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Benefits of Immediate Repetition versus Long Study Presentation on Memory in Amnesia

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Abstract

Objective—To resolve discrepant findings in the literature regarding the effects of massed repetition and a single long study presentation on memory in amnesia.

Method—Patients with amnesia secondary to anoxia or herpes encephalitis and matched controls participated in two experiments. They studied words under three presentation conditions – single short presentation, single long presentation, and massed repetition – and then performed a recognition test. In experiment 1, study conditions were intermixed, whereas in experiment 2 they were blocked.

Results—In experiment 1, control participants showed benefits associated with both types of extended exposure, and massed repetition was more beneficial than long study presentation, $p < .001$, partial $\eta^2 = .45$. In contrast, amnesic participants failed to show benefits of either type of extended exposure, $F < 1$. In experiment 2, control participants again benefited more from massed repetition than from long study presentation, $p < .001$, partial $\eta^2 = .58$; amnesic patients showed equivalent benefits of both types of extended exposure, $p = .015$, partial $\eta^2 = .41$.

Conclusions—These findings suggest that previous inconsistencies in the literature were due to procedural differences across studies. We discuss group differences in terms of the mechanisms by which both forms of extended exposure facilitate performance in each group.

Keywords

amnesia; repetition; recognition memory

Extensive research in individuals with intact memory shows that multiple study presentations lead to better recall and recognition performance than does a single study presentation. In an effort to elucidate the processes that mediate this repetition benefit, many studies have compared performance following massed (i.e., immediate) and spaced (i.e., distributed) repetitions. The typical finding is that spaced repetition is more beneficial than massed

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repetition, although massed repetition also yields better performance than does single presentation (Bird, Nicholson, & Ringer, 1978; Greene, 1989).

Like individuals with intact memory, patients with selective amnesia show improved recognition memory following spaced repetition (Cermak, Verfaellie, Lanzoni, Mather, & Chase, 1996; Hillary et al., 2003; Verfaellie, Rajaram, Fossum, & Williams, 2008), and similar findings have been obtained in patients with severe memory impairments in the context of traumatic brain injury (Hillary et al., 2003) and Alzheimer's disease (Moulin, Perfect, & Jones, 2000). However, in a study by Cermak et al. (1996), amnesic patients performed no better following massed repetition than following a single presentation on an immediate recall or recognition test – a finding that contrasts with the pattern seen in control subjects. This finding is surprising in light of the documented benefit associated with a single, long study presentation in patients with severe memory impairment. Indeed, a number of studies have successfully equated the recognition performance of amnesic patients and controls by providing amnesic patients with a single, long exposure duration and controls a single, short exposure duration (Hirst et al., 1986; Huppert & Piercy, 1978; Kopelman & Stanhope, 1998). One might expect that massed repetition and a single, long study presentation would be functionally equivalent.

Although few studies have examined the effect of massed repetition on the performance of patients with memory impairment, there is evidence to suggest that the failure to benefit from massed repetition is not limited to patients with selective amnesia. Hillary and colleagues (2003) demonstrated a similar failure in patients with severe memory impairment secondary to moderate or severe traumatic brain injury. Thus, understanding the nature of the repetition impairment in patients with amnesia may elucidate memory impairments in other clinical groups as well.

One reason for amnesics' lack of benefit from massed repetition may be the failure to engage in further encoding when an item is immediately repeated. Deficient processing of massed items is also evident in individuals with intact memory, and has been postulated as one of the reasons as to why massed repetition leads to inferior memory than spaced repetition (Braun & Rubin, 1998; Greene, 1989). Nonetheless, in normal individuals, the second presentation of an item undergoes some further processing, as evidenced by the fact that performance exceeds that seen following a single presentation. In amnesic patients, in contrast, encoding may be even further curtailed, so that immediate repetition yields no processing benefit over a single presentation.

Although the differential effects of massed repetition and long exposure duration in patients with severe memory impairment are potentially revealing, it is important to point out that these discrepant findings have been obtained in the context of distinct studies with different patient groups and different encoding parameters. Most importantly, the total presentation time employed in studies that have used a single, long presentation (Hirst et al., 1986; Huppert & Piercy, 1978; Kopelman & Stanhope, 1998) has typically been longer than that in studies that have used massed repetition (Cermak et al., 1996; Hillary et al., 2003). It is possible then that massed repetition may also enhance amnesic performance if the number of massed repetitions were extended to yield a total presentation time equivalent to that used in the long exposure studies.

