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Time of day effects on the use of distraction to minimise forgetting

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Abstract

Recent research found that implicit rehearsal of distraction can reduce forgetting for older adults, in part due to their inefficient regulation of irrelevant information. Here, we investigated whether young adults' memory can also benefit from critical information presented as distraction. Participants recalled a list of words initially and then again after a 15-min delay, with some of the critical studied words exposed as distraction during the delay. We tested young adults at an optimal versus non-optimal time of day, the latter a condition intended to mirror patterns of those with reduced attention regulation. We also varied task instruction to assess whether awareness of an upcoming memory task would influence implicit rehearsal of distraction. The task instruction manipulation was ineffective, but desynchronising time of testing and period of optimal cognitive arousal resulted in a memory benefit. Young adults tested at a non-optimal time showed minimal forgetting of words repeated as distraction, while those tested at an optimal time showed no memory benefit for these items, consistent with research suggesting that attention regulation is greatly affected by circadian arousal.

Keywords

Distraction; circadian rhythms; rehearsal effects

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Young adults typically show a substantial advantage on explicit memory tasks compared to older adults, especially when memory is tested using free recall (e.g., Craik, 1986; Craik & McDowd, 1987). It was particularly surprising then, that a study that capitalised on age-related declines in cognitive control could eliminate age differences in free recall (Biss, Ngo, Hasher, Campbell, & Rowe, 2013). The successful manipulation in that study re-exposed some of the originally learned words as distraction during the retention interval, which created an implicit rehearsal opportunity. Given older adults' tendencies to process distraction (e.g., May, 1999; Rowe, Valderrama, Hasher, & Lenartowicz, 2006), this re-exposure technique reduced and even eliminated forgetting for those items for older adults while having no impact on young adults.

The unique benefit older adults showed in memory for items repeated as distraction was attributed to three factors: (1) their greater susceptibility to and encoding of distraction (e.g., May, 1999; Rabbitt, 1965), (2) their greater tendency to transfer distraction from one task to a new task (e.g., Amer & Hasher, 2014; Campbell, Hasher, & Thomas, 2010; Kim, Hasher, & Zacks, 2007), and (3) the memory strengthening benefit of automatic maintenance rehearsal as triggered by the re-exposure to list items (e.g., Davachi, Maril, & Wagner, 2001; Greene, 1987; Jacoby, 1991; Rundus, 1971). In contrast, the finding that young adults did not benefit from re-exposure of list items as distraction is consistent with age differences in the abilities of young adults to effectively ignore and even suppress distraction (e.g., Healey, Ngo, & Hasher, 2014; Layton, 1975; May,

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1999; Rabbitt, 1965) as well as the fact that they do not always carry over information from one setting to another (e.g., Brewer, Knight, Marsh, & Unsworth, 2010; Scullin, Bugg, McDaniel, & Einstein, 2011; Scullin, McDaniel, & Einstein, 2010; Spencer & Weisberg, 1986). Young adults differentially engage inhibitory processes to narrow attention to goal-relevant information and suppress no longer relevant information (Hasher, Zacks, & May, 1999; Weeks & Hasher, 2014).

The relative efficiency of younger adults' cognitive control abilities may account for their failure to benefit from distraction, as older adults did, in the Biss et al. (2013) paradigm. However, there are at least two circumstances under which young adults' cognitive control has been reported to be reduced: (1) when in a positive mood (e.g., Biss, Hasher, & Thomas, 2010; Fredrickson, 2001; Schmitz, De Rosa, & Anderson, 2009; Vermeulen, 2010) and (2) when tested at off-peak times of day. With respect to time of day, there is substantial evidence that young adults operating at a time that is desynchronised with their circadian preference show reduced control relative to others operating at a peak time (e.g., Hornik & Tal, 2009; Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1999; Lara, Madrid, & Correa, 2014; Lehmann, Marks, & Hanstock, 2013; Ngo & Hasher, 2016; Pica, Pierro, & Kruglanski, 2014; Ramírez, García, & Valdez, 2012; Ramírez et al., 2006; Webb, 1982). For example, in a study by Rowe and colleagues (2006) using a 1-back task on pictures with superimposed distracting words, evening chronotype young adults showed priming for the irrelevant words when tested in the morning, but not when tested in the afternoon.

