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Gist extraction and sleep in 12-month-old infants

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Abstract

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Keywords

12-month-old, gist, infants, extraction, sleep

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Gist extraction and sleep in 12-month-old infants

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Abstract

Gist extraction is the process of excerpting shared features from a pool of new items. The present study examined sleep and the consolidation of gist in 12-month-old infants using a deferred imitation paradigm. Sixty infants were randomly assigned to a nap, a no-nap or a baseline control condition. In the nap and no-nap conditions, infants watched demonstrations of the same target actions on three different hand puppets that shared some features. During a 4-hour delay, infants in the nap condition took a naturally scheduled nap while infants in the no-nap condition naturally stayed awake. Afterwards, infants were exposed to a novel forth hand puppet that combined some of the features from the previously encountered puppets. Only those infants who took a nap after learning produced a significantly higher number of target actions than infants in the baseline control condition who had not seen any demonstrations of target actions. Infants in the nap condition also produced significantly more target actions than infants in the no-nap condition. Sleep appears to support the storage of gist, which aids infants in applying recently acquired knowledge to novel circumstances.

Keywords: gist extraction, schema, memory, sleep, infancy, imitation

1. Introduction

As adults, we command a large number of mental representations, or schemata, about the world around us. Schemata are extremely valuable in daily life as they can provide guidance in many situations, especially if they are flexibly applied to novel circumstances. Formally described, schemata are knowledge structures composed of units and their relations, and are derived from multiple episodes. They lack unit details and are adaptable in that they can be updated, modified, or even newly generated in the light of new experiences (Ghosh & Gilboa, 2014). In comparison to adults, infants have had significantly less time to collect information about the world, presumably meaning that they have fewer and less complex schemata at their disposal (Huber & Born, 2014; Quinn, 2011). In the present study, we asked whether sleep might enhance the usability of recently formed schemata for infants by supporting the consolidation of extracted gist. The process of gist extraction can be understood as combining information from a pool of new items which is then used to excerpt commonalities between these items (Stickgold & Walker, 2013). Gist extraction is essential for categorizing stimuli and experiences and thus, for schema generation.

Infants as young as 3 months of age group the physical world into categories (e.g., cats vs. dogs) based on similar physical appearance (Quinn, Eimas, & Rosenkranz, 1993). Towards the end of the first year of life, infants start to consider an object's familiar functions when manually grouping objects into categories (Träuble & Pauen, 2007). However, at 12 months of age, infants' ability to extract commonalities across different members of the same category is still limited. For example, in Träuble and Pauen's study, infants only used function for categorizing if a particular critical function was explicitly demonstrated. They did not spontaneously categorize according to function. Function-based and similarity-based categorization was also investigated in a deferred imitation study (Jones and Herbert, 2008). In that study, 12-month-old infants observed an experimenter demonstrate three target actions on each of two different hand puppets. There was either low variability (e.g., grey mouse, pink mouse) or high variability (e.g., brown kangaroo, pink mouse) between the demonstration puppets. After a 10-min delay, infants' ability to reproduce any of the target actions (removing, shaking, and replacing the puppet's mitten) was assessed with another hand puppet that had a different form than both demonstration puppets (e.g., pink rabbit). Infants in the high variability condition who had seen two puppets that were markedly different in their appearance during the demonstration did not exhibit imitation of the target actions at test. Apparently, they failed to extract the gist of the learning experience (i.e., the puppets' common functions) and to apply it to the novel stimulus. In contrast, infants in the low variability condition successfully applied their knowledge to the novel puppet at test, evidencing similarity-based generalization. Thus, 12-month-old infants extracted the common features of puppets similar in appearance and retained the information over a short period of time. How long infants store and can use extracted gist information for remains an open question.