The goal of experiment 1 was to directly compare the repetition benefit associated with massed repetition and a single, long study presentation and to evaluate whether the magnitude of the repetition benefit in each of these conditions differed in amnesic patients and individuals with intact memory. To this end, we compared recognition memory in a single, short presentation condition with that in two "extended exposure" conditions that were equated in terms of total study duration – a single, long presentation condition and a massed repetition condition.

Experiment 1

Method

Participants—The amnesic group consisted of 9 individuals (6 male, 3 female) who developed amnesia secondary to anoxia ($n=6$) or herpes encephalitis ($n=3$). MRI or CT scan indicated that for four of the anoxic patients damage was restricted to the medial temporal lobes (MTL), whereas for the encephalitic patients and the remaining anoxic patient, who had undergone a partial left temporal lobectomy, damage extended to the lateral temporal lobes in addition to the MTL. One anoxic patient could not be scanned, but MTL pathology was inferred from his etiology and similarity in presentation with the other anoxic participants. The combined group of amnesic participants had a mean age of 58.6 years ($SD=12.6$) and a mean education of 15.0 years ($SD=2.3$). Their general intellectual abilities were intact, as indicated by a mean verbal IQ on the Wechsler Adult Intelligence Scale- III (WAIS-III) of 105.6 ($SD=19.6$). Their attentional abilities were also intact, as indicated by a mean Wechsler Memory Scale-III (WMS-III) Working Memory Index of 104.2. Their memory functioning was severely compromised, as indicated by a General Memory Index of 56.6, a mean Visual Delay Index of 62.0, and a mean Auditory Delay Index of 60.9.

The control group consisted of 18 healthy participants (5 male, 13 female) who had no prior history of neurological or psychiatric disorder. They were matched to the amnesic group in age ($M=62.2$; $SD=12.1$; $t<1$), years of education ($M=14.7$; $SD=2.0$; $t<1$), and verbal IQ ($M=105.6$; $SD=13.0$; $t<1$).

Materials and Design—Ninety-six nouns of four to eight letters in length with a frequency of usage between 20 and 50 per million words ($M=30.9$) served as stimuli (Francis & Kucera, 1982). The stimuli were divided into 6 lists of 16 words, matched for word length and frequency. Three of these lists were used as study lists for the three encoding conditions, whereas the other three lists served as distractors for the recognition test. The assignment of lists to targets vs. distractors and of studied lists to each of the encoding conditions (short presentation, long presentation, massed repetition) was counterbalanced across subjects.

Procedure—Prior to the start of the task, participants were told that they would see a list of words presented one at a time on the computer screen. It was their task to study each word for a memory test. To ensure that amnesic individuals attended to the words, they were additionally asked to read them out loud. They were then shown the 48 target words (16 from each of the three target conditions) in a random order. Short presentation words appeared for 2500 ms, long presentation words appeared for 8500 ms, and massed repetition words appeared for 2500 ms three times in succession. There was a 500 ms interstimulus interval between each word presentation, such that functional presentation times in the long presentation and massed repetition conditions were equated at 9000 ms. This exposure is similar to that used in other studies that have used a single, long presentation for amnesic patients (Hirst et al., 1986; Huppert & Piercy, 1978; Kopelman & Stanhope, 1998).

Following a ten-minute break, participants were tested on their memory for the words that they had just studied. They were presented with the 48 studied words and the remaining 48 distractors intermixed. For each word they made a yes/no judgment as to whether they had seen the word presented previously. Each word remained on the screen for as long as the participant needed. The study and test phases were presented on a Macintosh Powerbook G3.

Results

For each participant, we calculated the proportion of “yes” responses as a function of encoding condition (hits) as well as the proportion of “yes” responses to nonstudied items (false alarms).

Group means are presented in Table 2. Because amnesic individuals had a significantly higher false alarm rate than control participants ($M = .30$ vs. $.17$, $t(25) = 2.39$, $p = .025$), analyses were performed on discriminability scores derived from signal detection analysis (d').