Chronotype in that study was measured with a widely used paper and pencil test, the Horne-Östberg Morningness-Eveningness Questionnaire (Horne & Östberg, 1976) known to correlate well with physiological markers of arousal (Roenneberg, Wirz-Justice, & Merrow, 2003; Zavada, Gordijn, Beersma, Daan, & Roenneberg, 2005). It categorises people into three main types: morning, neutral, and evening. Norms (e.g., May, Hasher, & Stoltzfus, 1993; Yoon, May, & Hasher, 1999) suggest that as many as 90% of young adults fall into the neutral and evening categories, hence the designation here and in many other studies as morning being an off-peak time of day for young adults. Because the ability to control distraction varies across the day in a manner that is synchronous with one's circadian arousal pattern, or chronotype (e.g., Hasher et al., 1999; May & Hasher, 1998), we considered the possibility that young adults might also benefit from the implicit rehearsal opportunities that distraction accorded older adults in the Biss et al. (2013) study. Access to the records of that study showed that all young adults were tested in the afternoon, as is common in university-based laboratory studies (e.g., May & Hasher, 1998; Zelenski, Rusting, & Larsen, 2003).

We report an experiment using the Biss et al. (2013, Exp 3) procedure with neutral and evening-type young adults tested either in the morning or in the afternoon. First, participants studied and recalled a list of words. Then during a 15-min delay, they did a 1-back task on pictures with superimposed irrelevant items, some of which were words from the studied list. This was followed by a final recall of the original list of words, about which half of the participants were forewarned and half were not. It seemed plausible that awareness of an upcoming memory task might impel participants to rehearse the list items and in so doing, implicitly benefit from the repetition of some of those words during the delay. Two critical questions were addressed: (1) would the afternoon-tested young adults replicate the original findings of Biss and colleagues (2013) and (2) would the morning-tested participants show the memory-strengthening benefit of exposure to distraction.

Method

Design

A factorial 2x2x2x2 design was used, with proportion of words recalled as the dependent variable. The between-group factors were time of testing (AM vs. PM) and task instruction (warned about the final memory test vs. unwarned), and the within-group factors were recall episode (immediate vs. delayed) and word type (repeated as distraction vs. unrepeated).

Participants

Ninety-six students from the University of Toronto (63 females) received course credit or monetary compensation for their participation in this experiment. All participants completed the Shipley Vocabulary test (Shipley, 1946) and the Morningness-Eveningness Questionnaire (MEQ; Horne & Östberg, 1976). Since our central interest was in the match between time of testing and chronotype for young adults, the majority of whom are neutral or evening-types (Yoon et al., 1999), participants who fell within the morning-type range on the MEQ were replaced ($n = 6$). Following the procedures of Biss et al. (2013), participants were replaced for scoring below 20 on the Shipley vocabulary test ($n = 3$), and reporting both awareness of the repeated words and using them at recall (AM: $n = 6$, PM: $n = 7$). Participants assigned to the morning and afternoon testing conditions did not differ on either vocabulary or on MEQ scores, $ps > .3$ (see Table 1 for demographic information).[1] Informed consent was obtained from all participants.

Materials

The materials were the same as those used by Biss and colleagues (2013, Exp. 3). The study list was composed of 20 concrete nouns, with 2 items each at the beginning and end of the series to reduce primacy and recency effects.

Table 1. Participant demographic information.

Participant groups	n	Age (years)		Years of education (M)	Vocabulary	MEQ
		M	Range			
Non-optimal time (AM)						
Unwarned	24	19.3 (2.3)	18-28	13.2 (1.6)	29.6 (3.3)	43.1 (6.4)
Warned	24	20.3 (2.6)	18-27	13.9 (1.8)	29.9 (3.8)	43.5 (9.2)
Optimal time (PM)						
Unwarned	24	19.2 (1.8)	18-26	13.7 (1.4)	30.0 (3.9)	43.1 (5.7)
Warned	24	18.9 (2.4)	17-29	12.9 (1.6)	31.1 (3.2)	42.3 (7.5)

Vocabulary measured using the Shipley (1946) vocabulary test (maximum score = 40). MEQ (Horne & Östberg, 1976) scores range from 16-86; scores below 41 are classified as evening-types, scores from 42-58 are neutral, and scores above 59 denote morning-type chronotypes. Standard deviations are in parentheses.

The 16 remaining words were divided into two sets of 8, one set repeated as distractors superimposed on pictures in the 1-back task and the other set did not repeat. Across conditions, each set was used equally often as repeated or unrepeated words. Each of the 8 repeated critical words appeared twice on the 1-back task, along with 8 other filler words and 24 non-word letter strings. The 16 critical words and the 8 filler words were equated for length (range = 4–7 letters, $M = 5.3$, $SD = 1.0$; Coltheart, 1981) and frequency of occurrence in written language ($M = 50$ instances per million words, $SD = 17$; Kučera & Francis, 1967). Forty-two rotated line drawings were selected from Snodgrass and Vanderwart (1980), and coloured red to distinguish them from the black-coloured text which was superimposed on the pictures.

Procedure

With the exception of our critical time of testing and task instruction manipulations, the procedure followed that used in Biss et al. (2013, Experiment 3). Half of the participants were tested in the morning, from 9:00 am to 12:00 pm, and the remaining participants were tested in the afternoon, from 1:00 pm to 4:00 pm. Then, half of the participants of each testing period were forewarned about the upcoming final memory test and half were not, the latter as in Biss et al. (2013). This was the sole difference in instructions to the two groups. The study began with a single trial of intentional learning, during which words were displayed one at a time at the centre of a computer screen for 3,000 ms (inter-stimulus interval = 500 ms). Prior to recall, participants counted backwards by 3's for 30 s. They were then given 45 s to recall out loud as many of the studied words as possible in any order. Participants then completed two 5-min nonverbal filler tasks and then the critical 5-min 1-back task. The 1-back task was a rapid series of line drawings superimposed with letter strings, presented one at a time on a computer screen for 1,000 ms (inter-stimulus interval = 500 ms) with participants instructed to ignore the irrelevant letter strings, and to press a key whenever the same picture was displayed consecutively. The task began with 4 pictures presented alone, followed by 8 pictures superimposed with non-words. The next 64 randomly mixed trials were pictures superimposed with 16 filler words, 16 critical studied words, and 32 non-words. The last 8 trials were more pictures with non-words. Every picture and letter string combination was presented twice throughout the task. For the 16 critical trials (8 studied words), the same picture was paired with the same word on each presentation, and none of them was followed by an identical picture, so that a key-press response was not required.

Immediately after the 1-back task, participants were asked to recall the words from the list studied at the beginning of the experiment. Once again, they were allotted 45 s to recall as many of the words as possible in any order. Finally, a graded awareness questionnaire was administered for awareness, along with the Shipley vocabulary test (Shipley, 1946), and the Morningness-Eveningness Questionnaire (Horne & Östberg, 1976).

Results

Performance on the 1-back task was at ceiling, with 98% correct detection of repetitions across participants tested in the morning or in the afternoon, whether or not they had been warned about the final memory test. Average reaction times on correct 1-back trials also did not differ between the morning and afternoon groups regardless of task instruction (AM: $M = 517$ ms, $SD = 67$ ms; PM: $M = 514$ ms, $SD = 76$ ms, $p > .8$).