Sleep could be a potent ally for infants in retaining newly generated schemata over a longer retention period, or even in the generation of new schemata, as it does in adults (e. g., Djonlagic et al., 2009; Lau, Alger, Fishbein, 2011). There is some suggestion that sleep facilitates a related process in infant memory, the extraction of grammatical rules in an artificial language. In two studies, only those 15-month-old infants who napped for at least 30 min within four hours after being exposed to an artificial language extracted the underlying structure of that language and applied it to word strings they heard during a test 4 (Gomez, Bootzin, & Nadel, 2006) or 24 h later (Hupbach, Gomez, Bootzin, & Nadel, 2009). Thus, sleep might help infants to extract rules from relations (Stickgold & Walker, 2013). However, extraction was not tested immediately after the initial language exposure in these studies (Gomez et al., 2006; Hupbach et al., 2009), leaving open the possibility that abstraction might have occurred prior to sleep already. Similarly, in a recent study by Friedrich, Wilhelm, Born, and Friederici (2015), only those 9- to 16-month-old infants who napped after learning, applied previously learned words to novel exemplars of the same category. A particular strength of this study was that the procedure allowed pinpointing the effect of sleep more specifically, revealing that infants only showed generalization effects after the nap and not already during acquisition and prior to the nap. In the context of language processing at least, sleep appears to facilitate gist extraction from a set of new words in infants.

Whether sleep supports the consolidation of gist that was extracted from a set of novel stimuli, rather than words, during wakefulness and whether use of such gist information can be observed in infants' overt behavior is currently unknown. Using a deferred imitation procedure, Konrad, Seehagen, Schneider, and Herbert (2016) recently found that napping after learning facilitated 12-month-old infants' ability to generalize knowledge from one hand puppet to another hand puppet that differed in color from the demonstration puppet. This finding, together with those of Jones and Herbert (2008)in which infants extracted gist from two similar puppets after a short delay spent awake, provide the opportunity to consider associations between sleep and gist extraction in infants' overt behaviour. In the present study, we used a similar imitation procedure as Jones and Herbert (2008) and asked whether napping after a learning experience that involved observing demonstrations of the same target actions with three different stimuli from the same category (i.e., hand puppets) would facilitate the retention of the extracted gist over a longer delay. We predicted that only infants who napped after learning would produce a higher number of target actions at test on a novel fourth puppet than infants in an age-matched control group who did not observe any demonstrations of the target actions. Furthermore, we hypothesized that infants in the nap condition would produce significantly more target actions than infants in the no-nap condition.

2. Material and methods

2.1 Participants

The final sample consisted of sixty full-term 12-month-old infants (M_{age} = 364 days, *SD* = 8 days) who were randomly assigned to a nap, no-nap, or a baseline control condition (50% females per condition). Families were recruited from local birth registers in Bochum, Germany. Six additional infants were tested but excluded from the final sample due to sleep in the no-nap condition (*n* = 3), no sleep in the nap condition (*n* = 1), experimenter error (*n* = 1), and refusal to remain seated during the test session (*n* = 1).

2.2 Apparatus

2.2.1 Stimuli

Four hand puppets were used in this experiment, two resembling a mouse and two resembling a rabbit, with one of each being pink and one being grey (see Figure 1). The puppets (30 cm high) were made out of soft fur and were developed for research purposes (e.g., Barr, Dowden, & Hayne, 1996; Hayne, MacDonald, & Barr, 1997). A removable felt mitten matching the color of the puppet (8 x 9 cm), with a jingle bell secured inside, was placed over the puppet's right hand.