A 2 (group) \times 3 (encoding condition) mixed analysis of variance (ANOVA) on d' scores revealed a main effect of group, $F(1,25) = 10.88$, $p = .003$, partial $\eta^2 = .30$, indicating higher accuracy in the control group ($M = 1.64$; $SD = .73$) than in the amnesic group ($M = .81$; $SD = .51$), as well as a significant main effect of condition, $F(2,50) = 8.75$, $p = .001$, partial $\eta^2 = .26$, indicating higher accuracy in the massed repetition condition ($M = 1.55$; $SD = .86$) than in the long presentation condition ($M = 1.39$; $SD = .72$; $t(26) = 2.14$, $p = .042$), and higher accuracy in the long presentation condition than in the short presentation condition ($M = 1.14$; $SD = .70$; $t(26) = 3.56$, $p = .001$). There was also a marginally significant group \times condition interaction, $F(2,50) = 2.79$, $p = .071$, partial $\eta^2 = .10$. In the control group, accuracy varied as a function of encoding condition, $F(2,34) = 14.03$, $p < .001$, partial $\eta^2 = .45$, with performance in the massed repetition condition exceeding that in the long presentation condition, $t(17) = 2.39$, $p = .028$, and performance in the long presentation condition exceeding that in the short presentation condition, $t(17) = 3.38$, $p = .004$. In the amnesic group, by contrast, performance did not differ as a function of encoding condition, $F < 1$.

Although amnesics' failure to benefit significantly from either form of extended exposure is striking, it is difficult to appreciate the magnitude of their impairment, as the benefit associated with extended exposure likely is influenced by one's baseline level of performance in the short presentation condition. To take into account baseline performance, we transformed each individual's discriminability scores to z-scores. We did so by using the mean and standard deviation in the short presentation condition for each group as the reference point. Thus, mean z scores for each group in the short presentation condition were 0. In the control group, the mean repetition benefits associated with long presentation and massed repetition were $z = .45$ and $z = .75$, respectively. Comparable scores in the patient group were $z = .21$ and $z = .32$. A 2×3 ANOVA on these scores revealed a main effect of condition, $F(2,50) = 8.39$, $p = .001$, partial $\eta^2 = .25$. The group \times condition interaction was not significant, $F(2,50) = 1.31$, $p = .279$, partial $\eta^2 = .05$, but the pattern of results paralleled that observed in the analysis of the d' scores. This was further evidenced by follow up comparisons, where the effect of condition was significant in the control group, $F(2,34) = 14.02$, $p < .001$, partial $\eta^2 = .45$, but not in the amnesic group, $F < 1$. These results, taking into account the impact of baseline performance on repetition-associated memory benefits, are broadly consistent with the untransformed d' findings.

Discussion

This study is the first to directly compare the benefits associated with massed repetition and long study presentation on recognition memory in amnesic patients. Confirming and extending previous reports (Cermak et al., 1996; Hillary et al., 2003; Verfaellie et al., 2008), we found that amnesics' performance following massed repetition did not exceed that following short presentation. This was true even though massed repetition items were presented three times in succession in the current experiment (whereas they had been presented only twice in succession in previous studies), and even though we ensured that amnesic participants processed each repetition of a stimulus by having them read the words aloud upon each presentation. Although the fact that amnesic participants, but not control subjects, read words aloud created an unfortunate procedural difference across groups, it is unlikely that this difference was responsible for amnesics' failure to benefit from repetition, as vocalization, if anything, leads to enhanced memory performance (Conway & Gathercole, 1987; Gathercole & Conway, 1988).

In contrast to previous studies demonstrating that amnesics' performance can be boosted to the level of controls by a single, long study presentation (Hirst et al., 1986; Huppert & Piercy,

1978; Kopelman & Stanhope, 1998), we failed to find any improvement associated with long presentation in amnesic participants, let alone an enhancement to the level of controls. Amnesics' failure to benefit from long study presentation in this experiment cannot be ascribed to differences in total exposure time in comparison to previous studies, as we specifically chose the long presentation time to be similar to that used previously. It is also unlikely that these contrasting results are due to differences in patient groups across studies, as previous studies have included amnesic patients with similar etiologies and of comparable severity as those in the present study.

One important procedural difference between studies lies in the fact that encoding conditions were intermixed in the current experiment, whereas in previous studies all stimuli were encoded using the same long study presentation. Differences associated with mixed versus blocked conditions have been reported in number of domains including memory (Brown, Neblett, Jones, & Mitchell, 1991; Los, 1996; Lupker, Kinoshita, Coltheart, & Taylor, 2003). To directly examine whether amnesics' failure to benefit from long study presentation was due to the intermixing of encoding conditions, Experiment 2 examined performance under conditions in which the three types of encoding – short presentation, long presentation, and massed repetition – were presented in blocked fashion.

Experiment 2

Methods

Participants—The amnesic participants and control participants in this experiment were identical to those who participated in Experiment 1. All amnesic and 13 control participants took part in Experiment 2 after participating in Experiment 1. For five control participants, this order was reversed¹. Participation in the two experiments was separated by an average 167 days (min =17 days; max=341 days).

