A Diary After Dinner: How the Time of Initial Retrieval Influences the Long-Term Retention of Autobiographical Memories

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Abstract

Iterative retrieval can shape long-term retention of autobiographical events. The retrieval of recent memories is usually realized by recording events in a diary at various points during the day, typically in the morning before work or in the evening before sleep. However, little is known about how the time of day of recording influences the long-term retention of autobiographical memories. In the present study, we investigated this question using an internet-based diary method. During five days, participants recorded recent autobiographical memories of the given day or those of the previous day. Recording took place either in the morning or in the evening. Following a 30-day long delay, they were tested for the recorded events in a free recall task. According to the results, the time of day and the delay between the original events and their diary recording had no effect on the amount of recorded events. However, participants who recorded their memories in the evening before sleep, performed significantly better 30 days later in the free recall task. These results suggest that the time of day of an initial reactivation and recording of recent episodic events has a significant effect on long-term retention of the memories of these events.

Keywords: time of day effect, retrieval, autobiographical memory, long-term retention, free recall

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The effect of circadian rhythm on human cognitive performance has been studied for a long time and a couple of findings showed that human memory does not operate at a constant level during wakefulness (for review see Schmidt, Collette, Cajochen, & Peigneux, 2007). For example in a series of experiments, Folkard and Monk (1979) found a number of important relationships between the time of encoding and the success of learning. In these experiments, participants were asked to study a list of words in different times of the day and then their memories for the previously studied materials were tested in free recall tasks immediately after the study phase or after various time delays. In one hand, when the recall occurred immediately after learning, recall rate was better in the morning than in the afternoon. On the other hand, this difference disappeared when participants were tested after a 20-minute long delay. Moreover, when there was a one-week long delay following the study phase, recall performance was better for a meaningful story studied in the afternoon than in the morning, while the time of testing had no effect on memory performance (Folkard & Monk, 1978).

In these early studies (Folkard & Monk, 1978; 1979), participants were between the ages of about 20 and 60 years and authors did not control an important factor, the chronotype that shows differences across individuals and depends on age. Later studies demonstrated that performance in different cognitive tasks depends on individual circadian preferences. For instance, Yoon (1999) found that whereas young adults preferred to perform numerous activities in the afternoon and evening (evening type), elderly people preferred the early hours of the day (morning type). In a well controlled study (Hasher, Chung, May, & Foong, 2001), younger and older adults' memories for three lists of previously studied words were tested after a 10-sec long delay. Results showed that young participants' performance was better in the afternoon than in the morning, whereas an opposite pattern for recall performance was observed in the elderly. This effect is usually referred to as the synchrony effect suggesting that people tend to perform better on various memory tests at their optimal time of day. Other studies provided evidence for synchrony effect on immediate recall performance too (e.g. Petros, Beckwith, & Anderson, 1990).

Later studies investigated the time of day effect on memory after longer time delays. Although the effect of time of learning was not investigated in a study by Mather and Knight (2005), authors found that the time of testing had an influence on recall performance. While older people recalled an increased number of words in the early hours of the day, young adults were better in the afternoon than in the morning. Most of other studies, however, reported rather different results suggesting that only the time of learning and not the time of testing influences long-term memory performance. Barbosa and Albuquerque (2008) investigated only undergraduate students and showed that the time of testing did not affect memory performance one week after the study phase, but participants were better in recognizing words learnt in the afternoon when compared to recall rate for words learnt in the morning.

Similarly to e.g. Folkard and Monk (1978) as well as Barbosa and Albuquerque (2008), Gais, Lucas and Born (2006) also found that only the time of learning influenced the long-term recall performance in a group of high school students, but the time of testing had no effect on later memory. Authors argued that a possible explanation of better memory for materials learnt in the evening could be that learning in the evening is usually followed by sleeping. Several authors (see e.g. Wixted, 2004; 2005) suggested previously that the beneficial effect of sleep after learning on long-term memory consolidation is due to the lack of interfering memories between learning and sleeping. This hypothesis is based on the numerous pieces of evidence found that interfering memories have a negative effect on the stabilization (consolidation) of a new memory as well as the restabilization (reconsolidation) of a memory after reactivation (for review see e.g. Nader, 2003; Sara, 2000). In a second experiment, Gais and his colleagues tested the effect of sleep after learning on later memory performance and showed that 2 days after the study phase, memory was better for materials learnt in the evening when participants went to sleep shortly after learning.