Recall performance (see Table 2 for means and *SD*s) was analysed using a time of testing (AM, PM) x task instruction (warned, unwarned) x recall episode (immediate, delayed) x word type (repeated as distraction, unrepeated) mixed analysis of variance (ANOVA), with time of testing and task instruction as the between-subject variables. The task instruction variable was not reliable as a main effect nor in interaction with other factors (largest $F = 1.335$). The critical higher order interaction between time of testing, recall episode, and word type was reliable,

Table 2. Proportion of items recalled.

Participant groups	Initial recall		Final Recall	
	Unrepeated words	Repeated words	Unrepeated words	Repeated words
Non-optimal time (AM)				
Unwarned	0.42 (0.20)	0.40 (0.16)	0.33 (0.18)	0.38 (0.16)
Warned	0.45 (0.20)	0.47 (0.25)	0.36 (0.19)	0.48 (0.24)
Mean	0.44	0.43	0.35	0.43
Optimal time (PM)				
Unwarned	0.42 (0.25)	0.45 (0.18)	0.37 (0.26)	0.39 (0.20)
Warned	0.41 (0.17)	0.43 (0.18)	0.36 (0.19)	0.37 (0.19)
Mean	0.41	0.44	0.36	0.38

Standard deviations are in parentheses.

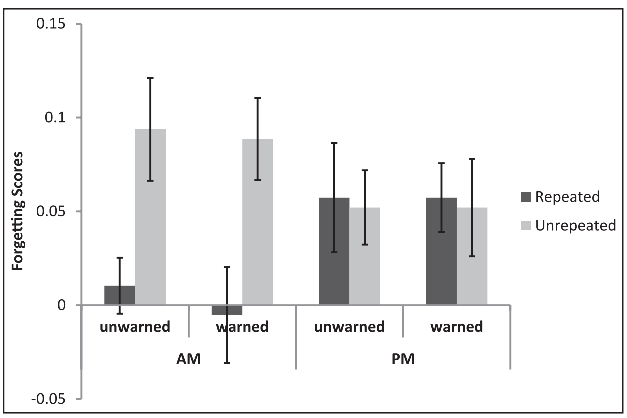

Figure 1. Mean forgetting scores, calculated as the difference between the proportion of words recalled during initial and final recall, as a function of time of testing (AM vs. PM) and word type (repeated as distraction vs. unrepeated) for participants with warned or unwarned task instructions. For both conditions, young adults tested in the afternoon showed similar forgetting of both word types, while those tested in the morning did not forget items repeated as distraction. Error bars show standard errors.

$F(1, 92) = 8.710$, $MSE = .409$, $p = .004$, $\eta_p^2 = .086$, and it qualified the remaining interaction between recall episode and word type, $F(1, 92) = 6.114$, $MSE = .409$, $p = .015$, $\eta_p^2 = .062$, and the main effect of recall, $F(1, 92) = 36.277$, $MSE = .426$, $p < .001$, $\eta_p^2 = .283$. The three way interaction is most easily seen in Figure 1 which illustrates forgetting scores calculated as the difference between items recalled in the immediate and delayed recall episodes.

We next compared the interaction between word type, immediate versus delayed recall, and task instruction separately for morning and afternoon-tested groups. Again, the task instruction variable showed no reliable effects (all Fs < 1). For young adults tested in the morning, recall declined from the immediate to the delayed test, $F(1, 46) = 13.403$, $MSE = .504$, $p = .001$, $\eta_p^2 = .226$, an effect that was qualified by the significant interaction between recall episode and word type, $F(1, 46) = 19.842$, $MSE = .303$, $p < .001$, $\eta_p^2 = .301$. That is, young adults tested in the morning showed significantly less forgetting of words that were repeated as distraction compared to unrepeated words. In fact, young adults' forgetting of repeated words in the morning was not statistically different from zero for either type of task instruction, 95% CI = [−0.46, 0.38] and [−0.16, 0.33] (warned and unwarned, respectively). In the afternoon, participants showed the pattern of young adults previously seen in Biss et al. (2013): Reliable forgetting between the initial and final tests, $F(1, 46) = 25.188$, $MSE = .348$, $p < .001$, $\eta_p^2 = .354$, with no evidence of an interaction involving repeated versus unrepeated words, $F(1, 46) = .091$, $MSE = .515$, $p > .7$.

