



Published in final edited form as:

*J Int Neuropsychol Soc.* 2008 May ; 14(3): 365–372.

## Not all repetition is alike: Different benefits of repetition in amnesia and normal memory

Mieke Verfaellie<sup>1</sup>, Suparna Rajaram<sup>2</sup>, Karen Fossum<sup>1</sup>, and Lisa Williams<sup>1</sup>

<sup>1</sup> *Memory Disorders Research Center, Boston VA Healthcare System and Boston University School of Medicine, Boston, Massachusetts*

<sup>2</sup> *Department of Psychology, Stony Brook University, Stony Brook, New York*

### Abstract

While it is well known that repetition can enhance memory in amnesia, little is known about which forms of repetition are most beneficial. This study compared the effect on recognition memory of repetition of words in the same semantic context and in varied semantic contexts. To gain insight into the mechanisms by which these forms of repetition affect performance, participants were asked to make Remember/Know judgments during recognition. These judgments were used to make inferences about the contribution of recollection and familiarity to performance. For individuals with intact memory, the two forms of repetition were equally beneficial to overall recognition, and were associated with both enhanced Remember and Know responses. However, varied repetition was associated with a higher likelihood of Remember responses than was fixed repetition. The two forms of repetition also conferred equivalent benefits on overall recognition in amnesia, but in both cases, this enhancement was manifest exclusively in enhanced Know responses. We conclude that the repetition of information, and especially repetition in varied contexts, enhances recollection in individuals with intact memory, but exclusively affects familiarity in patients with severe amnesia.

### Keywords

neuropsychology; amnesia; memory disorders; anoxia; encephalitis; Korsakoff syndrome

---

Repetition facilitates learning and memory not only in individuals with intact memory, but also in individuals with striking memory disorders. Indeed, the use of various forms of repetition forms the bedrock of virtually all memory rehabilitation programs. Yet, surprisingly little research has examined which forms of repetition are most beneficial for individuals with amnesia, and the mechanisms mediating these repetition effects remain poorly understood.

An increase in the number of times an item is presented at study clearly enhances recall and recognition in individuals with amnesia (Huppert & Piercy, 1978; Strauss et al., 1985; Weingartner et al., 1993). However, because the effect of stimulus repetition is often overshadowed by a large differential in absolute performance between amnesic patients and controls, it is difficult to determine whether memory-impaired individuals benefit from repetition to the same extent as memory-intact individuals. To address this question, we examined recall of repeated items under conditions in which recall of nonrepeated items was matched across groups. We found that the magnitude of the repetition effect was considerably smaller in individuals with amnesia than in control participants (Verfaellie & Cermak, 1994). This finding raises the possibility that the mechanism by which repetition enhances

performance may be different for memory-impaired individuals than for individuals with intact memory, and that various forms of repetition may affect the two groups differently.

Consistent with this possibility, Cermak and colleagues (Cermak et al., 1996) found that a group of individuals with intact memory showed a benefit associated with immediate (massed) repetition of items, whereas a group of individuals with amnesia did not. Both groups, by contrast, showed a benefit associated with distributed (spaced) repetition of items. Although the main focus of that study was on the benefit associated with spacing, it was suggested that the failure to benefit from massed repetition in the amnesic group might reflect a failure to benefit from encoding variability. That is, whereas normal individuals spontaneously elaborate upon different aspects of an immediately repeated item, amnesic individuals may not do so. Indeed, that study suggested that amnesic individuals might be less able than normal individuals to benefit from encoding variability even when varied cues are presented during study repetition.

The amount of encoding variability engendered by repetition of the same item in an experimental study list is clearly quite small, in comparison to that encountered in naturalistic learning conditions, where the same information may be encountered in very different learning contexts. Yet, no study has evaluated the effect of repetition in different contexts in individuals with memory impairment, and it is unknown whether varied repetition and fixed repetition have similar effects. Such a comparison is important, as it may have direct implications for the development of optimal procedures for memory remediation in a naturalistic setting.

