of nap status.

Outcome by Condition and Learner Type

We conducted a chi-square test of independence using a 2 x 4 contingency table to identify if there is a difference in habitually napping children's retention of source memories after a 24-hour delay between children who nap after learning and children who stay awake after learning. Table 1 shows the frequencies cross tabulated by condition (Nap vs. Wakefulness) and learner type (non-learner, similar-pair learner, dissimilar-pair learner, perfect learner). The table also shows the resultant chi-square statistic plus effect size, calculated using Cramer's V. This revealed no significant association between the conditions and learner type with a moderate effect χ^2 (3, N = 35) = 5.11, p = 0.16, φ_c = 0.38.

Table 1

Condition by Learner Type Chi-Square Test of Independence



Condition		Non-learner		Similar-pair learner		Dissimilar-pair learner		Perfect learner		χ^2	φ_c
		n	%	n	%	n	%	n	%		
Nap	Count	2	11.8	2	11.8	1	5.9	12	70.6	5.11	0.38
	Expected	2.9	17.2	2.9	17.2	2.4	14.2	8.7	51.5		
Wakefulness	Count	4	22.2	4	22.2	4	22.2	6	33.3		
	Expected	3.1	17.1	3.1	17.1	2.6	14.4	9.3	51.4		

As we hypothesized that habitual nappers who nap after learning would exhibit better source memory retention, we conducted targeted analyses for each condition. A Chi-square test of independence using a 1 x 4 contingency table resulted in a significant association with learner type for the Nap condition χ^2 (3, N =17) = 19, p < 0.001, reflecting greater numbers of perfect learners compared to other learner types, but not the Wakefulness condition, χ^2 (3, N =18) = 0.67, p = 0.88. This supports our hypothesis that habitually napping children who nap after learning will have greater perfect recall of learned source memories than those who stay awake after learning.

Discussion

We hypothesized if naps are necessary for retaining new source memories at 3.5-years, then the Nap group will show better retention than the Wakefulness group. The initial analysis did not support this, as it revealed that no association between condition and learner type. Further targeted analyses revealed an association across learner types within the Nap group. Specifically, we observed a significant association with the perfect learner category. In contrast, there was no significant association between the learner types within the Wakefulness group. These results indicate that napping after learning supports the retention of learned source memories after a 24-hour delay in habitually napping children. Moreover, while there are still observed frequencies of children having perfect recall when they stay awake after learning, these results are no greater than chance, indicating that staying awake is not beneficial for retaining source memories in habitually napping children. These findings further support that habitually napping children must nap to retain new memories, as observed in Kurdziel, Duclos, and Spencer’s study (2013) that investigated visuospatial declarative memory and Esterline and Gómez’s study (2021) that investigated associative memory.

Experiment 2: The effects of age on the long-term retention of similar and dissimilar objects in non-napping 3.5-, 4.5-, and 5.5-year-old children.

Methods

Preschool-aged children that no longer nap have been shown to not need naps to retain learned information seemingly due to the maturation of cognitive networks (Riggins, 2018; Riggins & Spencer, 2020). Furthermore, the brain continues to mature with age, resulting in improvements in source memory retention markedly between 4-years of age and 6-years of age

(Drummey & Newcombe, 2002; Lloyd, Doydum, & Newcombe, 2009; Sluzenksi, Newcombe, & Kovacs, 2006).

In the present experiment, we asked if children that no longer nap see differences in source memory retention from 3.5-years to 5.5-years. We had children that no longer nap habitually participate in the same procedure described in Experiment 1 and then stay awake at least four hours following the initial learning task. We hypothesized if children no longer need to nap soon after learning to support retention due to brain maturation, then there will be no observed difference in retention across age.

Participants

We recruited participants aged 3.5-, 4.5-, and 5.5-years-old through social media and local events in Tucson, Arizona. After recruiting, we emailed parents to gather more information on their sleep schedule, birthweight, and gestational age, to verify children were more than 5.5lbs at birth, a gestational age of 36 to 42 weeks, and categorize them as habitual nappers (napping more than 4 days per week) or non-habitual nappers (napping 3 or fewer times a week). When 3.5-, 4.5-, and 5.5-year-old non-habitual nappers were within the appropriate age range (42 - 47 months for 3.5-year-olds, 54 - 59 months for 4.5-year-olds, and 66 - 71 months for 5.5-year-olds), experimenters scheduled participants when they were expected to be awake for at least four hours (Wakefulness condition). If children assigned to the wakefulness condition slept within four hours of training, their data was excluded from the study.

