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Brief period of post-encoding wakeful rest supports verbal memory retention in children aged 10–13 years

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Abstract
Evidence exists that a brief period of wakeful rest after learning can support the retention of memories, whereas a period filled with a cognitive task after learning can weaken the retention of memories. The present study in 10–13 year old children investigated whether wakeful resting after encoding is more beneficial for the retention of new verbal information than watching movies, which reflects a common everyday life/learning break activity in children at this age. Children encoded a word list. After immediate recall of this word list, they wakefully rested for 12 min. Next, children encoded another word list. After immediate recall of this word list, they watched animated short movies for 12 min. The order of the delay conditions (rest, movies) was counterbalanced across children. At the end of the experimental session, a surprise free recall test took place. Overall analyses revealed that while memory performance decreased over time in both the resting condition and movies condition, it decreased significantly more in the movies condition. These results indicate that wakeful resting supports the retention of verbal information in children aged 10–13 years.

Keywords Wakeful resting · Memory retention · Retroactive interference · Memory consolidation · Children

Introduction

Studies indicate that memory retention can be significantly affected by the activity directly after learning (e.g. Dewar et al. 2012, 2007; Craig et al. 2015; Mercer 2015; Brokaw et al. 2016). Already Bigham (1894) found that younger adults showed less forgetting when the interval between learning and recall was 'unfilled' compared to processing a cognitively demanding distractor task. This view was extended by Müller and Pilzecker (1900) showing in adults that a shorter temporal separation between two learned word lists led to a lower recall performance for the first word list. However, these findings were offset with a higher temporal separation between the two word lists (see also Brown et al. 2007). Recent research efforts delineated the impact of a cognitive task delay period from a resting period after learning, defined as a state of low external stimulus input and task-related interference. The majority of these studies indicate that resting (eyes closed, relaxed) after learning supports memory retention more than a cognitive task delay period (Cowan et al. 2004; Dewar et al. 2007; Craig et al. 2015).

The reasons why wakeful resting supports memory retention has not been fully understood yet. Neuroscientific evidence exists that task-relevant brain areas stay active during post-encoding wakeful rest. These studies showed that activity and connectivity of those brain areas, which were also involved during learning, predicted (interindividual differences in) subsequent memory performance (e.g. Tambini et al. 2010; Schapiro et al. 2018). It is assumed that during periods of wakeful rest recent events are neurally 'replayed' (Deuker et al. 2013; Staresina et al. 2013; Dudai et al. 2015; Peigneux et al. 2006; Schapiro et al. 2018), which helps memories to get consolidated, i.e. to be transformed into longer-lasting, more stable memories less prone to interference (Robertson 2012; Deuker et al. 2013).

The majority of wakeful resting studies investigated healthy younger and older adults as well as patients with neurological diseases showing supporting effects of wakeful resting over shorter (minutes) and longer

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(days) retention delays with different learning material and post-learning cognitive filler tasks (Brokaw et al. 2016; Cowan et al. 2005; Della Sala et al. 2005; Dewar et al. 2007, 2012; Craig et al. 2015; Mercer 2015).

Only a few studies investigated the impact of a brief period of wakeful rest on memory in children. Studies showed that memory and memory consolidation develop across lifespan (Gathercole 1998; Wilhelm et al. 2012). For instance, the number and details of memories that can be maintained over short temporal intervals increase as children grow older (see Hertzog and Shing 2010). From sleep studies, it is known that long-term memory performance is positively affected by the time spent in specific sleep states (e.g. non-rapid eye movement sleep) and brain activity during this state (e.g. slow oscillatory activity) (Henderson et al. 2012, 2013; Wilhelm et al. 2008; Backhaus et al. 2008; Kurth et al. 2010; Ohayon et al. 2004). Based on this view, it stands to reason that age-related differences in the impact of a brief period of resting exist. Fatania and Mercer (2017) conducted a wakeful resting study in children (age 6–7 years) and adults (age 18–61 years). They found that children recalled more words in a delay condition, where they had to remain quiet for 5 min after learning, than in a delay condition, where they had to complete spot-the-difference puzzles after learning. Adults recalled more words than children in both delay conditions but showed no differences between the delay conditions (for similar findings in adults see Varma et al. 2017; Martini et al. 2017; see also Darby and Sloutsky 2015). In a second experiment in 6–7 year old children only, they found no differences between the wakeful resting condition and spot-the-difference condition, provided that children were given more time to learn and recall a word list. These results indicate that an increase in learning and recall times reduces the impact of post-learning interference (but see Bauer et al. 1999). Thus, resting may be especially important for children under suboptimal learning conditions or maybe similar between different delay conditions if one assumes generally weaker encoding strength in children. This view is supported by a recent study in children aged 13–14 years (Martini et al. 2018a). Martini et al. (2018a) showed that a 10-min post-encoding wakeful rest phase supported memory retention over 7 days, but only in children showing a lower immediate memory performance.