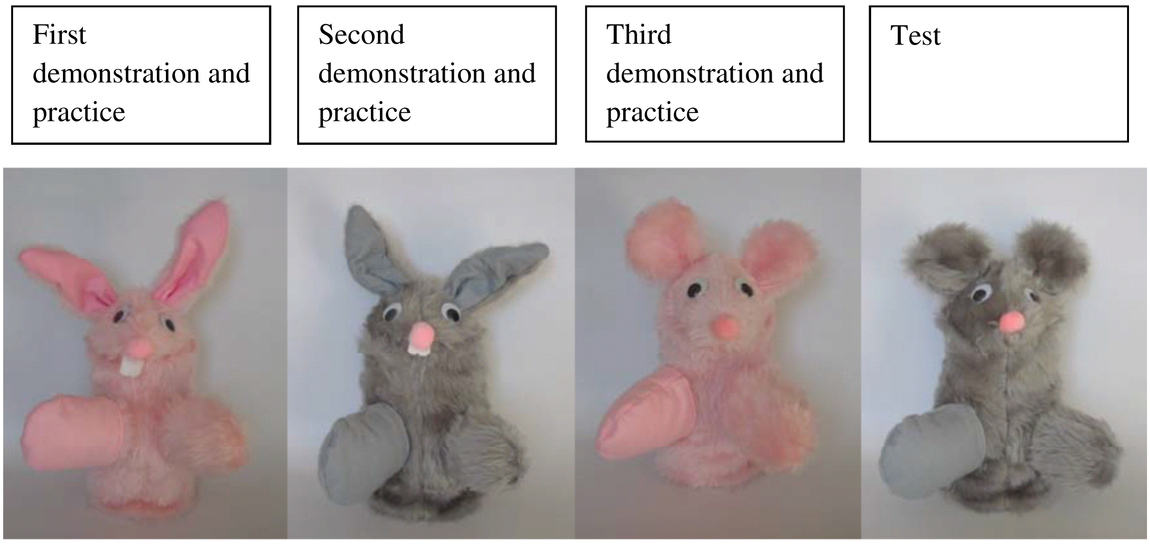

Figure 1. Example sequence of the puppet presentation in the demonstration/practice session and test session. The three target actions were demonstrated once on each of the demonstration puppets, and infants practiced one time immediately afterwards with the respective puppet.

2.2.2. Sleep records

Infants wore an actiwatch during the retention interval to assess sleep/wake patterns (Mircro Motionlogger®, Ambulatory Monitoring inc.). Actiwatches are wristwatch-like devices which record the frequency of body movement and a validated algorithm provides automatic minute by minute sleep/wake scoring (Mueller, Hemmi, Wilhelm, Barr, & Schneider, 2011; Sadeh, Acebo, Seifer, Aytur, & Carskadon, 1995; Sadeh, Sharkey, & Carskadon, 1994). Additionally, caregivers kept a diary about their infant's sleeping times as well as times of external movements and times when they removed the actiwatch (e.g., for changing) because such cases can create artefacts in the data. Sleep duration was derived from actiwatch data for all naps in the study except for one, which occurred during external movement. For this nap, sleep duration was extracted from the sleep diary. In the no-nap condition, actiwatches were used to ensure that the infants did not sleep during the 4 hour retention interval.

2.3 Procedure

Infants were visited twice in their own homes with a 4-h delay, in line with previous studies on infant sleep and cognition (Gomez et al., 2006; Hupbach et al., 2009; Konrad et al., 2016; Seehagen, Konrad, Herbert, & Schneider, 2015). During the first visit, infants participated in a demonstration/practice session in which they were shown a series of target actions on three puppets and had the opportunity to reproduce these actions immediately (see Figure 1 for an example demonstration and test sequence). During the demonstration/practice session the infant sat on the caregiver's lap, held by the hips. A female experimenter knelt in front of the infant and demonstrated three target actions once out of the infant's reach with the first puppet: removing the mitten from the puppet, shaking the mitten three times ringing the bell inside, and replacing the mitten (Jones & Herbert, 2008). Immediately after this demonstration, the infant had the opportunity to practice the target actions once to enhance encoding opportunities (Hayne, Barr, & Herbert, 2003). A three-step protocol was followed to ensure that all infants had similar experiences with the mitten (Konrad et al., 2016). If the infant did not remove the mitten, the experimenter pointed to it. If the infant still did not remove the mitten, the experimenter removed it halfway. As a last step, the experimenter gave the mitten to the infant. This sequence of demonstrations and practice was then repeated with the second and third puppet. Thus, during the first visit the infant saw three demonstrations of the target actions, during which they encountered at least one puppet of the same color and one of the same form as the remaining fourth puppet that would be present at the test session. The demonstration/practice session lasted approximately 2.5 minutes. The actiwatch was then attached to the infant's left ankle. Infants in the nap-condition participated in the demonstration/practice session before their usual scheduled naptime. Infants in the no-nap condition participated after they had had a naturally scheduled nap and were therefore expected to stay awake in the following 4 hours. Caregivers were instructed not to keep their infants awake for the study.