The final sample consisted of 26 3.5-year-olds (*M* = 43.8 months, range = 41.9 - 47.3 months), 27 4.5-year-olds (*M* = 55.5 months, range = 53.7 - 59 months), and 29 5.5-year-olds (*M* = 68.5 months, range = 65.9 - 71.8 months). We discarded data from 22 3.5-year-olds, due to experimenter error (*n* = 10), changes in the experimental design/condition assignment (e.g., a child in the Wakefulness condition sleeping within four hours of the first appointment) (n = 7), and refusal to participate (n = 5). Data from 12 4.5-year-olds were discarded due to experimenter error (n = 3), changes in the experimental design/condition assignment (n = 6), refusal to participate (n = 2), and not passing the practice task (n = 2). Data from 10 5.5-year-olds were discarded due to experimenter error (n = 2), changes in condition assignment (n = 5), low-birthweight (n = 1), refusal to participate (n = 1), and not passing the practice task (n = 1).

Materials

The same materials from Experiment 1 were utilized for Experiment 2 (see Figure 1).

Procedures

The same procedure from Experiment 1 was utilized for Experiment 2.

Results

Learning Trials to Criterion

We conducted a one-way analysis of means to determine if non-habitually napping children require a significantly different number of trials on average to reach criterion. This test assumes unequal variances for learner types across age groups, as indicated by Levene’s Test for equality of variances ($p < 0.001$). Criterion remains defined as the correct assignment of all four objects during training. The analysis revealed a significant difference in the number of trials to criterion among children in different age groups, $F(2, 39.01) = 13.42$, $p < 0.05$. Post hoc comparisons using Tukey’s Honest Significant Difference (HSD) test identified a significant difference in the number of trials to criterion between 3.5- (M = 2.38, SE = 0.27) and 5.5-year-olds (M = 1.14, SE = 0.07), $p < 0.001$. We observed no significant difference in the number of trials to criterion comparing 3.5- (M = 2.38, SE = 0.27) and 4.5-year-olds (M = 1.74, SE = 0.20), p = 0.051, and 4.5- (M = 1.74, SE = 0.20) and 5.5-year-olds (M = 1.14, SE = 0.07), p = 0.06.

Outcome by Age and Learner Type

We conducted a chi-square test of independence using a 3 x 4 contingency table to identify differences in retention of source memories by age. Table 2 shows the frequencies cross tabulated by age (3.5-, 4.5-, and 5.5-years) and learner type (non-learner, similar-pair learner, dissimilar-pair learner, perfect learner). This revealed no significant association between age and learner type with a moderate effect χ^2 (6, N = 82) = 6.78, p = 0.34, φ_c = 0.20.