In order to further specify conditions under which wakeful resting supports memory in children of different ages the present study with children aimed at investigating whether a brief period of wakeful rest after learning supports memory retention more than a period of task-related cognitive processing (Fatania and Mercer 2017, Experiment 1). In extension to previous wakeful resting studies (Fatania and Mercer 2017; Dewar et al. 2012; Craig et al. 2015; e.g. Cowan et al. 2004), we (i) investigated children aged 10–13 years and (ii) implemented a delay task close to everyday life, namely watching short movies, as this is one of the top online activities in children's internet usage (GSMA 2014; Ofcom 2017). Our study design was based on the design used in previous studies in children and adults in the field (Dewar et al. 2012, 2014; Craig et al. 2015; Fatania and Mercer 2017). Children were asked to encode two word lists. After the immediate recall of one word list, they were required to wakefully rest for 12 min or watch animated short movies. At the end of the experimental session, a delayed free recall test took place. Based on the findings discussed above (Fatania and Mercer 2017; Dewar et al. 2012; Mercer 2015; Brokaw et al. 2016; Craig et al. 2015), we assumed to find that resting after learning supports memory retention more than watching movies.

Material and Methods

Participants Twenty-four children took part in the experiment (12 female; mean age = 11 years, age range = 10–13 years). Children were recruited in a local school, whose headmaster confirmed willingness to support the study. Parents of children who agreed to participate gave written informed consent. Investigation of this specific age group resulted from children's and parents' readiness to take part in the study.

Materials and Procedure Figure 1 illustrates the experimental procedure (Dewar et al. 2012). Children went through two learning phases. Each learning phase consisted of (i) encoding a list of words, (ii) immediate free recall of the word list, and (iii) 12 min of wakeful resting or watching three animated short movies. Order of the delay conditions (rest, movies) was counterbalanced across children, i.e. word list 1 was followed by resting and word list 2 was followed by movies for half of the children (order 1; $n = 12$), whereas word list 1 was followed by movies and word list 2 was followed by resting for the other half (order 2; $n = 12$; Fig. 1).

The two word lists were taken from the Verbal Learning and Memory Test (Helmstaedter et al. 2001). Each word list consisted of 15 mono- and bi-syllabic nouns. Words were semantically unrelated within the word list and between the word lists. Words were presented sequentially in the middle of the screen for 1000 ms. In between word presentation, a blank screen was presented for 1000 ms. Children were instructed to memorize the words as accurately as possible and to immediately recall them in any order they wanted when a picture of a writing hand was presented on the screen 1000 ms after the last word of the word list (remained on screen for 1 min). Words were noted in written form on a blank sheet of paper (one for each word list) with a time constraint of 1 min per word list (Ecker et al. 2015b). No feedback of correctly recalled words was given. After the immediate free recall, children either rested wakefully or watched three animated short movies. Both delay conditions had the same length of about 12 min. During the resting phase, children were asked to relax quietly with their eyes closed. As in previous work (e.g.

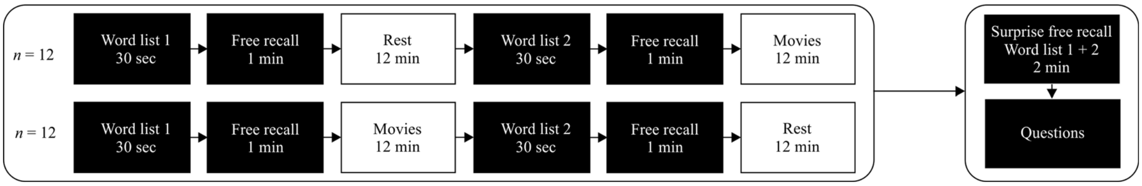

Fig. 1 Experimental procedure. Each children learned two word lists. Each word list was followed by an immediate free recall. After the immediate recall, children either rested or watched three movies for about 12 min followed by a surprise free recall test and post-experimental questions. Post-encoding conditions were counterbalanced across children (order group 1 and 2)

Dewar et al. 2012), the experimenter turned off the light to provide conditions of minimal sensory input and task engagement. The experimenter rested together with the children and did not leave the room to ensure that children were not active during the resting phase. In the movies condition, children were required to watch three short 'Minions' movies. We used movies that are simple and easy to understand, while telling a complete story including a fast sequence of changing scenes within ~4 min. All movies were watched at full length. Each encoding condition (rest, movies) was preceded by a clear instruction about the encoding, recall, and delay phase. Presentation and recall were tested with children in a practice trial with five words semantically unrelated to the two word lists in the main experiment.

