Immediate as well as delayed post learning sleep but not wakefulness enhances declarative memory consolidation in children

Jutta Backhaus a,*, Ralf Hoeckesfeld a, Jan Born b, Fritz Hohagen a, Klaus Junghanns a

a Department of Psychiatry and Psychotherapy, University of Luebeck, Ratzeburger Allee 160, D-23538 Luebeck, Germany
b Department of Neuroendocrinology, University of Luebeck, Germany

Received 5 June 2007; revised 21 August 2007; accepted 24 August 2007
Available online 29 October 2007

Abstract

While there is mounting evidence for the importance of sleep for declarative memory consolidation in adults, so far this issue has not been investigated in children despite considerable differences in sleep duration and sleep architecture between children and adults. Here, 27 children (aged between 9 and 12 yr) were examined on two conditions: on the Sleep–Wake condition, subjects learned word pairs in the evening and delayed recall was tested first in the next morning after sleep and then again in the following evening after daytime wakefulness. On the Wake–Sleep condition, learning took place in the morning and delayed recall was tested in the evening of the same day and again in the next morning after sleep. In both conditions retention of declarative memory was significantly increased only after an interval of sleep that either followed immediately after learning (as in the Sleep–Wake condition) or that followed after daytime wakefulness (as in the Wake–Sleep condition), respectively. The results support the hypothesis that sleep plays an active role in declarative memory consolidation even if delayed and further show for the first time the importance of sleep for declarative memory consolidation during childhood.

Keywords: Consolidation of declarative memory; Sleep; Children

1. Introduction

There is growing evidence that sleep critically contributes to the consolidation of memory (Born, Rasch, & Gais, 2006; Ellenbogen, Hulbert, Stickgold, Dinges, & Thompson-Schill, 2006; Maquet, Smith, & Stickgold, 2003; Smith, 2001; Stickgold, 2005). Sleep enhances the consolidation of procedural memories for skills (Fischer, Hallschmid, Elsner, & Born, 2002; Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002) as well as declarative memories for facts and episodes, the storage of which involves hippocampal function (Backhaus et al., 2006, 2007; Ekstrand, 1967; Ellenbogen et al., 2006; Gais, Lucas, & Born, 2006; Plihal & Born, 1997). Even short daytime naps facilitate memory consolidation in adults (Backhaus & Junghanns, 2006; Mednick, Nakayama, & Stickgold, 2003; Tucker et al., 2006).

Although children have usually a longer sleep duration and a different sleep architecture with particularly high amounts of slow wave sleep (SWS) in comparison with adults (Kahn, Dan, Groszwarser, Franco, & Sottiaux, 1996; Ohayon, Carskadon, Guilleminault, & Vitiello, 2004) the sleep associated consolidation of declarative memory has not been investigated in children so far. Whether declarative memory consolidation in children benefits from sleep similarly like in adults, is a tempting question, also in light of recent findings indicating differences between children and adults in sleep-dependent consolidation of non-declarative skill memories (Fischer, Wilhelm, & Born, 2007). In this study employing a serial reaction time task, 9–11 yr old children unlike adults did not improve but showed an acutely impaired implicit mem-
Participants had neither a psychiatric nor any somatic disorder and did not take any psychoactive drugs or medications that might affect sleep or memory. The study was approved by the local ethics committee and was conducted according to the Declaration of Helsinki. After a complete description of the study to the children and their parents, written consent was obtained from the children and their parents.

2.2. Procedure and tasks

Each child participated in both experimental conditions, i.e., the Sleep–Wake and Wake–Sleep condition. The two conditions for each subject were separated by an interval of 1 week, and order of conditions was balanced across the children. Measurements were performed at the children’s home. On the Sleep–Wake condition children learned the memory task in the evening before they went to bed at their usual bedtime. After a night of normal sleep retrieval was tested the first time in the next morning. A second retrieval test was conducted in the evening of the same day after a period of daytime wakefulness that had the same duration as the child’s habitual nocturnal sleep period.

In the Wake–Sleep condition, learning took place in the morning and retrieval was tested first in the evening of the same day after a period of wake-time (again corresponding in length with the child’s habitual sleep time). The first retrieval was followed by a night of regular sleep, after which the second retrieval took place in the next morning.

Declarative memory was tested using a word pair associate task consisting of 40 related word pairs of German concrete nouns that were standardized with respect to word frequency, length, emotionality, meaningfulness and concreteness. Two additional word pairs at the beginning and end of the test served to buffer primacy and recency effects and were not included in the analysis. Parallel versions of the word pair list were used (in random order) for the two subject’s experimental conditions. The word pairs were presented visually for 5 s each at the first presentation of the list and for 2 s for all following trials. The presentation of each word pair of the list was followed by cued recall testing where the subject was asked to recall orally the second word in a pair upon presentation of the first word. The list of word pairs was presented repeatedly in different order until the subject correctly recalled at least 20 words (50% criterion). During learning subjects were given feedback so that the subject’s response was always followed by presentation of the correct word pair for 1 s. At the first and second retrieval testing after, respectively, sleep and wakefulness subjects were again asked to recall the word pairs using the same cued recall procedure as during the learning phase except that no feedback was given, i.e., the subject’s oral response was not followed by presenting the correct word pair.

2.3. Polysomnography and actigraphic recordings

In both study conditions sleep was measured with an ambulatory polysomnography system. Standard polysomnographic recordings were obtained using EEG electrodes positioned at C3 and C4 and referenced against electrodes attached at A2 and A1, respectively (as defined by the international 10–20 system). Furthermore, eye movements and electromyographic activity were recorded. Sleep stages were scored according to standard criteria (Rechtschaffen & Kales, 1968) by experienced staff blind to the experimental condition. During wake-time children wore an actigraph to measure activity and to rule out that children took a nap.

2.4. Statistical analyses

Differences between the sleep conditions were analyzed by analyses of variance (ANOVA). Post hoc t-tests were used to specify significant main and interaction effects. Correlation analyses were performed between time in sleep stages and performance at delayed retrieval test. Retrieval performance was defined by absolute numbers of recalled words and by retention rates as determined by the difference in recalled words at the first/second retrieval minus the number of recalled words at the criterion trial during learning before the retention period. Accordingly, in the Sleep–Wake condition sleep-related retention of word pairs was defined...
دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات