The Quarterly Journal of Experimental Psychology

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pqje20

A diary after dinner: How the time of event recording influences later accessibility of diary events

Ágnes Szőllősi[a], Attila Keresztes[b], Martin A. Conway[c] & Mihály Racsmány[ad]

[a] Department of Cognitive Science, Budapest University of Technology and Economics, Budapest, Hungary

[b] Center for Lifespan Psychology, Max Planck Institute for Human Development, Berlin, Germany

[c] Centre for Memory and Law, Department of Psychology, City University London, London, UK

[d] Research Group on Frontostriatal Disorders, Hungarian Academy of Sciences, Budapest, Hungary

Accepted author version posted online: 19 Jun 2015.Published online: 25 Jul 2015.

To cite this article: Ágnes Szőllősi, Attila Keresztes, Martin A. Conway & Mihály Racsmány (2015): A diary after dinner: How the time of event recording influences later accessibility of diary events, The Quarterly Journal of Experimental Psychology, DOI: 10.1080/17470218.2015.1058403

To link to this article: http://dx.doi.org/10.1080/17470218.2015.1058403

THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 2015
http://dx.doi.org/10.1080/17470218.2015.1058403

Rapid communication

A diary after dinner: How the time of event recording influences later accessibility of diary events

Ágnes Szőllősi[1], Attila Keresztes[2], Martin A. Conway[3], and Mihály Racsmány[1,4]

[1]Department of Cognitive Science, Budapest University of Technology and Economics, Budapest, Hungary
[2]Center for Lifespan Psychology, Max Planck Institute for Human Development, Berlin, Germany
[3]Centre for Memory and Law, Department of Psychology, City University London, London, UK
[4]Research Group on Frontostriatal Disorders, Hungarian Academy of Sciences, Budapest, Hungary

(Received 5 June 2014; accepted 22 May 2015)

Recording the events of a day in a diary may help improve their later accessibility. An interesting question is whether improvements in long-term accessibility will be greater if the diary is completed at the end of the day, or after a period of sleep, the following morning. We investigated this question using an internet-based diary method. On each of five days, participants ($n = 109$) recorded autobiographical memories for that day or for the previous day. Recording took place either in the morning or in the evening. Following a 30-day retention interval, the diary events were free recalled. We found that participants who recorded their memories in the evening before sleep had best memory performance. These results suggest that the time of reactivation and recording of recent autobiographical events has a significant effect on the later accessibility of those diary events. We discuss our results in the light of related findings that show a beneficial effect of reduced interference during sleep on memory consolidation and reconsolidation.

Keywords: Time of day effect; Retrieval; Autobiographical memory; Accessibility; Sleep.

The effect of circadian rhythm on human cognitive performance has been extensively studied, and previous research has found that human memory does not operate at a constant level during wakefulness (for a review, see Schmidt, Collette, Cajochen, & Peigneux, 2007). For example, in a series of early experiments, Folkard and Monk (1978, 1979) found a number of important relationships between the time of encoding and the success of learning. They showed that memory for word lists was influenced by the time of day and that this effect was modulated by the time elapsed between learning and retrieval. Later studies, however, pointed out that there is an important candidate factor that seems to modify this time of day effect on memory—the chronotype that shows differences across individuals and across different age groups (Yoon, 1997). Accordingly, it has been demonstrated that performance on different cognitive tasks depends on individual circadian

Correspondence should be addressed to Ágnes Szőllősi, Department of Cognitive Science, Budapest University of Technology and Economics, 1 Egry József u., Budapest 1111, Hungary. E-mail: aszollosi@cogsci.bme.hu

We thank Éva Deliága and Gábor Kocsis for their help in data collection, Csongor Cserép, Linda Dezső, and Dóra Molnár-Bakos for their help in data analysis, and Pál Vakli for his comments on a previous version of the manuscript.

This work was supported by the KTIA NAP 13 [grant number 13-2-2014-0020].

preferences—people tend to perform better at their optimal time of day (a phenomenon termed the *synchrony effect*; for a review, see Yoon, May, & Hasher, 1999). For instance, young adults' memory is better in the afternoon and in the evening than early in the day. This time of day effect has been demonstrated for immediate recall (e.g., Petros, Beckwith, & Anderson, 1990), and also when participants were tested following a short delay (Hasher, Chung, May, & Foong, 2002).