The test session occurred after the 4-h retention interval, following removal of the actiwatch. Once the infant was seated on the caregiver's lap, the experimenter revealed the test puppet and placed it within the infant's reach. Infants had 90 seconds to reproduce the target actions, timed from first touch. The bell inside the mitten was removed before the test session to avoid prompting memory retrieval (Barr, Vieira, & Rovee-Collier, 2001; Hayne et al., 1997). The experimenter did not verbally or physically prompt the infant to produce the target actions. Each infant was tested with one puppet, and the presentation order of the puppets during the demonstrations and test session was counterbalanced between conditions and sexes. Half of the infants in each condition had a change in color between the third and the fourth puppet, and half of the infants had a change in form. Infants in the baseline control condition were only visited once for a test session, when their spontaneous production of any target actions on one puppet was assessed. All sessions were video-recorded from the right hand side of the experimenter.

2.4 Coding

Each practice and test session was coded for the presence of any target actions to calculate a practice and an imitation score. In line with Konrad et al. (2016), the practice score (range = 0-9) was derived by summing up the values from each of the three practice trials. In each trial, an infant could receive up to 1 point for removing the mitten (1 point: removal without any help, 0.66 points: removal after the experimenter pointed to it, 0.33 point: removal after the experimenter had removed the mitten half way, 0 points: experimenter gives the mitten to the infant). One additional point per practice trial was given for shaking and (attempt to) replacing the mitten. The imitation score (range = 0-3) was calculated by summing up the number of target actions an infant performed during the test session. One coder scored the videos for the presence of target actions during the test session using the software INTERACT (Mangold International GmbH). A second independent rater counter coded all videos. Interrater reliability was kappa = .94.

3. Results

Infants' naturally occurring nap time was usually around noon. Therefore for infants in the nap condition, the test session took place at 14:39h on average. Infants in the no-nap condition were usually visited after their nap and thus their test session occurred at 16:27h on average. Infants in the baseline control condition had a mean test time of 11:33h. Time of the test session differed significantly between all condition, $F(2, 57) = 26.58$, $p = .000$, $\eta_p^2 = .14$. However, time of test did not correlate with imitation scores in the nap ($r = -.203$, $p = .390$) or no-nap condition ($r = -.201$, $p = .395$). Infants in the nap condition slept an average of 100 minutes (*SD* = 38 min; range = 39 to 191 min) and took 1.2 naps (*SD* = 0.5) within the retention interval. The delay between the demonstration/practice session and the onset of the first nap was 67 minutes (*SD* = 38 min) on average. Pearson's correlations between total sleep duration, number of naps, delay between demonstration/practice session and onset time of the first nap and imitation scores were not significant, biggest $r = -.350$, $p = .131$.

There were no significant differences in practice scores (see Table 1) between the nap and no-nap condition, $t(38) = -0.25$, $p = .807$, $d = 0.06$, indicating that infants learned the target actions equally well. The practice score was significantly related to the imitation score in the nap ($r = .450$, $p = .047$), but not in the no-nap condition ($r = -.110$, $p = .645$). The practice scores remained constant across the three practice trials, $F(2, 78) = 1.85$, $p = .164$, $\eta_p^2 = .05$.

Table 1

Means and Standard Deviations for Interaction Behavior and Imitation Scores as a Function of Experimental Condition.

Condition	Practice score *M* (*SD*)	Latency to first touch during test session in s *M* (*SD*)	Imitation score *M* (*SD*)
Nap	3.2 (1.6)	7.6 (15.2)	1.05 (1.23)
No-nap	3.1 (1.8)	5.5 (9.1)	0.45 (0.83)
Baseline	-	5.8 (14.7)	0.15 (0.67)

There were no significant differences in the latency to first touch the puppet during the test session (see Table 1) between conditions, $F(2, 57) = 0.14$, $p = .869$, $\eta_p^2 = .01$, indicating that infant in all conditions were equally motivated to interact with the test puppet. There were no significant differences in imitation scores between infants experiencing either a color change or a form change between the puppet seen last at learning and the one seen at test, $t(33.75) = 0.58$, $p = .565$, $d = .19$, so data were collapsed across feature change for further analyses.