Materials—A new set of 288 nouns of four to eight letters in length with a word frequency between 20 and 50 ($M=31.4$) was selected (Francis & Kucera, 1982). These words were subdivided into 6 lists of 48 words, matched for number of syllables, word length, and word frequency. Three of these lists served as study lists for the three encoding conditions and three of these lists were unstudied and served as distractors for each of the three recognition tests. The assignment of lists to targets vs. distractors and the assignment of both studied and unstudied lists to each of the encoding conditions (short presentation, long presentation, and massed repetition) were counterbalanced across subjects.

The study list for each of the three encoding conditions contained 48 items, but because of the increased study time associated with items in the long presentation and massed repetition conditions, the mean study-test delay for items in these two conditions was on average greater than the mean study-test delay for items in the short presentation condition. To make possible analysis not only of the full set of items but also of a subset of items with identical study-test delay across the three conditions, a subset of 16 words was chosen from each study list. The words in the subset were matched for number of syllables, word length, and word frequency with the 32 remaining words in the list (all $t < 1$). These items appeared as the last 16 words in the long presentation and massed repetition study lists, and were evenly distributed across the short presentation study lists. Items in these subsets were also evenly distributed across test lists.

¹There were no effects involving order in any analyses of the control data.

Procedure—Prior to the start of each task, participants were told that they would see a list of words presented one at a time on the computer screen. Both amnesic participants and controls were told to read each word out loud each time that it appeared on the computer screen, and to study each word for a future memory test. They were then presented with a list of 48 words. In the short presentation condition, words were presented for 2500 ms; in the long presentation condition, words were presented for 8500 ms; in the massed repetition condition, words were presented for 2500 ms, three times in succession. In all conditions, there was a 500 ms delay between each word.

Following a ten-minute break, participants were tested on their memory for the words that had been studied. They were presented with the 48 target words that they had previously studied, intermixed with a set of 48 distractors. They were instructed to decide whether they had encountered the word during the study phase, and were given unlimited time to provide a yes-no judgment for each word.

Each participant completed the three encoding tasks on three separate days. The order of the short presentation, long presentation, and massed repetition conditions was counterbalanced across participants.

Results

Data were analyzed using the full set of test stimuli for each condition, as well as using the subset of 16 stimuli for which the study-test delay was matched across conditions. Because the pattern of results across these two sets of analyses was comparable, we report here only the results of the analyses of the full set of stimuli². Group means are presented in Table 3.

For each subject, the proportion of “yes” responses to studied items (hits) and to nonstudied items (false alarms) was calculated for each of the three encoding tasks. A 2 (group) × 3 (encoding condition) mixed ANOVA on false alarm rates revealed a significant effect of group, $F(1,25)=45.48$, $p=.000$, partial $\eta^2=.64$, indicating that amnesic participants ($M=.37$; $SD=.15$) made more false alarms than did nonamnesic participants ($M=.10$; $SD=.09$). There was also a significant effect of encoding condition, $F(2,50)=10.91$, $p=.000$, partial $\eta^2=.30$, indicating that participants made more false alarms in the short presentation condition ($M=.23$; $SD=.19$) than in long presentation ($M=.18$; $SD=.15$) and the massed repetition ($M=.16$; $SD=.17$) conditions, $t(26)=3.44$, $p=.002$ and $t(26)=3.71$, $p=.001$, respectively. To take into account differing false alarm rates across groups and conditions, discriminability scores derived from signal detection analysis (d') were used in subsequent analyses.

A 2 (group) × 3 (encoding condition) ANOVA on d' scores revealed a main effect of group, $F(1,25)=33.52$, $p=.000$, partial $\eta^2=.57$, indicating higher accuracy in the control group ($M=1.95$; $SD=.63$) than in the amnesic group ($M=.88$; $SD=.49$). There was also a significant main effect of condition, $F(2,50)=18.47$, $p<.001$, partial $\eta^2=.42$, indicating higher performance given massed repetition ($M=1.85$; $SD=.87$) and long presentation ($M=1.70$; $SD=.73$) than given short presentation ($M=1.23$, $SD=.59$), $t(26)=6.94$, $p<.001$ and $t(26)=5.92$, $p<.001$, respectively. These main effects were modified by a significant group × condition interaction, $F(2,50)=4.80$, $p=.012$, partial $\eta^2=.16$. Both groups showed significant effects of condition (controls: $F(2,34)=23.74$, $p<.001$, partial $\eta^2=.58$; amnesics: $F(2,16)=5.58$, $p=.015$, partial $\eta^2=.41$), but the two forms of repetition affected the two groups differently. The amnesic and control groups showed