Other studies investigated the time of day effect on memory after longer time delays and showed that only the time of learning and not the time of testing influences long-term memory performance (Barbosa & Albuquerque, 2008; see also Folkard & Monk, 1978; but see Mather & Knight, 2005). Accordingly, Gais, Lucas, and Born (2006) found that young adults' memory was better when they studied previously in the evening, but the time of retrieval had no effect on memory. These results are consistent with the synchrony effect, but the authors argued that a further possible explanation for better memory for materials learnt in the evening could be that learning in the evening is usually followed by sleep. Several authors (see e.g., Ellenbogen, Payne, & Stickgold, 2006; Jenkins & Dallenbach, 1924; Wixted, 2004, 2005) suggested previously that the beneficial effect of sleep after learning on long-term memory consolidation could be due to the lack of interfering memories during sleep. This hypothesis is based on earlier findings revealing a negative effect of interfering memories on the stabilization (consolidation) of a new memory as well as the restabilization (reconsolidation) of a memory after reactivation (for reviews, see e.g., Nader, 2003; Nader & Einarsson, 2010; Sara, 2000). Based on these works and ideas, in a second experiment, Gais and his colleagues tested the effect of sleep after learning on later memory performance and showed that two days after the study phase, memory was better for the previously learnt material when participants went to sleep shortly after learning, regardless of the time of day. In addition to sleep studies, a series of experiments (e.g., Cowan, Beschin, & Della Sala, 2004; Dewar, Alber, Butler, Cowan, & Della Sala, 2012) provided evidence for the beneficial impact of the lack of interference on the strengthening of a memory following a short (10–30 min) wakeful rest.

Although the time of day effect on memory for various materials, nearly all verbal, has been studied extensively over the past decades, there are no studies of the relationship between the recall of autobiographical memories and the time (morning/evening) of encoding or retrieval. Such studies of autobiographical memory could also strengthen the ecological validity of the time of day effect on memory in general. From a methodological viewpoint, it should be also highlighted that recalling everyday memories on the basis of previously recorded diary events has been a widely used method in autobiographical research for decades (see Linton, 1982). Because in a typical diary study participants tend to record their memories at either the beginning or the end of the day, such studies on time of day effects in autobiographical remembering could also have important methodological implications. Importantly, recording events in a diary is equivalent to the reactivation of those memories, after which an additional period of restabilization (reconsolidation) is needed. Here, as a first step, we assessed whether the time of recording of autobiographical events in a diary (reactivation) affects those events' accessibility in the long term.

In the present study, we investigated only young adults in order to control for age-related circadian preferences. Participants recorded recent autobiographical memories on the 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 participants were asked to free recall the diary events. Based on earlier findings that show a beneficial effect of sleep (and the lack of interference) on the stabilization of memory traces (e.g., Gais et al., 2006; Jenkins & Dallenbach, 1924; Wixted, 2004, 2005), we hypothesized that those who recorded their memories in the evening in the first phase of the experiment will recall more recorded events following a 30-day delay than participants who recorded their memories in the morning shortly after sleep.

EXPERIMENTAL STUDY

Method

Participants

To control for the possible impact of age-dependent circadian preferences, only young adults were recruited as participants (age range: 18–25 years; $M = 20.9$, $SD = 1.5$). Participants were 109 Hungarian undergraduate students, 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 group (20 men, 18 women; $M_{age} = 21.0$ years, $SD = 1.6$), 35 participants in the second group (20 men, 15 women; $M_{age} = 20.4$ years, $SD = 1.2$), and 36 participants in the third group (21 men, 15 women; $M_{age} = 21.2$ years, $SD = 1.8$).

Design, materials, and procedure

The experiment consisted of two phases, a recording and a test phase, separated by a 30-day retention interval. In the recording phase, participants were asked to record any event of that day (Group 1) or of the previous day (Group 2 and Group 3) that they could remember. They were told that the recorded memories did not have to be of emotionally charged and/or distinctive, they could simply be everyday events—for example, going to a lecture, and so on. Participants were asked to record their memories by using an internet-based questionnaire, at home, in quiet and calm conditions. Participants recorded events for one day 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 (Group 1) recorded events of the given day shortly before going to sleep at night, the morning group (Group 2) recorded memories from the previous day shortly after awakening, and the second evening group (Group 3) recorded events from the previous day shortly 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 a 5-point scale (1 = *not at all important*, 5 = *very important*), and they recorded the duration (in minutes) of each event.