Discussion

Cognitive control processes are vulnerable to fluctuations in circadian arousal. It has been known for some time that the ability to regulate distraction varies with both age and the synchrony between chronotype and time of testing (e.g., Petros, Beckwith, & Anderson, 1990; Rowe, Hasher, & Turcotte, 2009). In these studies, evening-type participants showed greater regulation over visual distraction in the afternoon than in the morning, and morning-type participants showed the reverse pattern. Similar patterns of synchrony effects have been reported for resistance to proactive interference (May, Hasher, & Foong, 2005), analytic thought (Yoon, Lee, & Danziger, 2007), and suppression of irrelevant information and incorrect responses (Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1998; May & Hasher, 1998; Ngo & Hasher, 2016; Schmidt, Peigneux, Leclercq, et al., 2012). Recent neuroimaging data also showed brain activation and connectivity differences across the day for both young and older adults (e.g., Anderson, Campbell, Amer, Grady, & Hasher, 2014; Anderson et al., 2017; Campbell, Grady, Ng, & Hasher, 2012; Schmidt, Peigneux, & Cajochen, 2012).

In the present study, young adults tested in the morning, an off-peak time of day, showed reduced forgetting for items seen as distraction during a delay interval. Participants tested in the afternoon did not show that pattern and instead replicated the young adult results of Biss and colleagues (2013): distraction did not benefit remembering. These findings are consistent with the suggestion that the ability to regulate attention varies across the day in a manner that is in synchrony with one's circadian arousal pattern, or chronotype (e.g., Hahn et al., 2012; Lara et al., 2014; May & Hasher, 1998; Rowe et al., 2006; Yoon et al., 1999).

We note that poor cognitive control which allows for processing of non-target stimuli is a double-edged sword (e.g., Amer, Campbell, & Hasher, 2016; Chiu & Egner, 2015; May, 1999; Weeks & Hasher, 2014; Yang & Hasher, 2007). Frequently studied costs of poor control include interference effects on the Stroop task (West & Alain, 2000) and the Flanker task (Zeef, Sonke, Kok, Buiten, & Kenemans, 1996). However, distraction processing can also be beneficial by improving implicit memory for previously relevant (May & Hasher, 1998) or irrelevant information (Rowe et al., 2006), and problem solving performance (May, 1999) especially when the distraction is congruent with a final test task. In our study, participants tested at off-peak times (in the morning) benefited from re-exposure to the studied items that occurred as distraction during a retention interval, whereas distraction had no impact on recall performance for those tested in the afternoon. By desynchronising individuals' time of peak circadian arousal and time of testing, we were able to capture the performance of young adults with reduced cognitive functioning, specifically the ability to inhibit distraction, and in so doing eliminated forgetting for items repeated as distraction.

Although time of testing influenced the use of distraction, warning participants about an upcoming test had no impact. The goal of this instruction had been to increase the likelihood that distraction during the delay interval would be implicitly encoded by warned participants. It seemed plausible that awareness of an upcoming test could have facilitated implicit retrieval of studied items when re-exposed as distraction, perhaps even by those tested in the afternoon. This manipulation was ineffective. In hindsight, these non-findings are consistent with literatures on problem solving (e.g., Spencer & Weisberg, 1986) and on prospective memory (e.g., Brewer et al., 2010; Scullin et al., 2010) with young adults failing to notice cues that occur in the midst of an ongoing task.

