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Rapid communication

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-h 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.

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 group the physical world into categories (e.g., cats vs. dogs) based on similar physical appearance (Quinn, Eimas, & Rosenkrantz, 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 & 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

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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 4 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 (Gómez, 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 (Gómez 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 behavior. 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 Fig. 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 × 9 cm), with a jingle bell secured inside, was placed over the puppet's right hand.

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 (Müller, 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 h 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 (Gómez 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 Fig. 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