²There was one difference between the two sets of analyses that merits comment. In the analysis of the full data set, performance expressed as d' , remained significantly lower for amnesics in the long presentation condition than for controls in the short presentation condition, $t(25)=2.32$, $p=.029$, whereas in the analysis of the matched subset of items, performance was not significantly different for amnesics in the long presentation condition and controls in the short presentation condition, $t<1$. Thus, consistent with other studies, the performance of amnesics was enhanced to the level of controls by providing amnesic patients with a long study presentation, provided that the study-test delay was equated across groups.

a similar benefit associated with long presentation (short vs. long presentation: group x condition, $F < 1$), but the control group showed a greater benefit associated with massed repetition than did the amnesic group (short presentation vs. massed repetition: group x condition, $F(1,25)=12.19$, $p=.002$, partial $\eta^2=.33$). Further, whereas control participants tended to perform better following massed repetition than following long presentation, this was not the case for the amnesic participants (long presentation vs. massed repetition: group x condition, $F(1,25)=3.54$, $p=.072$, partial $\eta^2=.12$).

We also compared the magnitude of the benefit associated with extended exposure in the two groups taking into account differences in baseline performance in the short presentation condition. As in Experiment 1, we transformed participants' discriminability scores to z-scores using performance of their group in the short presentation condition as the reference point. In the control group, the mean benefits associated with long presentation and massed repetition were $z=1.12$ and $z=1.77$, respectively. The benefits in the amnesic group were $z=.95$ and $z=.62$, respectively. A 2×3 ANOVA on z-scores revealed effects similar to those obtained in the analysis of the untransformed discriminability scores: there was a significant effect of condition, $F(2,50)=18.96$, $p < .001$, partial $\eta^2=.43$, which was modified by a significant group x condition interaction, $F(2,50)=4.30$, $p=.019$, partial $\eta^2=.15$. Both groups showed equivalent benefit associated with long presentation (short vs. long presentation: group x condition, $F < 1$) but the control group showed a larger benefit associated with massed repetition than did the amnesic group (short presentation vs. massed repetition: group x condition, $F(1,25)=10.47$, $p=.003$, partial $\eta^2=.30$). Additionally, the control group tended to benefit more from massed repetition than from long presentation, but this was not the case for the amnesic group (long presentation vs. massed repetition, group x condition, $F(1,25)=3.66$, $p=.067$, partial $\eta^2=.13$).

Comparison of Experiments 1 and 2—To directly assess how blocking the encoding conditions in Experiment 2 altered the benefits associated with extended exposure in comparison to the intermixed encoding conditions used in Experiment 1, a 2 (experiment) $\times 2$ (group) $\times 3$ (encoding condition) ANOVA was performed. We performed this analysis using z scores to place the data of the two experiments and the two subject groups on the same scale³. The only effect involving experiment was a significant experiment x condition interaction, $F(2,50)=5.42$, $p=.007$, partial $\eta^2=.18$. Follow-up analyses separately comparing each of the extended exposure conditions to the short presentation condition indicated that the benefit associated with both types of extended exposure was greater in Experiment 2 than in Experiment 1 for both groups (short vs. long presentation: experiment x condition, $F(1,25)=10.04$, $p=.004$, partial $\eta^2=.29$; short presentation vs. massed repetition, $F(1,25)=10.30$, $p=.004$, partial $\eta^2=.29$).

Discussion

Under conditions in which all stimuli in a study list received the same form of encoding, amnesic participants' recognition memory did benefit from extended exposure, both when extended exposure was instantiated in the form of a single long presentation to stimuli or in the form of multiple massed repetitions. The results concerning long study presentation are consistent with previous studies (Hirst et al., 1986; Huppert & Piercy, 1978; Kopelman & Stanhope, 1998), and here as in those studies, long study presentation was successful in boosting amnesics' performance to the level of controls. In the present study, this equivalence in performance was evident in the analysis of the subset of data for which the study-test delay was equated across conditions. A novel finding in this experiment was the effect of massed repetition, as massed repetition also enhanced amnesics' recognition, and yielded performance

³The analysis of d' prime scores yielded a similar pattern, although the experiment x condition interaction was not significant, $F(2,50)=2.24$, $p=.117$, partial $\eta^2=.08$.

similar to that obtained in the long presentation condition. Thus, it appears that either form of extended exposure can be beneficial for individuals with amnesia, provided that study conditions are blocked, allowing for consistency in the way study items are presented and encoded.

