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Brief Report

Naps improve new walkers' locomotor problem solving

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ABSTRACT

In this first study of the impact of sleep on infants' problem solving of a locomotor task, 28 newly walking infants who were within a week of having given up crawling trained to navigate a shoulder-height tunnel to reach a caregiver waiting at the end. During the transitional window between crawling and walking, infants are reluctant to return to crawling, making this task uniquely challenging. Infants were randomly assigned to either nap or stay awake during a delay between training and a later test session. For the Nap group, efficiency of problem solving improved from training to test, but there was no change for the No Nap group. These findings suggest that for newly walking infants, sleep facilitates learning to solve a novel motor problem.

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Introduction

That sleep plays a critical role in memory consolidation of pre-sleep experiences was demonstrated as early as the 1920s (Jenkins & Dallenbach, 1924). Memory consolidation refers to the stabilization of newly learned information without additional practice (Siengsukon & Boyd, 2009). It implies a long-lasting change and may stem from changes at the neuronal level that are triggered by learning (e.g., Laureys et al., 2001). Scores of studies on memory consolidation in adults have demonstrated that sleep enhances learning, especially for motor memory, a type of procedural memory in which a par-

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ticular sequence of actions is learned. Most studies have demonstrated that improvement in performance occurs only if a delay between learning and test includes sleep, but not with a delay that is simply the passage of time (e.g., Doyon et al., 2009; Korman et al., 2007; Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002; Walker & Stickgold, 2005). Thus, the old adage to ‘‘sleep on it” when trying to work out a solution to a problem is generally good advice.

However, the impact of sleep on problem solving is nuanced. Sleeping after learning a difficult problem helped adults to solve more problems later than adults who did not sleep or who were tested immediately after learning, but sleep did not confer an advantage on trying to solve easy problems (Sio, Monaghan, & Ormerod, 2013). Sleeping after learning how to solve a new problem improved adults' skill for the specific solution that they first came up with, but not for general information processing or all possible solutions (Stickgold & Walker, 2004).

Despite the abundance of research examining the impact of sleep on learning and problem solving in adults and the fact that sleeping is the primary brain activity of early development, few studies have addressed the effects of sleep on learning in young children (Ednick et al., 2009). Studies that address how sleep affects problem solving are scarcer still. We do know that, in general, the better the quality of 10-month-olds' sleep, as measured by night wakings or via motor activity and sleep efficiency, the better their recall memory and the higher their cognitive scores on a standardized assessment tool (Lukowski & Milojevich, 2013; Scher, 2005). Similarly, the better the quality of preschoolers' sleep, as measured via parent report or physiological recordings, the higher their cognitive scores on a standardized assessment tool and the better the consolidation of memories acquired earlier in the day (Jung, Molfese, Beswick, Jacobi-Vessels, & Molnar, 2009; Kurdziel, Duclos, & Spencer, 2013). When young infants learned to activate an overhead crib mobile by kicking their feet, a reminder benefited infants' retention over time after forgetting had occurred, especially when the time that elapsed from the demonstration included sleep (e.g., Fagen & Rovee-Collier, 1983).

Although Tarullo, Balsam, and Fifer (2011) pointed out that ‘‘conclusions about infant sleep cannot be extrapolated from adult studies” (p. 38), only recently have investigators begun to experimentally address the effect of sleep on infants' learning. In the few studies designed to examine the effect of sleep on learning during infancy, infants were able to learn an abstract language rule (Gomez, Bootzin, & Nadel, 2006), improve their vocabulary (Horváth & Plunkett, 2016), consolidate a declarative memory (Seehagen, Konrad, Herbert, & Schneider, 2015), generalize beyond specific word meanings to broader categories (Friedrich, Wilhelm, Born, & Friederici, 2015), and demonstrate flexibility of memory retrieval (Konrad, Seehagen, Schneider, & Herbert, 2016) after they took a nap, but not if they stayed awake during a delay. Without a nap, infants could retain specific information only in the short term (Hupbach, Gomez, Bootzin, & Nadel, 2009), whereas a nap that occurred within 4 h of learning was required for complex learning or generalization to occur (Friedrich et al., 2015). Infants appear to need frequent periods of sleep to parse and learn the ‘‘continuous stream of new information they are exposed to every day” (Hupbach et al., 2009, p. 1012). Of the studies that have directly examined the impact of sleep on infants' learning, as far as we can tell, none has examined the relation between sleep and problem solving.

One possible reason for this gap in the literature is that studying problem solving during infancy can be a significant challenge. Methods for studying problem solving in children typically involve verbal or math tasks that are beyond infants' abilities (Lemaire & Reder, 1999; Lemaire & Siegler, 1995; Tunteler & Resing, 2002). To address the goal of examining the impact of napping on problem solving during infancy, we turned to recent work demonstrating that novel locomotor tasks can be model contexts for studying the development of problem-solving strategies during infancy. For example, microgenetic documentation of 13- and 18-month-olds' strategy choices during stair descent revealed the same characteristics as older children's problem-solving behavior on more traditional cognitive tasks, namely variability, utilization deficiencies, and online planning (Berger, Chin, Basra, & Kim, 2014). Likewise, carrying out locomotor tasks can involve the same types of cognitive skills assessed in more classic tests of cognition. For example, to successfully navigate a tunnel to get to a caregiver waiting at the other end, walking infants must inhibit their preferred locomotor method of walking, devise an alternative locomotor strategy of crawling, and maintain that alternate strategy for the duration of the task (Berger, 2010). These demands are especially taxing for new walkers who frequently bump their head on a low entrance, or revert to a familiar but unstable posture, rather than adopt alternative