Thirty days after the recording phase, participants' memory for the recorded events was tested using the same internet-based user interface that they had used in the recording phase. We made an attempt to control for possible time of day effects in the second phase of the experiment by asking participants to complete the test either between 7:00 and 12:00 or between 12:00 and 17:00. Our web interface provided us an opportunity to check the time when participants started to complete the test. All participants were instructed to recall and describe (in one paragraph) as many of the previously recorded events as they could. Finally, they rated the certainty of each event on a 5-point scale (How sure are you that this event really happened? 1 = *not at all*, 5 = *absolutely*).

Results

Recording phase

We tested whether conditions of recording were identical across groups. Therefore, for each group, mean values were calculated for the amount of time the participants spent sleeping per night during the 5-day-long period of the recording phase as well as for the following aspects of all recorded memories: ratings of personal importance and durations of the recorded events (see Table 1). One-way analyses of variance (ANOVAs) showed that there were no reliable group differences either in the amount of time the participants spent sleeping, $F(2, 106) = 1.61$, $p = .21$, $MSE = 0.95$, $\eta_p^2 = .03$, or in the mean ratings of personal importance, $F(2, 106) < 1$, or in the duration of the events, $F(2, 106) < 1$.

Most importantly, there were no differences between the groups in the mean number of recorded events, $F(2, 106) < 1$ (Figure 1a). Finally, description lengths of the recorded events were compared between the groups. A one-way ANOVA established that there were no group differences in the mean number of words per event (Group 1:

Table 1. *Comparison of the three experimental groups in the recording phase*

Group	*Sleep/night (hours)*	*Importance/event (scale: 1–5)*	*Duration/event (minute)*
Group 1	7.4 (1.0)	3.1 (0.4)	62.7 (27.7)
Group 2	7.4 (1.1)	3.0 (0.8)	68.7 (21.1)
Group 3	7.8 (0.9)	3.1 (0.6)	67.9 (23.5)

Note: Values represent mean values; standard deviations are given in parentheses. Participants in Group 1 recorded events for that day in the evening (shortly before sleep); participants in Group 2 recorded events for the previous day shortly after morning awakening; and participants in Group 3 recorded events for the previous day in the evening (shortly before sleep).

$M = 21.6$, $SD = 9.3$; Group 2: $M = 26.2$, $SD = 11.1$; Group 3: $M = 21.7$; $SD = 12.9$), $F(2, 106) = 1.98$, $p = .14$, $MSE = 124.08$, $\eta_p^2 = .04$.

Test phase

In each group, approximately half of the participants completed the test between 7:00 and 12:00 (Group 1: 63.2%; Group 2: 54.3%; Group 3: 61.1%). The remaining participants recalled their diary events between 12:00 and 17:00. Distribution of time was similar across groups, $\chi^2(2) = 0.65$, $p = .72$.

Recall rate refers to the mean percentage of recalled events out of those the participants recorded in the first phase (Figure 1b). A one-way ANOVA showed a significant group difference, $F(2, 106) = 3.33$, $p < .05$, $MSE = 0.02$, $\eta_p^2 = .06$. Fisher's least significant difference (LSD) post hoc tests established that whereas there was no reliable difference between the two evening groups' recall rates ($p > .05$), the morning group recalled fewer events than either of the two evening groups (both ps $< .05$).

Despite the fact that the three groups' performances were not the same in the test phase, a one-way ANOVA established that there were no group differences in ratings of certainty, $F(2, 106) = 1.51$, $p = .23$, $MSE = 0.54$, $\eta_p^2 = .03$ (Group 1: $M = 3.56$, $SD = 0.80$; Group 2: $M = 3.85$, $SD = 0.74$; Group 3: $M = 3.67$, $SD = 0.65$). Furthermore, we found no reliable correlation between the number of recalled events in the test phase and the sleep hours during the recording phase, $r(109) = -.02$, $p = .82$; the personal importance of the recorded events, $r(109) = .14$, $p = .15$; the duration of the recorded events, $r(109) = .08$, $p = .43$; or the length of event descriptions, $r(109) = .08$, $p = .40$.