The comparison of fixed versus varied repetition in individuals with intact memory has generated an extensive literature, and although some studies have suggested a benefit associated with encoding items under varied conditions (Glenberg, 1979; Klein & Saltz, 1976; Paivio, 1974), others have found either no effect or a negative effect (Postman & Knecht, 1983; Soraci et al., 1999; Young & Bellezza, 1982). While most of the research on encoding variability has entailed recall tasks, similarly conflicting results have been obtained with recognition tasks (e.g., Ciccone et al., 1975; Winograd & Geis, 1974). It appears that these findings can best be understood as reflecting a trade-off between, on the one hand, the potential number of retrieval cues established during study and, on the other hand, the strength or effectiveness of any individual cue. Contextual variability increases the potential number of retrieval cues, but maintaining the same encoding context may enhance the strength of a single retrieval cue and the organizational stability of the memory trace itself (Postman & Knecht, 1983; Young & Bellezza, 1982).

To examine whether individuals with amnesia benefit differentially from repetition in the same context versus varied contexts, we evaluated recognition memory for words studied in a single exposure condition, a repeated same-context condition, and a repeated varied-context condition. Context was manipulated by presenting target words in association with a single or with multiple semantically related cue words. We had no a priori prediction about the effect of same versus varied context in individuals without memory impairment, given the mixed findings in the literature. However, our main goal was to establish whether these two forms of repetition have a similar or differential effect on the performance of individuals with amnesia, and if so, whether that pattern was similar to that observed in individuals with intact memory.

Our second goal was to examine the mechanisms by which these different forms of repetition affect performance. Studies in individuals with intact memory using the Remember/Know paradigm (Gardiner, 1988; Tulving, 1985) have shown that fixed (i.e. same-context) repetition consistently enhances recollection (Dewhurst & Hitch, 1999; Gardiner et al., 1996; Gardiner & Radomski, 1999; Jacoby et al., 1998; Parkin et al., 1995; Parkin & Russo, 1993). Effects of fixed repetition on familiarity have been obtained in only some studies (Dewhurst & Hitch,

1999; Gardiner et al., 1996; Gardiner & Radomski, 1999), but are likely underestimated by a failure to take into account that Know responses do not provide a direct measure of familiarity, but rather a measure of familiarity in the absence of recollection (Jacoby et al., 1998). Thus, we predicted that same-context repetition would enhance both recollection and familiarity in normal individuals. To our knowledge, no study has directly compared whether fixed and varied encoding contexts have differential effects on recollection and familiarity. Given that the varied-context condition allows for the establishment of multiple retrieval cues, which should aid recollection in memory-intact individuals, we predicted that recollection would be greater following varied-context repetition than following same-context repetition. As for the individuals with amnesia, we predicted that the effects of both same-context and varied-context repetition would be manifest largely in enhanced familiarity, given the severe impairment of recollection in that group (Verfaellie & Treadwell, 1993; Yonelinas et al., 1998). However, to the extent that repetition can enhance recollection in that group at all, we expected that this would be more likely to be evident in the varied-context than in the same-context repetition condition, again, because multiple retrieval cues were potentially available.

We examined the performance of amnesic individuals with lesions to the medial temporal lobe (MTL) secondary to anoxia or encephalitis, as well as amnesic individuals with primarily diencephalic damage secondary to Korsakoff syndrome. We did not anticipate differences between these subgroups for several reasons. First, with the exception of memory for spatio-temporal details (Chalfonte et al., 1996; Parkin, 1993), MTL lesions and diencephalic lesions lead to largely similar patterns of memory impairment (O'Connor & Verfaellie, 2002), and in particular, patients with either lesion show severe impairments in recollection (Verfaellie & Treadwell, 1993). Second, although the neuropathology in Korsakoff syndrome is primarily in diencephalic regions, there is evidence for both structural (Sullivan & Marsh, 2003) and functional disruption (Fazio et al., 1992; Heiss et al., 1992) of the hippocampus as well.

## Method

### Participants

Two groups of amnesic patients participated in this experiment. The first consisted of 7 individuals (2 female, 5 male) with amnesia secondary to medial temporal lobe (MTL) pathology. Five of these individuals had a history of anoxia, and two had suffered encephalitis. MRI or CT scan indicated that for four of the anoxic patients damage was restricted to the MTL, whereas for the two encephalitic patients and the remaining anoxic patient, who had undergone a partial left temporal lobectomy, damage also extended into the lateral temporal lobes. This group had a mean age of 55.9 years ( $SD=13.4$ ), an average of 16.3 years of education ( $SD=2.7$ ), and a mean verbal IQ of 104.4 ( $SD=18.5$ ), as measured by the Wechsler Adult Intelligence Scale, Third Edition (Wechsler, 1997). The second group consisted of 5 individuals (1 female, 4 male) with Korsakoff syndrome, whose amnesia is thought to be due primarily to diencephalic pathology. This group had a mean age of 71.4 years ( $SD=12.4$ ), an average of 13.4 years of education ( $SD=3.3$ ), and a mean verbal IQ of 99.6 ( $SD=10.4$ ). Table 1 summarizes the demographic and clinical neuropsychological data for the patients.

