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Synchrony Effects in Automatic and Controlled Retrieval

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Abstract

Using a speeded retrieval procedure, we investigated time of day effects in automatic and controlled retrieval. Morning-type adults were tested at either peak (early morning) or off-peak (late afternoon) times on a speeded implicit (Experiment 1) or explicit stem completion task (Experiment 2). In Experiment 1, retrieval strategies were identified by changes in response speed between a practice phase with rapid retrieval and an implicit memory test. Performance based on controlled retrieval (shown by slow-down participants) showed more priming at peak than at off-peak times of day, a finding confirmed in Experiment 2 in which participants were given intentional retrieval instructions when the materials switched. In contrast, performance based on automatic retrieval (shown by non-slow-down participants) did not differ across peak and off-peak times. The finding suggests a robust synchrony effect in controlled retrieval, but not in automatic retrieval which does not appear to vary across the day.

Keywords

Time of Day; Synchrony Effect; Automatic Retrieval; Controlled Retrieval; Speeded Retrieval

Synchrony Effects in Automatic and Controlled Retrieval

Performance on explicit memory tasks is widely reported to be better at peak than at off-peak times of day for both younger and older adults (e.g., Hasher, Chung, May, & Foong, 2002; Hasher, Goldstein, & May, 2005; Petros, Beckwith, & Anderson, 1990; West, Murphy, Armilio, Craik, & Stuss, 2002; Yoon, 1997)[1],Similar synchrony effects have been reported, again for both younger and older adults, in tasks requiring controlled processing including regulation of distraction (May, 1999) and of strong responses (May & Hasher,

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[1]Based on normative data, the majority of older adults are Morning-types and have a peak intellectual and physical period sometime in the morning while a substantial group of young, university students are Evening-types and have a peak time later in the day (Hasher et al., 2005; Roenneberg et al., 2004).

1998), as well as on a measure of adolescents' fluid intelligence (Goldstein, Hahn, Hasher, Wiprzycka, & Zelazo, 2006).

In contrast with this emerging literature examining controlled processes across time of day, there is little evidence regarding synchrony effects on automatic processes. To our knowledge, there is only one such study and it reported a *reverse* synchrony effect for implicit as compared to explicit memory performance; that is, both younger and older adults showed better performance at their *off-peak* than *peak* times of day (May, Hasher, & Foong, 2005).

In this study, we sought to do a conceptual replication of the dramatic dissociation in the synchrony effects in explicit and implicit memory. In selecting a task, we took account of evidence that implicit performance can be either facilitated (e.g., Jacoby, 1991) *or* disrupted by intentional processes (e.g., Beilock, Bertenthat, McCoy, & Carr, 2004; Howard & Howard, 2001; Roβnagel, 2001) presumably depending on whether the intentional process is congruent or incongruent with the automatic process. In the current study, we chose a procedure with an intention to minimize reliance on intentional processes by training participants to retrieve words very rapidly prior to introducing an implicit test of memory (Horton, Wilson, & Evans, 2001; Wilson & Horton, 2002). A unique advantage of this procedure is that it enables us to discriminate between individuals who likely use controlled retrieval and those who primarily reply on automatic retrieval by tracking changes in their retrieval speed.

In this procedure, participants are initially trained to use cues to retrieve words rapidly from semantic memory before introducing an implicit test that consists of a mix of cues, some only solvable with words from semantic memory and some solvable with words presented in an earlier study phase. Individual retrieval strategies can be determined by comparing each participant's response times in the semantic retrieval phase to those in the critical test phase. Given evidence that controlled retrieval takes longer than automatic retrieval (Richardson-Klavehn & Gardiner, 1995), we assume that participants who slow down from the semantic retrieval phase to the test phase are likely switching to controlled retrieval strategies, while those who continue to respond rapidly are relying on automatic retrieval. Having identified those participants who continue to rely on automatic processes and those who switch to controlled processes, we then compared priming scores across time of day separately for these two groups to examine the synchrony effects on the two different retrieval processes.