In comparing the effects of different forms of extended exposure in the amnesic and control groups, there were both similarities and differences. The effect of long presentation was directly comparable in the two groups, as both groups showed a similar increase in performance compared to short presentation. However, the amnesic group showed a smaller increase in performance associated with massed repetition than did the control group. This pattern of results held not only when raw scores were compared, but also when participants' performance was assessed relative to their own group's baseline level of performance in the short presentation condition. This pattern was due to the fact that massed repetition yielded higher performance than long presentation in the control group, but similar performance in the amnesic group. We discuss possible reasons for this finding in the General Discussion.

General Discussion

The current study was motivated by conflicting findings in the literature regarding the effect of two forms of extended exposure on amnesics' recognition memory – long presentation and massed repetition of stimuli. While previous studies have found that amnesic individuals benefit from long presentation (Hirst et al., 1986; Huppert & Piercy, 1978; Kopelman & Stanhope, 1998), no similar benefits have been obtained with massed repetition in patients with severe memory impairment in the context of selective amnesia (Cermak et al., 1996; Hillary et al., 2003) or traumatic brain injury (Hillary et al., 2003), raising questions as to the nature of this discrepancy. The results of the present study suggest that procedural factors are most likely responsible for these divergent outcomes: when (1) study presentation time was equated across the two extended exposure conditions, either by presenting stimuli three times in succession, with the subject reading each presentation out loud, or by providing one stimulus exposure of similar total duration, and (2) both conditions were administered in a blocked format so that all to-be-remembered stimuli received similar processing, both forms of extended exposure were effective in enhancing amnesics' performance.

Changing encoding from mixed to blocked study conditions had a dramatic effect on the performance of the amnesic group, as blocked study conditions made it possible for amnesic individuals to benefit from extended exposure – a benefit that was not seen given intermixed study conditions. The consistency of study conditions in Experiment 2 affected not only the presence of an extended exposure benefit in the long presentation condition, as we predicted, but also the presence of an extended exposure benefit in the massed repetition condition. Thus, to the extent that intermixed study conditions made it more difficult for amnesic participants to take advantage of the enhanced encoding afforded by extended exposure, this was the case for both types of extended exposure. Further, the change from intermixed to blocked study conditions had an equally large impact on the performance of the control group, as the benefits of both forms of extended exposure in nonamnesic individuals were also much larger in the blocked condition. This suggests that the “suboptimal” performance we postulated as an explanation of amnesics' inability to benefit from long presentation in Experiment 1 reflects a more general encoding phenomenon that affects amnesic individuals and control subjects alike.

One possible reason for the impact of the blocking manipulation is that in the intermixed condition, participants expend disproportionate encoding resources or rehearsal on items in the short presentation condition – items that are most difficult to remember – at the cost of encoding of items in either extended exposure condition. An alternative possibility is that there is a

generalized cost associated with uncertainty and the need to adjust encoding strategy on each trial in the intermixed condition. The former view would predict poorer processing of items that received short study presentation in Experiment 2 than in Experiment 1, whereas the latter view would predict that performance in the short presentation condition would be at least equivalent, and possibly better, in Experiment 2 than in Experiment 1. Unfortunately, the current study cannot distinguish between these possibilities, as the study list length and study-test delay were not equated across the short presentation conditions of the two experiments. Nonetheless, the possibility that amnesic patients, like controls (Son & Metcalfe, 2000), can allocate encoding time according to perceived item difficulty is intriguing, and deserves further investigation.

An unexpected finding of the current study is the differential benefit of massed repetition compared to long presentation in the control group, but not in the amnesic group. In the absence of any studies in normal individuals that directly compare these two conditions, we made the assumption that these two conditions would yield equivalent performance, given that total study duration was equated. However, this assumption was incorrect. One possibility is that in the control group, refreshment of the item on the screen and/or its repeated reading aloud in the massed repetition condition encouraged mental refreshment and further processing of the item that benefited subsequent memory (Johnson, Reeder, Raye, & Mitchell, 2002). In the long presentation condition, by contrast, attention to and processing of the item may have ended before the allotted study time was over. The rather unusually long exposure time in that condition may have contributed to participants' sense that stimulus encoding was complete and would not benefit from further processing. Future studies will be needed to examine the contribution of repeated presentation versus repeated vocalization to the processing advantage in the massed repetition condition.

Whatever the precise reasons for the enhanced processing normal subjects carried out in the massed repetition compared to the long exposure condition, it is of note that amnesic participants did not demonstrate this enhancement. We have previously suggested that amnesic individuals are less likely than nonamnesic individuals to engage in variable encoding, elaborating on different aspects of a to-be-remembered stimulus (Cermak et al., 1996). It is possible that the re-presentation of stimuli in the massed repetition condition encouraged further elaboration in nonamnesic individuals, but not in amnesic participants.