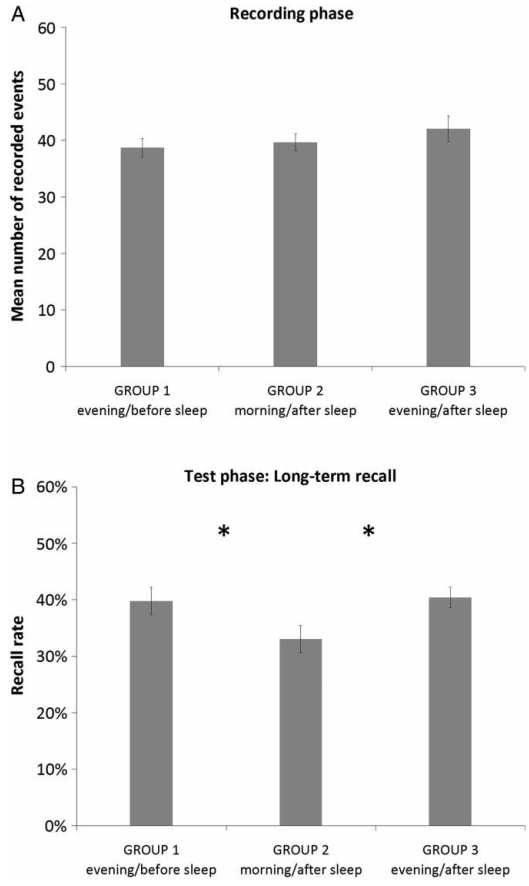

Figure 1. *Recalled autobiographical events in the two phases of the experiment. (A) Mean number of recorded memories in the first phase of the experiment. (B) Recall rate for diary events in the long-term free recall task.* *p < .05; *error bars represent standard error of the mean (*SEM*). Horizontal axis labels indicate the time of recording in the first phase of the experiment: evening/morning; before sleep/after sleep.*

Discussion

This study aimed to investigate the relationship between the time of recording and the later

accessibility of autobiographical events. According to the results, participants who recorded their memories in a diary in the morning performed at a lower level 30 days later in a long-term free recall task, when compared to the recall rates of the other two groups of subjects who recorded their memories in the evening. In other words, participants were significantly better at remembering events that had been recorded in the evening about a month earlier.

Our results obtained in the long-term recall task can not be explained by differences in the mean number of recorded events in the first phase of the experiment. Whether subjects were asked to complete their diary in the morning or in the evening, they recorded the same number of events. These 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; but see e.g., Mather & Knight, 2005). Moreover, whether there was a sleep period between the event and its recording had no effect on the number of memories recorded and the number recalled in the long-term recall task.

Further explanations can be excluded as well. Although here we did not aim at investigating the qualitative nature of the diary events, we showed that the recorded events did not differ either in their importance ratings or in their durations or description lengths. Furthermore, there was no difference in the amount of time participants spent sleeping per night during the recording phase. Finally, transfer-appropriate processing also can not explain our findings obtained in the test phase, because in each group, approximately half of the participants were tested at a completely different time from the time of day when they completed their diary 30 days earlier. In sum, our novel findings have shown the relationship between the time of initial recall (morning vs. evening) and the long-term accessibility of autobiographical memories.

Our results fit nicely with theories of reconsolidation (for reviews, see e.g., Nader & Einarsson, 2010; Sara, 2000). These theories argue that consolidated memories become labile whenever they are reactivated, and this period of lability is followed by a period of stabilization, referred to as the reconsolidation process. Recording events in a diary is indeed the reactivation of memories for those events. From the perspective of the reconsolidation theories, our results could be considered as evidence that the time of reactivation (morning vs. evening) affects the reconsolidation of these memories. One possible explanation for this effect might be that when a memory trace is in an unstable form (i.e., 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 that had 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 (Jenkins & Dallenbach, 1924; Wixted, 2004, 2005; see also Gais et al., 2006).

Furthermore, there is an alternative interpretation of our findings. It is possible that participants did not recall their original experiences in the final test (long-term recall). Instead, they might have retrieved the first recall of the events (i.e., when they recorded their memories in the diary). Even in this case it is possible that the lack of interference during sleep had a beneficial impact on the consolidation of the memories (but not on the reconsolidation of the memories for the original events, as suggested above).

An interesting question for future research would be to test the validity of our results in elderly samples, because we know from previous studies (e.g., Hasher et al., 2002; Mather & Knight, 2005; Petros et al., 1990) that young adults tend to perform better on various memory tasks in the evening than in the early hours of the day, whereas an opposite pattern is typical for the elderly. Here, our sample included only young adults to control for the possible impact of

age-dependent circadian preferences on recall performance.

In sum, it seems that the recall of an everyday memory shortly before sleep has a beneficial impact on its later accessibility in the long term. The lack of interference during sleep seems to be a convincing explanation, but there is a need for further studies to test other possible influencing factors. Nevertheless, we have shown that the time of day can affect not only memory for laboratory-based materials, but the long-term accessibility of previously reactivated everyday memories. These findings also have important methodological implications and practical relevance for future studies on autobiographical remembering, especially for studies that aim at testing memory for an everyday event on the basis of its previous recording.