We report two experiments using this procedure. In Experiment 1, participants were uninformed about the change in cues between the retrieval training phase (with its cues to new words) and the testing phase (with its mix of cues to old and new words) and we examined time of day effects for participants who relied on more automatic versus more controlled retrieval. In Experiment 2, we explicitly instructed participants to use controlled retrieval to validate the time of day effects seen in Experiment 1 for those participants identified as using controlled retrieval. To date there is substantial and consistent evidence that younger and older adults show identical synchrony effects (e.g., Hasher et al., 2005; Hasher, Zacks, & May, 1999), despite an overall age-related decline in episodic memory (e.g., Balota, Dolan, & Duchek, 2000). Thus, although there are limits to generalizability, we tested only Morning-type older adults.

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Experiment 1

There were three major phases in the experiment: study, retrieval practice, and test. In the study phase, participants completed stems (e.g., ELE___) in response to a semantic cue (e.g., large animal with a trunk). In the retrieval practice phase, participants were trained to quickly generate words to novel stems. In the test phase, speed of generation continued to be

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encouraged, but now some stems could be completed by words generated during the study phase. Participants were not informed about the change in materials.

Method

Participants

The final sample consisted of 53 healthy Morning-type older adults (ages 60 - 76 years, M = 67.89, SD = 4.19). They were screened using the Morningness-Eveningness Questionnaire (MEQ, Horne & Ostberg, 1976), a valid and reliable tool for determining temporal preference patterns (e.g., Smith, Reilly, & Midkiff, 1989). Their mean MEQ score was 67.32 (range: 59 - 80), within the range of Morning-type people (59 - 86, Horne & Ostberg, 1976).[2] The Short Blessed Test (SBT, Pfeiffer, 1975) was used to screen for cognitive impairment. Twenty-seven participants were tested in the morning (9 - 10 am) and 26 in the afternoon (4 - 5 pm). These testing times and cutoff scores were similar to those used in previous work, including the May et al.'s study (2005). Each participant received 10 Canadian dollars as compensation. Nine original participants were replaced, one for being a non-native English speaker, one for having a high SBT score, two due to technical problems, and five for reporting the intentional use of studied words to complete the test stems. The morning-testing and afternoon-testing groups did not differ on the demographic variables displayed in Table 1 (ts < 1.34, ps > .18).

Materials

Four lists of critical words, each with 24 words, one list of 24 fillers, and 8 buffers were selected from the items used by Wilson and Horton (2002). No proper nouns were used and all words had straightforward spellings and unique 3-letter stems. The stems for the four lists of critical items had an equal average baseline completion rate of .23 in Wilson and Horton (2002), as well as in the context of the present study. The lists were counterbalanced across participants and testing times (i.e., morning vs. afternoon) so that each list served equally often as a study list, a nonstudy control list, and as one of the two practice lists. In the *study phase*, the 24 critical words were presented intermixed with 24 filler words, with two buffer items at the beginning and two others at the end of the list. Fillers were used to reduce awareness of the connection between the study and test lists. In order to track changes in retrieval speed and also to encourage rapid responding, the *retrieval practice phase* was divided into two phases, each with 24 items from one of the two practice lists. For the same purpose, the final *test phase* was also divided into two phases, each of which started with four buffer items followed by 24 stems, 12 from the study list (i.e., old stems) and 12 from the nonstudy control list (i.e., new stems). The buffer items in both the study and test phases served to eliminate warm up effects on response times for critical items.

Procedure

Figure 1 illustrates the basic experimental procedure of Experiments 1 and 2.

Study phase.—Participants generated a series of words, each in response to a semantic cue along with a 3-letter stem, both presented on a computer screen until a response was made.