Another difference between the effects of extended exposure on the performance of the control group and the amnesic group may shed further light on the mechanisms by which extended exposure operates in both groups. The increased accuracy in recognition memory associated with extended exposure (both massed repetition and long presentation) in control participants was reflected in enhanced hit rates and reduced false alarm rates. Such strength-based mirror effects (Glanzer & Adams, 1985) are prevalent throughout the recognition memory literature, and our findings in control subjects are in line with a number of studies that have observed a mirror effect in association with stimulus repetition (Cary & Reder, 2003; Stretch & Wixted, 1998). However, in amnesic participants, extended exposure did not yield a mirror effect: the false alarm rate decreased, but the hit rate did not increase.

To understand the absence of a mirror effect in amnesia in the present study, it is useful to consider how a strength-based mirror effect has been explained in the context of dual process theories of recognition that postulate that recognition judgments can be based on either recollection or familiarity (Jacoby, 1991; Mandler, 1980). Cary and Reder (Cary & Reder, 2003) have proposed that strength-based mirror effects reflect shifts in the criterion used to decide whether an item is old. Such criterion shifts occur depending on an item's perceived ease of recognition, which in turn is thought to be influenced heavily by the availability of recollection (Cary & Reder, 2003; Joordens & Hockley, 2000). When recollection is relatively

difficult (as for nonrepeated items), few items are recollected, leading to a relatively low number of “old” responses. Under such circumstances, familiarity-based responding dominates, and the familiarity criterion is lowered to ensure that a reasonable number of hits are obtained. However, this leads to a corresponding increase in false alarms. Conversely, when recollection is relatively easy (as for repeated items) a larger number of items are recollected and a relatively strict criterion can be placed on familiarity, leading to a low level of false alarms. Thus, according to this model, the enhanced hit rate associated with stronger items is due to greater reliance on recollection, whereas the enhanced false alarm rate associated with the weaker items is due to greater reliance on familiarity.

Accordingly, the absence of a differential hit rate for short exposure and extended exposure items in the amnesic group suggests that extended exposure does not enhance amnesic individuals’ reliance on recollection. This interpretation is consistent with findings from a recent study in which we used remember/know judgments as a means of gaining insight into the processes mediating repetition (Verfaellie et al., 2008). In that study, we found that repetition enhanced both recollection and familiarity in nonamnesic individuals, but only familiarity, and not recollection, in amnesic participants. That study evaluated spaced repetition, but the current findings suggest that massed repetition similarly fails to enhance recollection in amnesia.⁴

Amnesics’ failure to enhance recollection through extended exposure is perhaps not surprising, given their severe impairment in recollection, which is thought to result from damage to the hippocampus (Aggleton & Brown, 1999; Eichenbaum, Yonelinas, & Ranganath, 2007). More strikingly, our findings raise the question as to how the familiarity-based enhancement effects observed in this study are mediated. One possibility is that the benefits associated with extended exposure are mediated by remaining MTL tissue, as patients’ lesions were not complete. Remaining tissue in subhippocampal cortices may be particularly critical, in light of the proposal that these cortices mediate familiarity-based recognition (Aggleton & Brown, 1999; Eichenbaum et al., 2007). Alternatively, it is possible that the benefits associated with extended exposure are mediated by neocortical regions outside the MTL system, although these regions typically support a much slower learning process that requires many repetitions (Bayley & Squire, 2002). To examine whether lateral neocortical regions were critical for the benefit associated with extended exposure, we compared the performance of the four patients whose lesion extended into lateral temporal neocortex to that of the five patients whose lesion was limited to the MTL. The mean benefit associated with either form of extended exposure in Experiment 2 was .12 in the former group and .13 in the latter group. Acknowledging the small sample size of this comparison, these findings nonetheless suggest that the repetition benefits were unlikely to be mediated by a slow neocortical learning system mediated by lateral temporal cortex.

