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Beneficial effects of a daytime nap on verbal memory in adolescents☆

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ABSTRACT

This study aimed to examine the sleep-dependent memory consolidation of verbal declarative memory in Chinese adolescents in a naturalistic experimental setting. Thirty-nine healthy boarding school students (ages 15–18, 70% female) were randomized to either a one-hour afternoon nap or wake group between the baseline and the retest sessions of three verbal declarative memory tasks: a Prose Stories Recall task, a Word Pair Associates task, and Rey Auditory Verbal Learning Test. Results showed that the nap group performed better than the no-nap group on both the Prose Stories Recall task and the Word Pair Associates task, but not on list learning. Our findings suggest that napping is beneficial to verbal declarative memory in adolescents, providing ecologically-valid empirical support for the sleep-dependent memory consolidation hypothesis using a napping paradigm in participants' naturalistic habitat. Our results demonstrate the potential importance of napping as a practical mnemonic intervention/compensatory strategy for student populations.

1. Sleep-dependent memory consolidation

Previous studies suggest that sleep is important to a multiplicity of cognitive functioning, in particular learning and memory (Maquet, 2001). The 'sleep-dependent memory consolidation hypothesis' suggests that individuals remember more and forget less when offered a period of sleep over an equivalent period of wake (Stickgold, 2005). Findings supporting this hypothesis have been established for declarative (Ellenbogen, Hulbert, Stickgold, Dinges, & Thompson-Schill, 2006), procedural (Walker & Stickgold, 2006), and working memory (Lau, Wong, Lau, Hui, & Tseng, 2015; Lo et al., 2012). Whilst it is beyond the scope of this paper to explore all of the possible mechanisms involved in sleep-dependent memory consolidation, converging evidence from behavioral, genetic, and neuroimaging studies suggests that offline memory reprocessing during sleep is an important part of how memories are formed, organized and retrieved (Stickgold, 2005). For example, evidence from fMRI research has shown that a night of sleep increases activation in brain areas associated with the initial learning of memory tasks, and also shows a positive correlation with improvement in task performance (Walker, Stickgold, Jolesz, & Yoo, 2005). Studies in rats have also found that several genes believed to play a role in memory consolidation and brain plasticity are upregulated during sleep (Ribeiro, Goyal, Mello, & Pavlides, 1999).

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For verbal memory, in particular, it has been shown that sleep reduces the negative effect of interfering information on memory consolidation, which results in greater recall performance after sleep than after an equivalent period of wake (Ellenbogen, Hulbert, Jiang, & Stickgold, 2009).

2. Inadequate sleep in adolescents

Chronic sleep restriction is increasingly common among adolescents worldwide (Gradisar, Gardner, & Dohnt, 2011). The National Sleep Foundation recommends that teenagers get 8–10 h sleep a night (Hirshkowitz et al., 2015). However, with nightly sleep averaging 7.5 h in the US (Wolfson & Carskadon, 1998), 7.3 h in Hong Kong (Chung & Cheung, 2008), 6.3 h in Japan (Tagaya et al., 2004), and 5.4 h in Korea (Yang, Kim, Patel, & Lee, 2005), inadequate sleep seems to be the rule rather than the exception in many developed countries. Insufficient weekday sleep, coupled with weekend compensatory "sleeping-in", leads to large weekday-weekend disparities in sleep duration, which in turn has been reported to predict outcomes such as falling asleep, lower grades and late arrival to school (Gibson et al., 2006). Late rise times likely result in further delays in sleep phase due to minimized light exposure in the morning, aggravating nighttime sleep difficulties such as insomnia, and leading to daytime dysfunction such as sleepiness and other cognitive and affective problems (Fallone, Owens, & Deane, 2002; Gibson et al., 2006). A recent study in a boarding school population found that a week of partial sleep deprivation (5 h sleep a night) impaired visual declarative memory in high school adolescents and that the negative impact continued even after two nights of recovery sleep (Lo, Ong, Leong, Gooley, & Chee, 2016). Not surprisingly, research suggests that sleep disturbance and inadequate sleep are associated with poorer academic results in adolescents (e.g., Chung & Cheung, 2008; Wong et al., 2013). Unrelenting academic demands, coupled with the ever-increasing use of internet and online social platforms (Chung & Cheung, 2008; Woods & Scott, 2016), means that students have limited ways and motivation to improve their nocturnal sleep. Attempts to address this problem (e.g., school-based sleep education) provides immediate short-term benefits but research suggests improvements in sleep are not sustained (Chung, Chan, Lam, Lai, & Yeung, 2017).

3. Napping as a potential strategy to enhance memory in adolescents

Most studies have established the benefits of sleep on memory by evaluating outcomes following a night of sleep or nighttime sleep deprivation. However, more recent studies have also investigated the benefits of additional daytime sleep and have found promising results in declarative (Antonenko, Diekelmann, Olsen, Born, & Mölle, 2013), procedural (Morita, Ogawa, & Uchida, 2012) and working memory (Lau et al., 2015). Whilst it is difficult to eradicate the negative effects of insufficient sleep by increasing nighttime sleep, or by delaying school start times, the introduction of daytime naps is a potential way to reduce daytime sleepiness and maintain learning and academic performance. Indeed, nocturnal sleep and daytime naps were found to have comparable effects in facilitating memory consolidation (Lo, Dijk, & Groeger, 2014; Tucker & Fishbein, 2009). Whilst daytime napping may not be a replacement for nocturnal sleep for optimum performance or other psychophysiological functioning, its strategic use in mitigating the effects of chronic sleep loss, ameliorating the commonly observed circadian rhythm effect of the "post-lunch dip" in alertness (Broughton, 1989), and improving memory warranted the current investigation.

4. The present study

The aim of the present study was to test the sleep-dependent memory consolidation hypothesis using a napping paradigm in adolescents, a population prone to chronically-inadequate sleep. Whilst a previous study conducted in a naturalistic setting (boarding high school) showed that participants who had taken a nap had faster response times and benefitted more from practice than those who had an equivalent period of wake (Lim, Lo, & Chee, 2017), the current study was the first to investigate the effects of napping in a similar naturalistic setting on verbal memory consolidation in adolescents. We were interested in verbal declarative memory given its high relevance to learning. Classroom teaching usually comprises a large amount of information presented verbally. Students' ability to acquire and retain verbal materials in different formats (e.g., free recall and cued recall) is crucial in the 'real-life' learning of information such as vocabularies and terminologies. We hypothesized that adolescents given a nap opportunity would have reduced sleepiness and better memory performance, relative to baseline, than peers who stayed awake for the same period.

5. Methods

5.1. Participants

Thirty-nine healthy adolescents (aged 15–18, 27 females) were recruited from a live-in, full time English-speaking boarding school in Hong Kong. Participants signed up voluntarily with the Head of Boarding at the school after a recruitment presentation.

Participants were screened with a questionnaire and were excluded if they reported a: 1) sleep disorder, 2) significant medical condition, 3) reading, writing or language disorder, and 4) visual or hearing impairment. Students' responses were reviewed by a clinical psychology trainee (SM) supervised by a qualified clinical psychologist (EYYL). Students aged 18 were provided with written informed consent, while consent for students under 18 was provided by the headmaster, who acted '*in loco parentis*' for them. The study was reviewed and approved by the Psychology Department Research Ethics Committee, The University of Hong Kong.