Although the time of day effect on declarative memory has been studied extensively over the past decades, studies on relationship between the recall of autobiographical memories and the time (morning/evening) of encoding or retrieval of those events are largely missing. Therefore we aimed to investigate time of day effect on the recall of autobiographical events. In the present study, participants (undergraduate students) reactivated recent autobiographical memories (recording phase): on the same day when the events occurred (in the evening, Group 1) or the next day (in the morning, Group 2 or in the evening, Group 3). Thirty days later (long-term recall phase) participants' memories for the previously reactivated events were tested in a free recall task when the time of retrieval was not controlled. Most of the previous studies (e.g. Barbosa & Albuquerque, 2008; Folkard & Monk, 1978; Gais et al., 2006) showed that the time of recall has no influence on memory performance (for opposite results see e.g. Mather & Knight, 2005). Therefore, we assumed that the three groups of subjects would recall the same number of autobiographical events in the recording phase of the experiment. Furthermore, we have several pieces of evidence for the beneficial effect of sleep on the stabilization of memory traces (for review see e.g. Paller & Voss, 2004). According to several theorists (e.g. Gais et al., 2006; Wixted, 2004; 2005) this is due to the lack of interfering information during sleep. Based on these findings, we hypothesized that due to the lack of interfering information during sleep after reactivation in the evening, the two groups of participants who recorded their memories in the evening in the first phase of the experiment would recall a larger number of memories in the long-term memory task than participants who reactivated their memories immediately after sleeping in the morning.

Method

Participants

Participants were 109 Hungarian students between the ages of 18 and 25 years (M = 20.9 years, SD = 1.5), 61 men and 48 women. They were recruited at the Budapest University of Technology and Economics and they received extra course credits for their participation. Participants were randomly assigned into three experimental groups. There were 38 participants in the first, 35 in the second and 35 in the third group.

Materials and procedure

The experiment consisted of two main phases, a recording and a test phase, separated by a 30-day long interval. In the recording phase participants were asked to record any event of the given day (Group 1) or of the previous day (Group 2 and Group 3) they could remember. They were told that the recorded memories did not have to be emotionally charged and/or personal, but they were asked to try to record any event they could remember. Participants were asked to record their memories by using an internet-based questionnaire, possibly at home, in quiet and calm conditions. Participants recorded only one day events at a time, and this process was repeated for five consecutive days.

Participants' tasks in the three groups differed only in respect of the time of recording. The first evening group recorded events of the given day right before going to sleep at night, the morning group recorded memories from the previous day immediately after awakening, and the second evening group recorded events from the previous day right before going to bed at night. Each day, participants were first asked about the hours of sleep they had during the previous day. Then they were asked to describe the contents of the events in one paragraph. Finally, participants rated the personal importance of each memory on 5-point scales, and they recorded the duration (in minutes) of each event.

30 days after the recording phase, participants' memories for the recorded events were tested in the test phase of the experiment. They used the same internet-based user interface

they have used in the recording phase. There were no differences between the tasks of the three groups in the test phase: the time of recall (morning/evening) was not controlled in the recall phase. Participants' task was to describe as many of the previously recorded events as they could. Finally, they rated the certainty of each event on a five-point scale (How sure are you that this event really happened? 1 = *not at all*, 5 = *absolutely*).

Results

Recording Phase

Table 1 summarizes the results of the recording phase. One-way ANOVA analyses showed that there were no significant group differences in the following aspects: the amount of time the participants spent sleeping $F(2, 106) = 1.61$, $p = .21$; the mean ratings on personal importance $F(2, 106) = 0.58$, $p = .56$ and the duration of the events $F(2, 106) = 0.77$, $p = .47$. Furthermore, there were no differences between the groups in the mean number of recorded events $F(2, 106) = 0.49$, $p = .61$ (Figure 1).

(Table 1 about here)

Test Phase

Recall rate refers to the mean percentage of recalled events out of those the participants described in the recording phase. Figure 1 represents the mean number of recalled memories in the test phase. One-way ANOVA showed significant group difference $F(2, 106) =3.33$, $p < .05$. Fisher's LSD post hoc tests proved that while there was no significant difference between the two evening groups' recall rates ($p = .85$), the morning group recalled a reduced number of memories than both of the two evening groups (Group 1: $p < .05$ and Group 3: $p < .05$).

Despite the fact that the three groups' performances were not the same in the test phase, one-way ANOVA proved that there were no group differences in ratings on certainty $F = 1.51$, $p = .23$. Furthermore, significant correlation was not found between the answers provided by the participants in the recording phase and the number of recalled events in the test phase: sleep hours r(109) = -.02, p = .82; personal importance r(109) = .15, p = .13 and the duration of the events r(109) = .06, p = .52.