Returning to the key findings of the present experiments, it is clear that both massed repetition and long study presentation can enhance recognition memory in amnesia and that discrepancies regarding these encoding manipulations in previous studies likely arose because of procedural differences across studies. Notably, not only has the study exposure time for massed repetition

⁴The account of mirror effects in normal individuals, which assumes the operation of both recollection and familiarity, leaves unanswered the question as to why the false alarm rate in the amnesic group differed as a function of the strength of studied items. (Lloyd, Westerman, & Miller, 2003) have shown that, in the absence of recollection, subjects’ willingness to endorse an item as familiar on a recognition test is influenced by their expectation about the amount of fluency that should be associated with that item, and that expectation depends on the number of times the item was presented at study. Items seen more frequently are expected to be more familiar. Assuming such fluency-expectations are intact in amnesia, amnesic participants may have set a stricter criterion for repeated items than for nonrepeated items, just as control participants did. This would lead to a lower false alarm for unstudied items seen in the context of repeated items than for unstudied items seen in the context of nonrepeated items, as we observed. However, whereas a stricter criterion was counteracted by enhanced recollection in control subjects, this was not the case in amnesia. Hence, item repetition did not yield enhanced hit rates in amnesia.

and for longer study presentations varied across previous studies, massed repetition items have typically been included in intermixed study lists whereas longer study presentation has been used for all items in a study list. Our study shows that uniform application of study enhancement procedures across all study items is critical for improving memory performance in amnesia.

This demonstration has clear implications for rehabilitative training procedures, not only in amnesic patients, but possibly also in patients with memory impairments in the context of other disorders such as traumatic brain injury or Alzheimer's disease. First, study practice can enhance new episodic learning, and whether instantiated through repetition or through long presentation of study materials, equivalent gains may be expected in memory performance, so long as all study items receive equivalent processing. Second, the impact of uniform processing of study items in patients with severe memory impairment revealed in this study points to the importance of consistency in training procedures. Third, our results call into question the practical implications of previous studies comparing the efficacy of massed and spaced repetition in patients with severe memory problems, because these studies have used intermixed study conditions (Cermak et al., 1996; Hillary et al., 2003). Future clinical studies are needed that compare the effects of massed and spaced repetition in blocked study conditions – conditions shown here to optimize encoding in patients with severe memory impairment. Finally, although this study pertains to the acquisition of new episodic memories, the findings may also have relevance for the rehabilitation of lexical and semantic impairments, as the acquisition of such information is typically facilitated by episodic learning mechanisms (Tulving, Hayman, & Macdonald, 1991; Verfaellie, 2000).

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Table 1
Demographic and neuropsychological characteristics of the amnesic patients

Patient	Etiology	Age	Edu	WAIS-III			WMS-III		
				VIQ	GM	AD	VD	AD	WM
MTL01	Anoxia	78	18	113	75	80	72	80	102
MTL02	Anoxia	57	12	83	52	55	56	55	91
MTL03	Anoxia	43	16	86	49	52	53	52	93
MTL04	Anoxia	49	14	90	45	52	53	52	93
MTL05	Anoxia	51	14	111	59	52	72	52	96
MTL06	Anoxia	55	17	134	70	67	75	67	126
MTL07	Encephalitis	52	14	92	45	55	56	55	85
MTL08	Encephalitis	63	12	106	69	77	68	77	111
MTL09	Encephalitis	79	18	135	45	58	53	58	141
Control Mean		62.2	14.7	105.6	-	-	-	-	-
[range]		[39-79]	[12-18]	[78-125]	-	-	-	-	-

Note. WAIS-III = Wechsler Adult Intelligence Scale-III; WMS-III = Wechsler Memory Scale-III; VIQ = Verbal IQ; GM = General Memory; VD = Visual Delay; AD = Auditory Delay; WM = Working Memory.

Table 2
Proportion of “yes” responses to studied items (hits) as a function of encoding condition and nonstudied items (false alarms) in experiment 1. The false alarm rate used to calculate d' scores was constant across conditions a result of the intermixed design. Standard deviations are given between parentheses

	Short Presentation	Long Presentation	Massed Repetition
Control			
Hits	.62 (.19)	.73 (.15)	.79 (.14)
False Alarms		-----.17 (.12)-----	
d'	1.35 (.71)	1.67 (.69)	1.89 (.73)
Amnesic			
Hits	.56 (.14)	.60(.14)	.62 (.13)
False Alarms		-----.30 (.18)-----	
d'	.73 (.46)	.82 (.39)	.88 (.69)

Table 3
Mean proportion of “yes” responses to studied (hits) and nonstudied items (false alarms) as a function of encoding condition in experiment 2, and corresponding d' scores. Standard deviations are given between parentheses

	Short Presentation	Long Presentation	Massed Repetition
Control			
Hits	.60 (.16)	.75 (.14)	.74 (.17)
False Alarms	.13 (.11)	.11 (.08)	.07 (.06)
d'	1.51 (.46)	2.02 (.58)	2.32 (.59)
Amnesic			
Hits	.67 (.10)	.71 (.10)	.66 (.17)
False Alarms	.44 (.14)	.33 (.15)	.35 (.16)
d'	.67 (.41)	1.05 (.54)	.92 (.49)