[2]A recent study proposed new cutoff scores for Morningness based on a sample of adults from 44 to 58 years of age (Taillard, Philip, Chastang, & Bioulac, 2004). We did not change the cutoffs used here to be consistent with previous work (e.g., May et al., 2005). As well, Taillard et al.'s "Neither type" and "Morning-type" people had the same peak performance period (8 -10 am) as was used in the present study.

Filler task phase.—A 10-minute number fragment completion task required participants to complete a series of equations (e.g., for '2_ +15 = 35', answer '0'). The filler task prevented participants from deliberately rehearsing the studied items.

Retrieval practice and test phases.—Participants were instructed to quickly complete a series of word stems with the first word that comes to mind. Both the practice and test phases were further divided into two in order to put pressure on retrieval speed by providing mean response times at the end of each phase along with instructions urging participants to try to go faster in the next phase. Subdividing the practice and test phases into two for each also enabled us to closely track speed changes across the test. Note that the instructions did not differ for the practice and test phases, thus to participants, the test phase seemed to be a continuation of the practice phase.

Finally, participants were given an awareness questionnaire, a background questionnaire, the Extended Range Vocabulary Test (ERVT: Educational Testing Service, 1976), and the SBT.

Results

Response Times (RTs)

For each participant, we calculated median RTs for the 24 items in the first and second retrieval practice phases as well as for the 12 new (i.e., nonstudied) items in each of the two test phases (see Figure 2). The data from one outlier (>3 *SD*s) in the practice phase were removed from the final sample. An ANOVA with time of testing as a between-subjects factor and test phase as a within-subjects factor revealed only a reliable phase effect, $F(3,153) = 23.34$, $MSE = 11003.57$, $p < .001$, stemming from the speed-up from the first to the second retrieval practice phases, $t(52) = 5.47$, $p < .001$; speed did not change thereafter, *t*s < 1.06.

Because our main interest is in priming at peak and off peak times of day by participants who employed different retrieval strategies, we divided the morning-tested and afternoon-tested participants into two groups based on individuals' retrieval speed change from the second retrieval practice phase to the combined test phases. Twenty five participants (14 tested in the morning and 11 in the afternoon) slowed down (i.e., $RT_{test} - RT_{practice2} > 0$), and thus were presumably using controlled retrieval. The average slow-down of this group was 62.7 msec ($SD = 55.9$), $t(24) = 5.62$, $p < .001$. Twenty-eight participants (13 tested in the morning and 15 in the afternoon) did not slow down (i.e., $RT_{test}-RT_{practice2} < 0$), and thus were presumed to be relying on automatic retrieval. In fact, on average, this non-slow-down group actually sped up by 71.0 msec ($SD = 60.7$), $t(27) = 6.20$, $p < .001$. Note that the two groups produced by this RT split did not differ in their demographic characteristics (*F*s < 2.06, *p*s > .15).

Priming Effects

To assess retrieval, we calculated a priming score by subtracting the baseline stem completion rate (i.e., the percentage of control stems completed with nonstudied critical words) from the target completion rate (i.e., percentage of studied stems completed with studied words). An overall 2 (testing time: morning vs. afternoon) × 2 (retrieval strategy: controlled vs. automatic) between-subjects ANOVA on the priming score revealed greater priming in the morning ($M = 27.62$, $SD = 12.51$) than in the afternoon ($M = 19.71$, $SD = 14.32$), $F(1, 49) = 5.17$, $MSE = 172.81$, $p < .05$. This main effect was accompanied by a reliable interaction between testing time and retrieval strategy, $F(1, 49) = 4.11$, $MSE = 172.81$, $p < .05$. Planned contrasts indicated that the overall time of day effect was driven solely by the group engaged in controlled retrieval. They showed greater priming in the morning (*M* = 31.55, *SD* = 11.75) than in the afternoon (*M* = 15.91, *SD* = 16.96), $t(23) = 2.72$, $p < .05$. In contrast, the automatic retrieval group did not differ in priming across time of day (morning: *M* = 23.40, *SD* = 12.33; afternoon: *M* = 22.50, *SD* = 11.87), $t(26) = 0.20$, $p = .85$ (See the two panels on the left of Figure 3).