Two groups of control participants also took part in the experiment. The control group for the MTL amnesics consisted of 12 healthy participants (6 female, 6 male) who had no prior history of neurological or psychiatric disorder. They were matched in age ( $M=60.8$  years,  $SD=9.3$ ;  $t<1$ ), education ( $M=14.8$ ,  $SD=2.9$ ,  $t(17)=1.16$ ), and verbal IQ ( $M=106.9$ ,  $SD=18.3$ ,  $t<1$ ) to the MTL amnesics. The control group for the Korsakoff patients consisted of 7 participants (all male) with a history of alcoholism who had abstained from alcohol consumption for at least one month prior to testing, and who otherwise showed no signs of neurological or psychiatric illness. They were matched in age ( $M=67.7$ ,  $SD=6.4$ ,  $t<1$ ), education ( $M=13.0$ ,  $SD=3.1$ ,  $t<1$ ), and verbal IQ ( $M=106$ ,  $SD=13.3$ ,  $t<1$ ) to the Korsakoff amnesics.

The research was conducted in compliance with regulations of the Institutional Review Board of Boston University School of Medicine and the VA Boston Healthcare System and was completed in accordance with the guidelines of the Helsinki Declaration.

## Materials and design

Sixty-four target words were selected and subdivided into 4 sets of 16 words, matched for word frequency (Francis & Kucera, 1982). Study condition (single presentation, same-context repetition, varied-context repetition, nonstudied) was counterbalanced across these four sets of words, resulting in 4 study formats. Repeated items were presented three times, and therefore, for each target word, three context words were created. Context words were conceptually related to the target words, such that the two words, in combination, formed a meaningful unit, and each pair elaborated on the core meaning of the target item. For example, for the target item CHOCOLATE, the three context items were: BAR, CAKE and MILK; for the target item BRIDGE, the three context items were: COVERED, TOLL and SUSPENSION. For half of the target words, the context word was typically encountered as the second word in the two-word relation (e.g., chocolate - BAR, chocolate - CAKE); for the other half of target words, the context words were typically seen as the first of the set (e.g., TOLL - bridge, SUSPENSION - bridge). Half of the items in each set were in the target-first order, and the remainder in the target-second order. For each target item, three unrelated filler words were also selected. These items were used during the encoding task as the alternative response in a forced-choice semantic relatedness decision.

Study and test phases were presented on a Macintosh Powerbook G3. Study phase stimuli were presented in lowercase 24-point Geneva font, and test phase stimuli were presented in 36-point Geneva font. Participants were seated approximately 18 inches from the screen. The experimenter recorded all responses using the keyboard.

## Procedure

During the study phase, the word "READY" was presented prior to the start of each trial. Upon a button press by the experimenter, the target word was displayed, centered on the computer screen. Subjects were required to read aloud the target item. After this, two additional items were presented, one of the context words for the target and a filler. These items were presented just above the target (in the case of the target-second order) or just below the target (in the case of the target-first order). Items were offset such that one choice was to the left of the target, the other to the right. Subjects were required to decide which of the two words was semantically related to the target item, and to respond by saying aloud the target item and their response choice in the appropriate order. For example, for the target word CHURCH, HALL and DIET would be presented, and for correct response, subjects would say aloud "CHURCH HALL". The correct alternative was presented on half of the trials to the right of the target, and on the other half to the left. Participants were informed that when the alternatives were displayed above the target word, their choice was to be read prior to the target word, and that when the alternatives were below the target word, they were to read the target word, followed by their response decision. Once the participant made a verbal response, the experimenter recorded which alternative they chose by keyboard response, and this resulted in the presentation of the "READY" signal for the next trial. The study phase thus was self-paced and involved incidental learning.