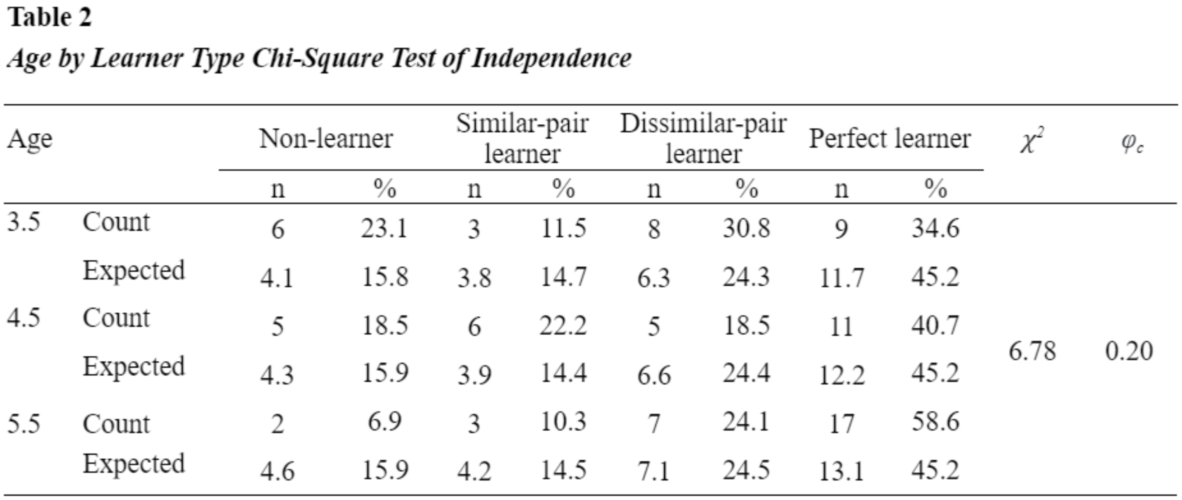


Table 2

Age by Learner Type Chi-Square Test of Independence

Age		Non-learner		Similar-pair learner		Dissimilar-pair learner		Perfect learner		χ^2	φ_c
		n	%	n	%	n	%	n	%		
3.5	Count	6	23.1	3	11.5	8	30.8	9	34.6	6.78	0.20
	Expected	4.1	15.8	3.8	14.7	6.3	24.3	11.7	45.2		
4.5	Count	5	18.5	6	22.2	5	18.5	11	40.7		
	Expected	4.3	15.9	3.9	14.4	6.6	24.4	12.2	45.2		
5.5	Count	2	6.9	3	10.3	7	24.1	17	58.6		
	Expected	4.6	15.9	4.2	14.5	7.1	24.5	13.1	45.2		

Although we hypothesized there would be no difference in source memory retention across age once children cease habitual napping, we conducted targeted analyses for each age group, due to the significant differences observed between age and trials to criterion suggesting potential developmental cognitive differences between age groups, specifically between the older 5.5-year-olds and younger 3.5-year-olds. We conducted three Chi-square tests of independence with a 1 x 4 contingency table for each age group. This revealed no significant difference in the percentage of 3.5-year-old children in each learner type χ^2 (3, N = 26) = 3.23, p = 0.36. Similarly, there was no significant difference in the percentage of 4.5-year-old children in each learner type χ^2 (3, N = 27) = 3.67, p = 0.30. In contrast, there was a significant difference in the percentage of 5.5-year-olds by learner type χ^2 (3, N = 29) = 19.41, p < 0.001.

Discussion

We hypothesized if children no longer need to nap soon after learning to support retention due to brain maturation, then there will be no observed difference in retention across age. The initial analysis did not support this, as it revealed no association between age and learner type. We conducted further targeted analyses given the observed differences in the average number of trials to criterion between age, which may indicate there may be significant development of episodic memory between 3.5-years and 5.5-years. Further analysis indicated that only the 5.5-year-old group has significant associations with learner type, specifically with the perfect learner category. This indicates that the 3.5- and 4.5-year-old groups performed no greater than chance. Combined with the observed differences in the number of trials to reach criterion, these results reveal that despite nap cessation, there is continued cognitive development between 4.5-years and 5.5-years, specifically relating to episodic memory. These results contradict the initial speculation that children transition out of naps due to maturation in cognitive networks (Lam et al., 2011; Riggins, 2018; Riggins & Spencer, 2020). However, we do not have brain data to fully support this contradiction. These results do support the continued development of memory from 3- to 6-years of age (Drummey & Newcombe, 2002; Lloyd, Doydum, & Newcombe, 2009; Sluzenksi, Newcombe, & Kovacs, 2006).

General Discussion

Episodic memory involves using specific contextual details to establish the source of previous experiences (Lee et al., 2016). The combinations of details are used to develop relationships between them and a memory, resulting in memory binding. It is this process that allows us to retrieve memories after delays. In the present study, we observed how this process may develop in preschool-aged children, taking into consideration the influences of napping and age. We had 3.5-, 4.5-, and 5.5-year-old children learn associations between object pairs and a puppet and then tested them after a 24-hour delay. To do this, the children must first identify the visual differences between a similar object and dissimilar object, then they must identify differences between each similar item (varying only in pattern) and each dissimilar object (varying in shape and pattern), before finally, binding each object pair to their assigned puppets.

In the first experiment, we compared the retention of new source memories for similar and dissimilar object pairs in habitually napping 3.5-year-olds by whether they napped within two hours of learning or stayed awake within four hours of learning. Based on preliminary studies that identified no differences in retention of learned information after an immediate delay but observed improved memory retention when habitually napping children nap after learning, we predicted that children who nap after learning will have greater perfect recall than children that stay awake (Esterline & Gómez, 2021; Kurdziel, Duclos, & Spencer, 2013). This prediction was supported in our findings, as we identified that children in the Nap group have greater perfect recall compared to other learner types, and children in the Wakefulness group performed no better than chance across each learner type. These results implicate the importance of maintaining nap times in preschools to support early learning and cognitive development.