The data suggest that automatic retrieval, indexed by the performance of participants who maintained a rapid speed in the test phase, is invariant across the day. By contrast, controlled retrieval, indexed by the performance of participants who slowed down in the test phase, is better at peak than at off-peak times. To verify the suggestion that the slow-down in responding is primarily driven by engaging in controlled retrieval, we conducted Experiment 2 using an explicit version of the present task.

Experiment 2

The only change from the first experiment was that participants were fully informed, prior to the test phase that some of the stems could be completed with initially studied words. Furthermore, participants were encouraged to use those studied words to complete the stems. If the slow-down in Experiment 1 was, as we suggest, primarily driven by the use of controlled retrieval, we should see slow-down in Experiment 2 when participant were instructed to switch to controlled retrieval, along with greater priming at a peak than off peak time of day.

Method

Participants

The final sample consisted of 46 healthy older adults (ages 60 - 78 years, *M* = 66.24, *SD* = 4.51), with a mean MEQ score of 65.38 (range: 60 - 74), within the range of Morning-type (59 - 86, Horne & Ostberg, 1976). All participants scored below a cutoff score of 6 on the SBT. Twenty-two participants were tested in the morning (9 - 10 am) and 24 were tested late in the afternoon (4 - 5 pm). Six original participants were replaced, two for being non-native English speakers and four due to health issues or technical problems. The morning-testing and afternoon-testing groups did not differ on any demographic variables (see Table 1, *t*s < 1.59; *p*s > .11).

Results

Response Times (RTs)

An ANOVA revealed only a reliable main effect of phase, $F(3,132) = 15.97$, $MSE = 136827.73$, $p < .001$ (see Figure 2). As in the first experiment, there was a reliable speed-up in responding from the first to the second retrieval practice phase, $t(45) = 7.36$, $p < .001$. As anticipated, there was a reliable slow-down between the second practice retrieval phase and the collapsed test phases, $t(45) = 4.15$, $p < .001$. An inspection of individual participants' data, using the same standard as in Experiment 1, confirmed that 43 out of 46 participants slowed down, consistent with the intentional retrieval instructions. The pattern of results for both RTs and priming scores remained unchanged after removing the three participants who did not slow down. Note that there was a speed-up between the first and second test phases (see Figure 2), $t(45) = 3.94$, $p < .01$. This speed-up within test might be due to a practice effect or to a decreased reliance on controlled retrieval or both, but it is not consistent with a suggestion that people slow down in this task because they are fatigued.

Priming

As before, priming scores were calculated by subtracting the baseline stem completion rate from the target completion rate. An analysis of the priming scores showed greater priming in the morning ($M = 29.36$, $SD = 11.54$) than in the afternoon ($M = 21.70$, $SD = 12.04$), $t(44) = 2.20$, $p < .05$ (see the right-most panel of Figure 3). This pattern parallels that seen for the participants in the first study who slowed down during the test phase, and is consistent with the results of a number of explicit memory tasks (Petros et al., 1990; West et al., 2002; Yoon, 1997).

General Discussion

The results of these two experiments suggest that controlled retrieval is better at a peak than at an off-peak time, whereas truly automatic retrieval appears to be unaffected by time of day. The synchrony effect observed here for controlled retrieval replicates a robust effect in the literature (e.g., Anderson, Petros, Beckwith, Mitchell, & Fritz, 1991; Hasher et al., 2005; May & Hasher,1998; May et al., 2005; Petros et al., 1990; West et al., 2002; Winocur & Hasher, 2002; Yoon, 1997). We found the synchrony effect both when participants chose controlled retrieval in an ostensibly implicit memory task (i.e., the participants who slowed down during test in Experiment 1) and when participants were instructed to use controlled retrieval (Experiment 2).