The study phase consisted of 120 trials: 4 filler trials each at the start and the end of the phase, and a randomly distributed combination of 16 single condition trials, 48 same-context repetition trials (16 target items X 3), and 48 varied-context repetition trials (16 target items X 3). Study condition was randomly ordered within each of the four study forms, with the specification that no more than two trials from the same condition occurred in a row, and that

the same target item in either of the repeated conditions never appeared twice in a row. For the single condition trials, the target item was presented once, with one context item, and one filler item. For the three same-context condition trials, the target item was presented with the same context word but a different filler word on each exposure. For the three varied-context condition trials, the target item was presented with a different context word and a different filler word on each exposure. On average, there were 32 intervening items ( $SD= 16.8$ ) between successive presentations of the same target.

The study phase took between 15 and 20 minutes to complete. Participants were given a 10-minute filler task, consisting of reading aloud nonwords, prior to the test phase.

Participants were then given the surprise recognition, Remember/Know test. They were informed that words would be presented on the computer screen, some of which had been encountered in the initial task they completed, and some of which were not presented during that task. They were requested to respond whether they believed the item had been encountered during the earlier phase or not. They were further instructed to be specific about their 'old' claims. The experimenter explained that two 'old' claims were possible, a Remember response or a Know response. They were instructed to respond Remember if they could remember something specific about having encountered the item, whether that be remembering a context word, a particular thought or idea that came to mind when they originally experienced the item or any other such specific recollection. They were instructed to respond Know if they knew the item had been presented in the study phase, but could not recollect any specific detail surrounding that experience. These responses thus represent subjective measures of the memorial experience, as is customary in the literature. A total of 98 test trials were presented, 16 items in each of the study conditions (for a total of 64 experimental trials), and an additional 34 novel filler items that were intermixed between experimental trials. These filler items were included in order to better balance the proportion of old vs. new items during the recognition task, but were not included in the analysis.

## Results

Because the proportion of "yes" responses to nonstudied items (i.e. false alarms) was greater for amnesic participants than for controls (see Table 2),  $F(1,27)=24.04$ ,  $p<.01$ , analyses were performed on corrected recognition scores (hits – false alarms). Corrected recognition scores were submitted to a 3 way mixed factorial analysis of variance (ANOVA) with as factors amnesia (control vs. amnesic), etiology (nonalcoholic vs. alcoholic), and presentation condition (single, same context, varied context). Etiology was included in the analysis to examine whether the obtained results held across alcoholic and nonalcoholic etiologies. There was a main effect of amnesia,  $F(1,27)=31.55$ ,  $p<.01$ , indicating better performance in the control groups ( $M=.59$ ,  $SD=.24$ ) than in the amnesic groups ( $M=.27$ ,  $SD=.20$ ). There was also a main effect of condition,  $F(2,54)=27.83$ ,  $p<.01$ , indicating that both repetition conditions (same context  $M=.53$ ,  $SD=.27$ ; varied context  $M=.58$ ,  $SD=.26$ ) yielded better performance than the single presentation ( $M=.29$ ,  $SD=.19$ ) condition. There was no difference in performance between the same-context and varied-context condition,  $t(30)=1.57$ . Although this pattern was evident in the performance of the amnesic groups as well as in the control groups, there was a significant amnesia x condition interaction,  $F(2,54)=6.86$ ,  $p<.01$ , reflecting the fact that the amnesic groups benefited less from repetition than did the control groups (see Table 2). The only effect involving etiology was a marginal interaction between amnesia and etiology,  $F(1,27)=3.84$ ,  $p=.06$ , which indicated that the difference in performance between the nonalcoholic control group ( $M=.63$ ,  $SD=.24$ ) and the nonalcoholic amnesic group ( $M=.22$ ,  $SD=.16$ ) was greater than that between the alcoholic control group ( $M=.54$ ,  $SD=.26$ ) and the alcoholic amnesic (Korsakoff) group ( $M=.35$ ,  $SD=.23$ ). Importantly, neither the interaction between etiology and condition, nor the three-way interaction between amnesia, etiology, and

condition was significant. This indicates that the pattern of repetition effects, and the impact of amnesia on this pattern, did not differ as a function of alcohol history.