After the two learning phases, a surprise delayed free recall test took place. Children were asked to write down as many words as possible from the two previously learned word lists. Children noted them in any order they wanted (Dewar et al. 2012) on a blank sheet of paper within a time constraint of 2 min. The delayed recall test was followed by post-experimental questions on rehearsal behavior during the rest and movies condition (from 1 = 'not at all' to 5 = 'very often'), expectation of a surprise delayed free recall test (yes/no), motivation to take part in the experiment (from 1 = 'not at all' to 7 = 'very much') and motivation to show a good memory performance (from 1 = 'not at all' to 7 = 'very much').

Scoring Children received one point for each correctly recalled word. Based on previous studies (e.g. Dewar et al. 2012; Varma et al. 2017), we calculated a retention score for each child to examine how much of the immediately recalled words were retained over the delay in each condition (resting, movies). We calculated the retention score by dividing the number of correctly recalled words in the delayed recall test by the number of correctly recalled words in the immediate recall test.

Results

Figure 2 shows the number of correctly recalled words for immediate and delayed recall in the rest and movies condition. Descriptive statistics can be found in Table 1.

A mixed ANOVA with condition (memory retention in the rest vs. movies condition) as within-subject factor and order of the conditions (rest then movies; movies then rest) as between-subjects factor was conducted. The analysis revealed a significant main effect of condition, $F(1,22) = 9.82$, $p < .005$, $\eta^2 = .260$, and a significant condition*order interaction, $F(1,22) = 5.88$, $p = .024$, $\eta^2 = .156$. The main effect of order was non-significant, $F(1,22) = .16$, $p = .690$. Based on the significant condition*order interaction, we ran separate repeated measures ANOVAs. Results revealed no significant differences in memory retention when the rest condition was followed by the movies condition, $F(1,11) = .232$, $p = .639$ (Table 1). However, when the movies condition was followed by the rest condition children retained about 36% more words in the rest condition, $F(1,11) = 16.79$, $p = .002$, $\eta^2 = .604$.

Simple effects analyses of immediate memory performance (Table 1) revealed no difference between the rest and movies condition, $t(23) = .18$, $p = .856$. More words were recalled from the second word list than the first word list, $t(23) = -2.22$, $p = .036$, $d = -.45$. Children in the respective order condition recalled a similar amount of words from word list 1, $t(22) = -.97$, $p = .342$, and word list 2, $t(22) = -1.12$, $p = .273$. The effect of higher correctly recalled words from the second word list disappeared when order-specific analyses were conducted (rest then movies condition: $t(11) = -1.56$, $p = .147$; movies then rest condition: $t(11) = -1.54$, $p = .153$). Analyses of our data on a non-parametric level did not change our findings (see supplemental material).

Analyses of the post-experimental questions revealed that motivation of taking part in the experiment ($M = 5.04$, $SD = .81$) and showing a good memory performance ($M = 5.29$, $SD = 1.52$) was high. Children rehearsed words to a similar low extent during resting ($M = 1.79$, $SD = 1.10$) and watching movies ($M = 1.54$, $SD = 1.02$), $t(23) = .97$, $p = .341$, $d = .194$. Six children expected a delayed recall test. Controlling for these children by excluding them from analyses did not change our results. Spearman correlations between the post-experimental questions and immediate and delayed recall performances revealed low, non-significant relations in the rest and movies condition, p's > .20, except for a positive correlation between the expectation of a surprise free recall test and delayed recall performance in the movies condition, $r = .491$, $p = .015$.