In contrast to the synchrony effect for controlled retrieval, we found no difference in priming across the two testing times for participants who relied on automatic retrieval (i.e., those who did not slow down in Experiment 1), suggesting the possibility that automatic retrieval is invariant across the day. At first glance, this finding is at odds with May et al.'s (2005) evidence of a reverse synchrony effect for implicit memory, that is, better performance at off-peak relative to peak times of day. Although the precise source of this difference remains to be determined, we offer a speculation based on the cover story used by May et al. (2005) which described the implicit test as a game to assess word knowledge, and gave no time limit for generating a word. At peak times, when participants are most alert and proactive, they might have occasionally rejected the first, automatically-generated word in favor of producing a word they judged to better reflect their knowledge. As a consequence, output from automatic retrieval may have been masked, resulting in an underestimation of automatic priming at peak times. In support of this argument, we note that providing participants too much time can interfere with their implicit performance (Roβnagel, 2001), as can providing some participants with instructions to search for patterns in implicit learning (Howard & Howard, 2001). Similar evidence for the blocking or masking of automatic processes by deliberate processes is also reported in the skill learning literature (Beilock et al., 2004).

Our findings have implications for the design of educational programs and the organization of daily activities. Effortful or controlled activities or programs will clearly be most efficient when scheduled at an individual's peak time of day. Because there is considerable evidence of age and individual differences in peak times of day, beginning at least prior to adolescence and extending through the lifespan (Hasher et al., 2005; Kim, Dueker, Hasher & Goldstein, 2002; Roenneberg et al., 2004), taking these into account may optimize school achievement and work success for a majority of individuals.

Automatic processes may not change across the day suggesting the possibility that pure automatic processes can be effective even at off peak times of day. Recent evidence suggests that even difficult tasks, such as decision making, can rely on automatic processes (e.g., Dijksterhuis & Nordgren, in press) and so may be successfully performed at off peak times of day. By contrast, if automatic processes are vulnerable to strategic facilitation (e.g., Jacoby, 1991) in some circumstances and disruption in others (e.g., Beilock et al., 2004; Howard & Howard, 2001; May et al., 2005; Roβnagel, 2001), then performance at peak times will be complexly determined. The untangling of facilitation and interference effects from deliberate processes to automatic ones is a matter for further research. In closing, we acknowledge that although all studies to date report synchrony effects that are comparable for both older and younger adults, the present time of day conclusions are based on a sample of older adults and so there may be limits to their generalizability.