Discussion

This study aimed to investigate the relationship between the time of recording and the long-term retention of autobiographical memories. Participants retrieved their memories in two cycles: they recorded autobiographical memories a few hours after the events have occurred and 30 days later in a free recall task. In the recording phase, participants recorded recent memories on the same day when the events occurred (in the evening) or the next day (in the morning or in the evening). The time of retrieval was not controlled in the long-term recall phase. According to the results, whether there was a sleep period between the event and its recording it had no effect on the number of recorded memories and the number of recalled events in the long-term recall task. This surprising results is highly interesting considering the wealth of studies showing that sleep plays a fundamental role in the stabilization of memory traces (for reviews see e.g. Paller & Voss, 2004; Walker & Stickgold, 2004). However, our findings are consistent with previous results showing that the time of retrieval (morning/evening) did not affect the current memory performance (e.g. Barbosa & Albuquerque, 2008; Folkard & Monk, 1978; Gais et al., 2006). Although the time of reactivation of the events (morning vs. evening) had no effect on the number of recorded events in the first phase of the experiment, the time of recording had a significant influence on the long-term accessibility of the reactivated memories. Participants, who recorded their memories in the morning, performed poorer thirty days later in the long-term recall task, when compared to the recall rates of the other two groups of subjects who recorded their memories in the evening. In sum, participants were significantly better at remembering events which have been recorded in the evening about a month earlier. According to the best of our knowledge, our results are the first evidence for the relationship between the time of first recall and the long-term retention of autobiographical memories.

Recording the events in the first phase of the experiment can be considered as the first reactivation of those memories. This could be an important factor from the point of view of the so-called reconsolidation theories arguing that consolidated memories become labile when they are reactivated, and an additional period of stabilization is required which is referred to as the reconsolidation process (for review, see e.g. Sara, 2000). From the perspective of this theory, our results could be considered as evidence that the time of reactivation (morning vs. evening) affects the later reconsolidation of these memories. One possible explanation for this effect might be that when a memory trace is in an unstable form (e.g. after reactivation), it is more exposed to interference, and people who recorded their memories in the morning continued their daily activities immediately after the reactivation. Therefore, contrary to the evening groups' memories, events which have been reactivated in the morning were more exposed to interference, and the interfering events could disrupt the reconsolidation process. This is in line with theories suggesting that the lack of interfering memories plays a key role in the beneficial effect of sleep on the stabilization of memories (Wixted, 2004; 2005; see also Gais et al., 2006). This is also consistent with previous results of for example Schwabe & Wolf (2009), whose participants studied a meaningful but unfamiliar story right after they reactivated recent autobiographical events in response to emotionally positive, negative and neutral cue words. Participants showed impaired memory for neutral events in a long-term recall task as a consequence of previous recall of autobiographical events.

How the time of reactivation influences the long-term consolidation of episodic memories is presently unknown. It is the task of future studies to unfold the mechanisms of episodic retrieval and consolidation of autobiographical memories

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Table 1

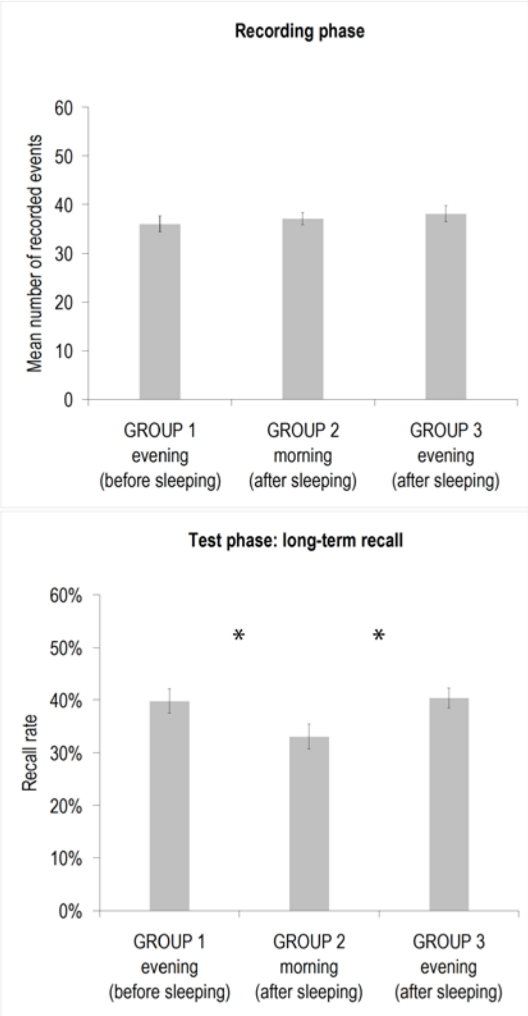
Comparison of the Three Experimental Groups in the Recording Phase

Groups	Sleep/night (hour)	Importance/event (scale: 1-5)	Duration/event (minute)
Group 1	7.4 (1.0)	3.1 (0.5)	62.3 (29.1)
Group 2	7.4 (1.1)	3.0 (0.8)	69.6 (24.7)
Group 3	7.8 (0.9)	3.1 (0.6)	68.7 (28.1)

Note. Values represent mean values; standard deviations are given in parentheses.

Figure 1.

Mean Number of Recorded Recent Autobiographical Memories in the First Phase of the Experiment, and Recall Rate Following a 30-Day Long Retention Interval



Notes. * $p < .05$; error bars represent standard error of the mean.

Horizontal axis labels indicate the time of recording in the first phase of the experiment: evening/morning; before sleeping/after sleeping.