REFERENCES

Barbosa, F. F., & Albuquerque, F. S. (2008). Effect of the time-of-day of training on explicit memory. *Brazilian Journal of Medical and Biological Research*, *41*, 477–481. doi:10.1590/S0100-879X2008005000023

Cowan, N., Beschin, N., & Della Sala, S. (2004). Verbal recall in amnesiacs under conditions of diminished retroactive interference. *Brain*, *127*, 825–834. doi:10.1093/brain/awh107

Dewar, M., Alber, J., Butler, C., Cowan, N., & Della Sala, S. (2012). Brief wakeful resting boosts new memories over the long term. *Psychological Science*, *23*, 955–960. doi:10.1177/0956797612441220

Ellenbogen, J. M., Payne, J. D., & Stickgold, R. (2006). The role of sleep in declarative memory consolidation: Passive, permissive, active or none? *Current Opinion in Neurobiology*, *16*, 716–722. doi:10.1016/j.conb.2006.10.006

Folkard, S., & Monk, T. H. (1978). Time of day effects in immediate and delayed memory. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory* (pp. 142–168). London: Academic Press.

Folkard, S., & Monk, T. H. (1979). Time of day and processing strategy in free recall. *Quarterly Journal of Experimental Psychology*, *31*, 461–475. doi:10.1080/14640747908400739

Gais, S., Lucas, B., & Born, J. (2006). Sleep after learning aids memory recall. *Learning and Memory*, *13*, 259–262. doi:10.1101/lm.132106

Hasher, L., Chung, C., May, C. P., & Foong, N. (2002). Age, time of testing, and proactive interference. *Canadian Journal of Experimental Psychology*, *56*, 200–207. doi:10.1037/h0087397

Jenkins, J. G., & Dallenbach, K. M. (1924). Obliviscence during sleep and waking. *The American Journal of Psychology*, *35*, 605–612. doi:10.2307/1414040

Linton, M. (1982). Transformations of memory in everyday life. In U. Neisser (Ed.), *Memory observed: Remembering in natural contexts* (pp. 77–92). San Francisco, CA: W. H. Freeman and Company.

Mather, M., & Knight, M. (2005). Goal-directed memory: The role of cognitive control in older adults' emotional memory. *Psychology and Aging*, *20*, 554–570. doi:10.1037/0882-7974.20.4.554

Nader, K. (2003). Memory traces unbound. *Trends in Neurosciences*, *26*, 65–72. doi:10.1016/S0166-2236(02)00042-5

Nader, K., & Einarsson, E. Ö. (2010). Memory reconsolidation: An update. *Annals of the New York Academy of Sciences*, *1191*, 27–41. doi:10.1111/j.1749-6632.2010.05443.x

Petros, T. V., Beckwith, B. E., & Anderson, M. (1990). Individual differences in the effects of time of day and passage difficulty on prose memory in adults. *British Journal of Psychology*, *81*, 63–72. doi:10.1111/j.2044-8295.1990.tb02346.x

Sara, S. J. (2000). Retrieval and reconsolidation: Toward a neurobiology of remembering. *Learning and Memory*, *7*, 73–84. doi:10.1101/lm.7.2.73

Schmidt, C., Collette, F., Cajochen, C., & Peigneux, P. (2007). A time to think: Circadian rhythms in human cognition. *Cognitive Neuropsychology*, *24*, 755–789. doi:10.1080/02643290701754158

Wixted, J. T. (2004). The psychology and neuroscience of forgetting. *Annual Review of Psychology*, *55*, 235–269. doi:10.1146/annurev.psych.55.090902.141555

Wixted, J. T. (2005). A theory about why we forget what we once knew. *Current Directions in Psychological Science*, *14*, 6–9. doi:10.1111/j.0963-7214.2005.00324.x

Yoon, C. (1997). Age differences in consumers' processing strategies: An investigation of moderating influences. *The Journal of Consumer Research*, *24*, 329–342. doi:10.1086/209514

Yoon, C., May, C. P., & Hasher, L. (1999). Aging, circadian arousal patterns, and cognition. In N. Schwarz, D. Park, B. Knauper, & S. Sudman (Eds.), *Aging, cognition and self reports* (pp. 117–143). Washington, DC: Psychological Press.