In the second experiment, we compared the long-term retention of similar and dissimilar source memories in non-habitually napping 3.5-, 4.5-, and 5.5-year-old children. Source memory is correlated with the volume of hippocampal subfield, CA1, where children with a smaller CA1 have better source memory retention compared to those with a larger CA1 (Riggins, 2018). This subfield is smaller in 4- to 6-year-old children who no longer nap compared to those that do nap, suggesting that habitual napping is associated with less mature cognitive networks and non-habitual napping is related to matured cognitive networks (Riggins & Spencer, 2020. Since children 4- to 6-years of age who no longer nap are suggested to have reached similar cognitive maturity, we predicted there will be no significant difference in source memory retention of similar and dissimilar objects across age groups. Our findings did not support this prediction, instead we found a significant association with perfect retention with the older, 5.5-year-old group, but no significant associations with the younger, 3.5- and 4.5-year-old groups, suggesting there may be age-related cognitive differences in children who no longer nap. While Riggins and Spencer (2020) posit that 4- to 6-year-old children who no longer nap have similar cognitive maturity, our results suggest otherwise; however, since we do not have brain data to further support our findings, Riggins and Spencer's suggestions may stay fundamentally the same. Instead, our results support previous research that identified improvements in memory and memory binding between 4- and 6-years of age (Drummey & Newcombe, 2002; Lloyd, Doydum, & Newcombe, 2009; Sluzenksi, Newcombe, & Kovacs, 2006).

Limitations and Future Research

There were some limitations observed in this study. First, the dissimilar objects, originally named "distinct objects" are more similar than intended. Similar objects are similar in color, shape, and size, differing in their pattern, whereas, the dissimilar objects are similar in color and size, differing only in shape and pattern. With that in mind, the observed differences in recall of similar and dissimilar objects are similar across condition and age groups, which may indicate that the dissimilar objects are not distinct enough to be as clearly separated as intended. Future research should investigate the differences in recall of similar and dissimilar objects using more distinct dissimilar objects. This will allow us to understand at what age children may begin to distinguish between similar objects. The similarities in observed frequencies of similar-pair learners and dissimilar-pair learners may also be due to small sample sizes. A larger sample size will indicate whether it would be necessary to use more distinct dissimilar objects because this would provide greater power. Furthermore, a larger sample size may strengthen our chi-square findings, as a chi-square test assumes greater than five frequencies in each cell, and we have observed less than frequencies of less than five in many of the cells. However, it is possible that increasing the sample size will not result in greater than five observed frequencies in each cell due to the inability to manipulate the type of learner each child is.

Moreover, data collection has been ongoing for multiple years now and has been run by many research assistants over this time. This may present differences in how the study is conducted, which limits control over the study's procedures. For example, during the start of the coronavirus pandemic, researchers wore masks with clear cutouts so the children could see the experimenter's mouth; however, masks muffle speech and this may distort what the children were able to understand. Additionally, in summer of 2022, the lab did not have any more clear masks, so experimenters wore typical surgical masks during the study, and in spring of 2023, the lab no longer required masks be worn during the experiment, so experimenters no longer wore masks. This discontinuity may have altered the results as this is limiting control over the procedure and has contributed greatly to the number of discards because of experimenter errors.

Finally, location may work as another binding feature for memories, which would mean that children may have greater retention of learned source information when they are tested in the environment they learn in. However, in the present study, children are tested in a different environment than they learn in, which may result in worse retention than may occur. To counteract this, we have ensured that all children learned in their own homes on the first day of the study and then tested in the lab on the second day, providing more control to the location of learning and test.

Conclusion

Our experiments have investigated the development of source memories in preschool-aged children, specifically investigating the retention of similar and dissimilar source memories across age and following periods of naps and wakefulness. We predicted that children that nap regularly require a nap after learning to fully support long-term retention. We also predicted that children who have transitioned out of napping will have similar long-term retention regardless of age. Our findings suggest that naps are necessary to support learning in habitually napping children. They also suggest that episodic-like memory continues to develop between 3- and 6-years of age, which may indicate that naps are still necessary for younger children to support learning, even if they have transitioned out of biphasic sleep. Even though more data is needed to provide more power to our findings, investigating the role of naps in early development of source memory is important to understanding the implications of maintaining nap times in preschools.

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