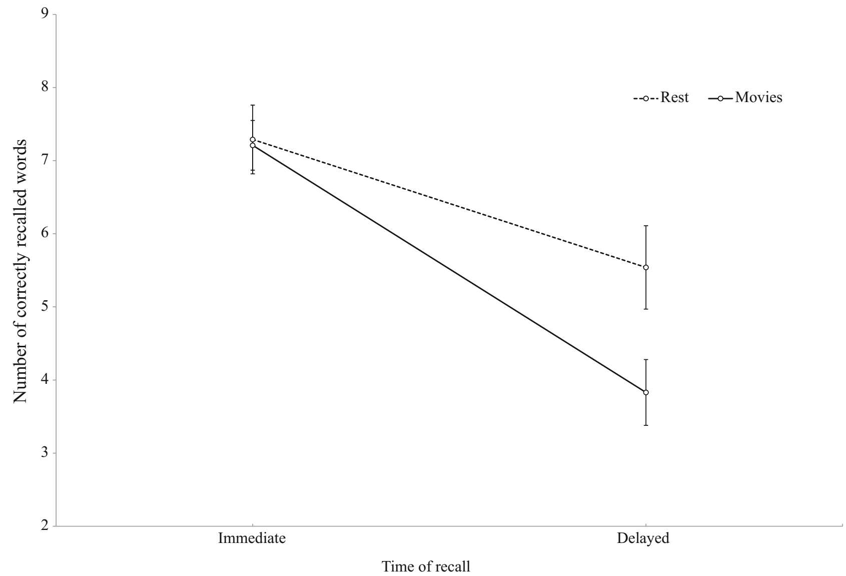

Fig. 2 Number of correctly recalled words (max = 15 words per word list). Plotted separately for recall time (immediate, delayed) and post-encoding condition (rest, movies). Error bars represent standard errors of the mean

Discussion

Various studies in healthy younger and elderly adults as well as patients with neurological deficits indicate that post-learning rest supports memory consolidation compared to a period of distraction after learning (Brokaw et al. 2016; Cowan et al. 2004; Craig et al. 2015, 2016; Della Sala et al. 2005; Dewar et al. 2007, 2009, 2012; Mercer 2015). In line with this, we found that delayed memory performance in children aged 10–13 years profited more from a brief period of wakeful rest than watching short movies after encoding a word list.

It is an open question why resting after learning supports memory retention more than working on a (cognitively demanding) task. Views exist that memories are in a labile state after their acquisition and thus prone to interference. Interference after learning can diminish memory consolidation and as a consequence memory retention (Robertson 2012; Wixted 2004). Research indicates that similar (McGeoch 1931, 1933; Müller and Pilzecker 1900) and dissimilar/diversion/non-specific interference (Dewar et al. 2007; Fatania and Mercer 2017) after learning can have detrimental effects on memory retention. For instance, retention of a word list can be interfered by encoding a second word list (Müller and Pilzecker 1900; McGeoch 1931), retention of a story or vocabularies can interfere with tasks like searching for errors in pictures (Dewar et al. 2012; Fatania and Mercer 2017), playing games (Brokaw et al.

Table 1 Overall and order-specific memory performances in the rest condition and movies condition

	Overall ($N = 24$)		Condition order 1[c] ($n = 12$)		Condition order 2[d] ($n = 12$)	
Memory performance	*M*	*SD*	*M*	*SD*	*M*	*SD*
Immediate rest[a]	.49	.15	.43	.12	.54	.17
Immediate movies[a]	.48	.11	.48	.09	.48	.13
Delayed rest[a]	.37	.19	.30	.16	.44	.19
Delayed movies[a]	.26	.15	.30	.13	.21	.16
Retention rest[b]	.73	.26	.67	.31	.79	.19
Retention movies[b]	.52	.27	.62	.23	.42	.28

M, mean; *SD*, standard deviation

[a] number of correctly recalled words divided by 15 (length of the word list)

[b] number of correctly recalled words in the delayed recall test divided by the number of correctly recalled words in the immediate recall test

[c] rest then movies condition

[d] movies then rest condition

2016), remembering faces (Mercer 2015), listening to the radio, watching videos, and detecting tones (Dewar et al. 2007). Wakeful resting, here defined as low amounts of external stimulus input and task-related mental activity (eyes closed, relaxed), seems to support the retention of memories. During this low interference state, labile memory representations seem to have a higher chance to get consolidated resulting in higher delayed memory performances (Mednick et al. 2011; Tambini et al. 2010; Karlsson and Frank 2009; van Kesteren et al. 2010).