Our results show that young adults' reduced inhibitory control at a non-optimal time of day allows the implicit rehearsal and strengthening of studied items, despite having only occurred as distraction. These findings are consistent with the suggestion by Biss and colleagues (2013) that there are benefits from automatically induced rehearsals. However, unlike older adults' absolute memory benefit of eliminating forgetting of repeated items with no cost to the memory of unrepeated items (Biss et al., 2013), the present data show equivalent total recall for young adults tested at both times of day: Young adults tested at an off-peak time of day did not recall more total items than those tested at the peak time. Consequently, one might suspect that the memory benefit reported here for young adults is that the sparing of repeated items in the morning comes at a cost of forgetting unrepeated items. However, we failed to find a reliable difference in the forgetting of unrepeated items for morning vs. afternoon-tested participants, $t(94)=1.556$, $p=.123$. It is possible that the lack of a significant effect in recall may be partially due to the inclusion of neutral-type participants in our study. Recent research on synchrony effects found no difference in performance across the day for neutral-type young adults in a battery of cognitive tasks, including inhibitory processing and memory tasks (May & Hasher, 2017). Thus, performance of neutral-type individuals may have reduced the predicted memory advantage for the afternoon group. Nevertheless, given the significant time of day difference in the forgetting of repeated items, $t(94)=2.176$, $p=.032$, $d=.44$, we suggest there is indeed a memory benefit for words repeated as distraction when young adults are tested at an off-peak time.

It is useful to note that as common in university-based laboratory research, young adults in this study were recruited through an online system through which either morning or afternoon testing times were posted in advance. Given that young adults typically prefer to be tested in the afternoon (May & Hasher, 1998; Zelenski et al., 2003), and that circadian arousal past adolescence tends to shift from evening to morning (e.g., Mecacci, Zani, Rocchetti, & Lucioli, 1986; Roenneberg et al., 2007), it is conceivable that those who selected the earliest testing slots within the morning period reflect a group of neutral-type young adults inclined to morningness tendencies. To address whether self-selection may have impacted the desynchronisation between individuals' circadian preferences and time of testing, we compared the proportion of neutral and evening-type participants in morning and afternoon testing periods. There was no reliable difference in the distribution of neutral or evening-type young adults in the two testing periods, $\chi^2(1)=1.099$, $p=.294$. In fact, numerically, more neutral-type young adults selected afternoon testing times (67%) than morning testing times (56%). While the majority of studies on synchrony effects in cognitive functioning have focused on individuals with strong morningness versus eveningness tendencies, we were able to observe reduced forgetting for items repeated as distraction for participants tested at non-optimal times of day despite the inclusion of neutral-type young adults. In future studies, we expect that larger memory benefits would be observed by testing only evening-type young adults. As well, the difference between morning and afternoon testing times is relative, future work could amplify the desynchronisation between time of testing and peak circadian arousal by testing at extremely early mornings or late evenings. Together these factors suggest the possibility that the differences reported here likely underestimate circadian desynchronisation effects.

Our results are consistent with observations that inhibitory attentional control varies with circadian arousal, and that healthy young adults tested at a non-optimal time of day have less cognitive control than those tested at an optimal time of day, which here resulted in reduced forgetting of items re-exposed as distraction. In a broader context, our findings suggest that young adults, such as high school students, operating at non-optimal times of day can implicitly encode and rehearse information by way of distraction, with possible implications for pedagogical practices and learning approaches for those with difficulty focusing attention. It is possible that similar results of memory benefits for items exposed as distraction would be seen with mood differences as well, given reports that young adults in a positive mood take a broader orientation towards information (e.g., Biss et al., 2010; Fredrickson, 2001; Schmitz et al., 2009; Vermeulen, 2010). Patterns of cognitive control may be more variable than typically reported in the research literature.

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Declaration of conflicting interests

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Note

1. The mean MEQ scores of all participants fall into the Neutral range (42-58), the modal category for young adults (May et al., 1993).

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