To examine infants' imitation scores, a one-way ANOVA was conducted. There was a significant effect of condition on imitation scores (see Table 1), $F(2, 57) = 4.75$, $p = .012$, $\eta_p^2 = .14$. In deferred imitation studies, memory is inferred if infants in the demonstration conditions produce a significantly higher number of target actions than infants in the baseline control condition (e.g., Barr et al., 1996). Therefore, we conducted post-hoc Dunnett's *t*-tests which compare a fixed control condition with several treatment conditions while controlling for Type I error. Dunnett's *t*-tests indicated that only infants in the nap condition produced significantly more target actions than infants in the baseline control condition, $M_{\text{diff}} = 0.90$, $p = .004$, $d = 0.93$. Infants in the no-nap condition did not produce significantly more target actions than infants in the baseline control condition, $M_{diff} = 0.30$, $p = .255$, $d = .41$. An additional one-tailed *t*-test indicated that infants in the nap condition produced significantly more target actions than infants in the no-nap condition, $t(33.2) = -1.81$, $p = .040$, $d = 0.59$.

4. Discussion

The present findings point to a causal role of sleep for the flexible use of gist information in infants. Only infants who took a nap between learning and retrieval used the gist information derived from the three demonstration puppets when encountering a novel, but related, fourth puppet. This effect was especially pronounced in infants who encoded better (i.e., practiced more target actions), as indicated by the significant correlation between practice and imitation score in the nap condition. Infants in the no-nap condition, on the other hand, likely forgot the gist during the 4 h period of wakefulness.

The present results are in accordance with Friedrich et al.'s (2015) study. In both paradigms, infants learned the combination of several exemplars of a category with a certain event (i.e., the same target actions with different puppets in the present study and the same name for different objects in Friedrich et al.) and were tested on their ability to apply their knowledge to a novel exemplar of the category. Both studies indicate that only infants who napped after learning were able to solve this task, outcomes that were visible in brain responses in Friedrich et al.'s study and in infants' overt behavior in the present study. Unlike Friedrich et al.'s study, the present study does not provide a definite answer to the question of whether infants already extracted gist during the demonstration/practice session (i.e., during wakefulness), or whether sleep had an additional role in supporting the extraction of this gist. An additional control condition which is tested immediately after the demonstration/practice session would be needed to further elucidate this question. However, Jones and Herbert (2008) found that 12-month-olds applied their knowledge about two different hand puppets of a similar overall appearance to a novel puppet after a 10-minute delay during which the infants were awake. Given the similarity between the present experiment and Jones and Herbert's paradigm in terms of stimuli and studied age group, this suggests that infants in our study extracted gist information during or shortly after the demonstration/practice session, that is, *before* sleep. Presumably, infants in the nap condition were then able to use this knowledge when encountering the novel forth puppet during test while infants in the no-nap condition forgot the gist during wakefulness. Sleep might thus enhance the usability of recently formed schemata for infants by supporting the consolidation of extracted gist.

Alternatively, it is possible that sleep promoted qualitative changes in infants' memories (perhaps in addition to the stabilization of the extracted gist). In support of this view, infants' practice score did not increase across practice trials, suggesting that they were limited in their ability to extract gist about the different puppets online and/or to apply this knowledge promptly to the following practice puppet. Pinpointing the specific contributions of sleep for gist extraction and consolidation in imitation paradigms will be an important avenue for future research.

While schema formation and gist extraction is especially valuable for infants, knowledge extraction might also be paid for by forgetting specific details of the units used for schema creation. For example, in the present study infants in the nap condition might have forgotten specific details of the three puppets they encountered during the demonstration. In fact, it has been recently suggested that during infancy, sleep might primarily facilitate generalization processes, rather than the stabilization of specific memory traces (Gomez & Edgin, 2015). Yet, there is also recent experimental evidence for sleep-dependent declarative memory consolidation in 6- and 12-month-old infants (Seehagen et al., 2015). The relative importance of sleep-dependent strengthening versus generalization and the respective consequences for infant memory in the longer term is yet to be determined.

In sum, the present study shows that sleep facilitates 12-month-old infants' ability to use gist information in novel circumstances after a substantial delay. These findings add to a growing body of research suggesting that sleep is an important resource for infants to make sense of the world around them.

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