Alternatively, it could be argued that higher retention scores in the rest compared to the movies condition are no evidence for memory consolidation, but rather the effect that retroactive interference is absent in the wakeful resting condition (Ecker and Lewandowsky 2012; Lewandowsky et al. 2012). For instance, according to the temporal-distinctiveness theory (Brown et al. 2007), retroactive interference effects are determined by temporal proximity. Accordingly, interfering material competes with the to-be-remembered words during retrieval depending on their proximity in temporal space, i.e. the shorter the temporal interval, the higher the interference, the lower the memory performance (Ecker et al. 2015a). Based on our study design, we cannot rule out whether memory consolidation was disrupted or whether the movies condition interfered with the word list during retrieval.

A discussion of age-related differences in the impact of a brief period of wakeful rest after learning on memory retention (compared to a cognitive task delay period) should also be led based on the view that the brain is subject to age-related and developmental changes. Differences in the effect of a brief period of post-encoding wakeful rest in children and adults might be based on differences in the maturity of brain areas relevant for processing the task at hand. Task-relevant brain areas involved in, for instance, binding of information elements during encoding or protection of memory representations against interference may not be fully developed in children (e.g. prefrontal cortex, hippocampus; Riggins et al. 2018; Shing et al. 2010; Ofen et al. 2007; Keresztes et al. 2017). This might, in turn, result in memory representations of lower strength and/or higher susceptibility to interference (Darby and Sloutsky 2015). Low interference phases, like during wakeful resting, might thus support memory consolidation resulting in higher delayed memory performance when compared to a cognitive task delay period.

It is also conceivable that the disruption of rehearsal strategies in the movies condition led to lower delayed memory performances than in the resting condition. However, we assume that rehearsal played a minor role due to our finding of low rehearsal rates in both delay conditions and low relations between rehearsal rates and delayed memory performance. These results support recent findings in young adults indicating that intentional rehearsal during resting seems not to be a determining factor for memory retention (Dewar et al. 2014).

A limitation of our study is that we have no information on whether resting after learning supports memory retention also over the long term (e.g. days). Studies with healthy elderly adults and amnesic patients indicate that a memory supporting effect of resting persists up to 7 days (Alber et al. 2014; Dewar et al. 2012).

These 'long-term' resting effects were supported by a recent study of Martini et al. (2018a) in children aged 13–14 years showing a higher memory retention in lower immediate memory performers over 7 days in a 10-min post-encoding resting condition compared to a problem-solving condition.

Additionally, our study gives no information on memory-related developmental changes in the impact of watching movies after learning (for reviews about memory development across the life span see Hertzog and Shing 2010; Gathercole 1998). Investigations into developmental changes in the effect of wakeful resting are scarce. The study of Fatania and Mercer (2017) with children and adults showed that children profited from resting, while adults did not (Martini et al. 2017; Varma et al. 2017). This result, together with others (Darby and Sloutsky 2015), indicates that under specific conditions retroactive interference seems to be more detrimental in children than adults (but see also Howe 1995; Koppenaal et al. 1964).

Unexpectedly, based on the fact that we fully counterbalanced the rest condition and movies condition, our results indicate that the time point of resting might play a role. We showed similar retention performances when the rest condition was followed by the movies condition. Significantly higher retention performance was found when the movies condition was followed by the rest condition. Due to the low sample size per order of condition, our interpretations are limited. It is conceivable that consolidation of the first word list was disrupted by the second experimental condition (encoding and recall of the second word list followed by the respective delay condition). Given that the exact time course of consolidation is still unclear, it is conceivable that words needed more time to get stabilized, and consequently to become less prone to interference. This would be an interesting future research question, which should be conducted in view of a study by Dewar et al. (2009) in older amnesic patients and healthy older adults. They showed that memory retention of verbal material in amnesic patients was higher when post-encoding interference occurred at the end of a 9-min delay interval than when it occurred in the middle (3–6 min) or at the beginning (0–3 min) of the interval. Investigating the optimal length of a resting phase and the optimal time point for resting (e.g. beginning or ending of a longer learning session) are interesting future research topics.

Conclusion

We found that a brief period of wakeful resting after encoding new verbal information supported memory retention in children. Our results extend existing findings (Fatania and Mercer 2017; Experiment 1) in that we found the resting effect (i) in children aged 10–13 years (ii) with the implementation of a delay interference task close to children's everyday life activity (GSMA 2014; Ofcom 2017). Adding some minutes of wakeful rest to periods of intensive learning would be a cheap and quick intervention to increase memory performance and learning-related outcome in children. Identifying conditions under which wakeful resting after learning is effective as well as age-specific modulating factors for the resting effect (see Martini et al. 2018a, b) are important issues for future research.

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Compliance with Ethical Standards

Conflicts of Interest None.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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