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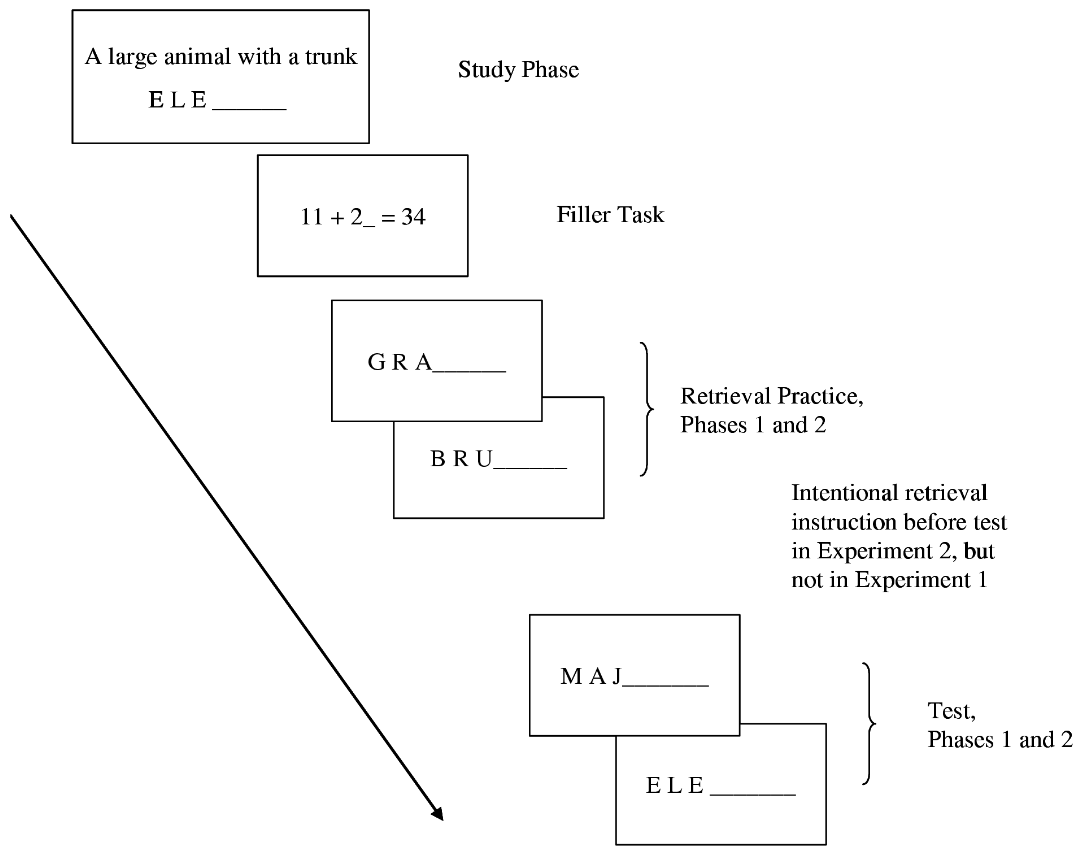

Figure 1.
Experimental procedure of Experiment 1 and Experiment 2.

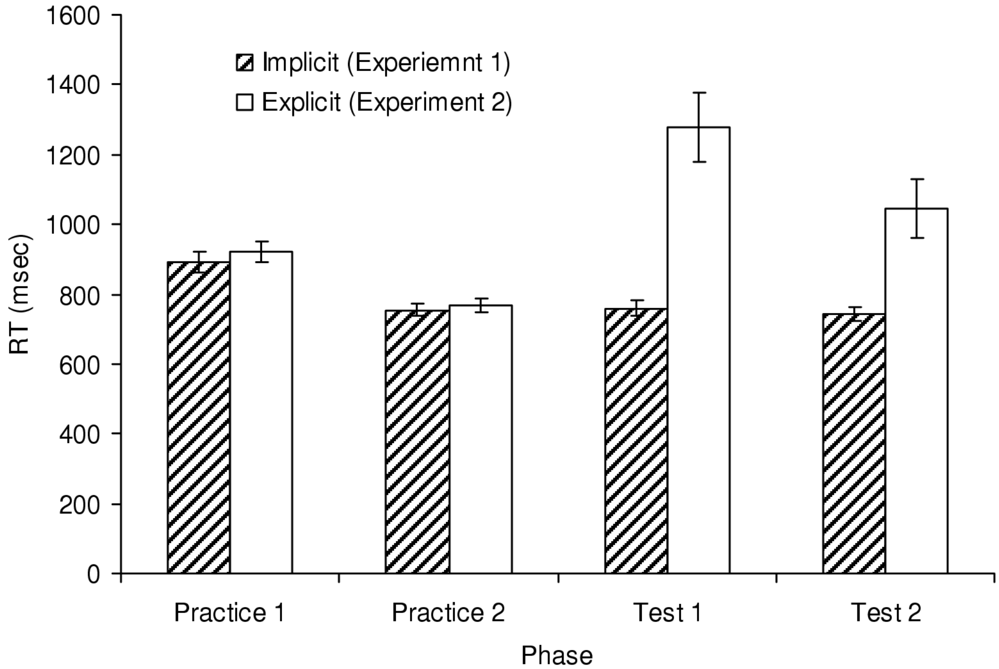

Figure 2.
Median response times (RTs) in milliseconds as a function of phase and task. Error bars refer to the mean standard errors.

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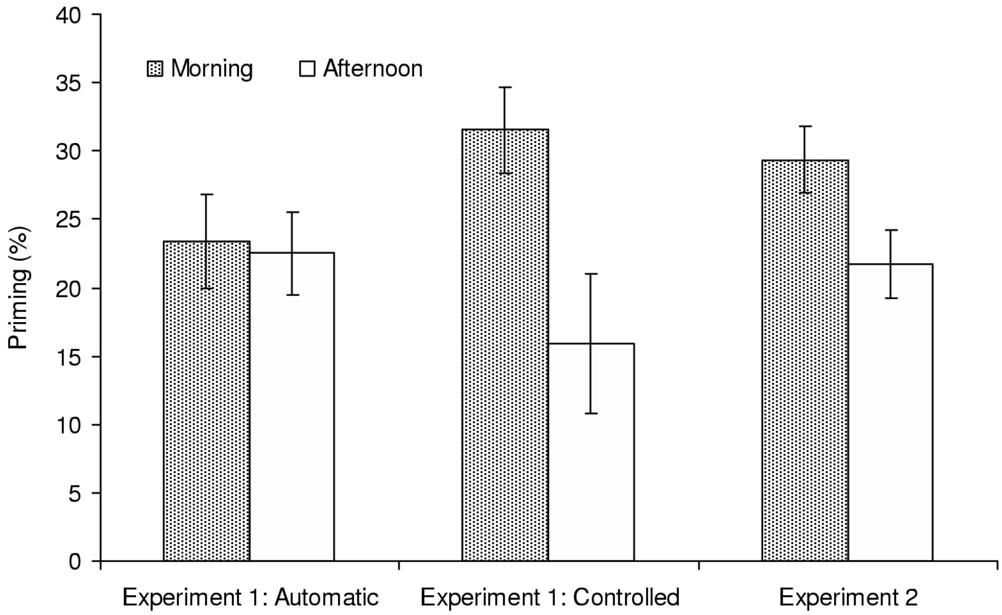

Figure 3.
The percentage of priming as a function of testing time, with the left-most panel for the group using automatic retrieval in the implicit memory task (Experiment 1), the middle panel for the group engaging in controlled retrieval in the implicit memory task (Experiment 1), and the right-most panel for the explicit memory task (Experiment 2). Error bars refer to the mean standard errors.

Table 1

Demographic Characteristics of the Final Sample

Experiment	Variables	Testing Time: Morning Mean	Morning SD	Afternoon Mean	Afternoon SD
	Age	68.56	4.41	67.19	3.91
	Years of education	16.63	3.19	16.19	2.33
Experiment 1	Vocabulary*	33.74	8.70	34.55	8.24
	MEQ†	67.81	5.27	66.81	5.39
	SBT‡	0.26	0.66	0.54	0.86
	Age	65.95	4.98	66.50	4.13
	Years of education	15.59	2.56	16.38	3.23
Experiment 2	Vocabulary*	27.50	9.23	31.62	8.32
	MEQ†	65.98	4.27	64.83	3.81
	SBT‡	0.27	0.70	0.71	1.40

Note. In Experiment 1, $n = 27$ for the morning-testing group and $n = 26$ for the afternoon-testing group; in Experiment 2, $n = 22$ for the morning-testing group and $n = 24$ for the afternoon-testing group.

*measured with Extended Range Vocabulary Test (ERVT: Educational Testing Service, 1976).

†MEQ = Morningness-Eveningness Questionnaire (MEQ, Horne & Ostberg, 1976).

‡SBT = Short Blessed Test (SBT: Pfeiffer, 1975).