Table 2 also provides the proportion of Remember responses, which represents a subset of the total “yes” responses. For example, for control subjects, the overall hit rate following single presentation (.40), was composed of .18 responses that were labeled Remember, and .22 that were labeled Know. Know responses were used to calculate for each participant an estimate of the contribution of familiarity to recognition, using the Independent Remember Know calculation, whereby  $IRK = K / (1 - R)$ . Thus, the IRK value in the example above was  $.22 / (1 - .18) = .27$ . Because etiology did not impact on the pattern of repetition effects, Remember and Know responses were analyzed in 2 (group: control vs amnesic)  $\times$  3 (condition) mixed ANOVAs.

Turning first to Remember responses, false alarms to nonstudied stimuli were more frequent in the amnesic group than in the control group,  $t(29) = 3.28$ ,  $p < .01$ . Therefore, a subsequent analysis was performed on corrected R-scores (hits-false alarms). The results of this analysis revealed a significant effect of group,  $F(1,29) = 20.44$ ,  $p < .01$ , with higher R-responses in the control group ( $M = .40$ ,  $SD = .24$ ) than in the amnesic group ( $M = .15$ ,  $SD = .18$ ). There was also a significant effect of condition,  $F(2,58) = 23.88$ ,  $p < .01$ , which was modulated by a significant group  $\times$  condition interaction,  $F(2,58) = 12.86$ ,  $p < .01$ . Follow up analyses indicated that the effect of condition was significant in the control group,  $F(2,36) = 57.38$ ,  $p < .01$ , but not in the amnesic group,  $F(2,22) < 1$ . Specifically, in the control group performance differed across all three conditions, with R-responses in the same-context repetition condition exceeding those in the single presentation condition,  $t(18) = 7.78$ ,  $p < .01$ , and R-responses in the varied-context repetition condition exceeding those in the same-context condition,  $t(18) = 2.20$ ,  $p < .05$ . By contrast, in the amnesic group R-responses did not differ as a function of condition.

Turning next to IRK scores, IRK scores for nonstudied stimuli were greater in the amnesic group than in the control group,  $t(29) = 4.89$ ,  $p < .01$ , and therefore, corrected IRK scores (hits – false alarms) were subjected to further analysis. There was a main effect of group,  $F(1,29) = 10.33$ ,  $p < .01$ , with familiarity-based recognition scores being higher in the control group ( $M = .39$ ,  $SD = .25$ ) than in the amnesic group ( $M = .20$ ,  $SD = .23$ ). There was also a main effect of condition,  $F(2,58) = 6.90$ ,  $p < .01$ . This reflected the fact that familiarity-based recognition was higher in both repetition conditions (same context:  $M = .36$ ,  $SD = .27$ ; varied context  $M = .39$ ,  $SD = .28$ ) than in the single presentation condition ( $M = .20$ ,  $SD = .17$ ). There was no difference between the two repetition conditions. The group  $\times$  condition interaction failed to reach significance,  $F(2,58) = 1.28$ ,  $p = .29$ .

## Discussion

The results of the present study confirm previous findings indicating that individuals with amnesia benefit from repetition, but do so to a lesser degree than controls. They extend these findings by demonstrating that the amount of encoding variability brought about by repetition has no impact on the performance of individuals with severe memory impairment: Whether information was repeated in a single semantic context or in multiple contexts, recognition memory improved to the same extent. Moreover, this improvement was manifest exclusively in familiarity-based responses, and had no effect on Remember responses. Thus, despite three presentations of the same target items, even in varied contexts, the contribution of recollection to memory for the target information did not change. Multiple repetitions did not make available additional retrieval cues, but merely enhanced the sense of familiarity of the targets. These findings not only clarify the mechanism by which repetition facilitates performance in individuals with amnesia, they also reinforce the severity of the recollection deficit and its

imperviousness to improvement (for a similar failure to enhance recollection following five exact repetitions, see Schacter et al., 1998).

There were both similarities and differences in how the two forms of repetition affected the performance of individuals with amnesia and individuals without memory impairment. Like the memory-impaired group, the memory-intact group showed no difference in overall recognition performance between the same-context and varied-context condition. Yet, a striking qualitative difference was apparent, in that in the control group, Remember responses were significantly higher following varied-context than following same-context repetition. In keeping with our prediction, individuals with intact memory were able to take advantage of the multiple study contexts as cues to retrieve the target words, and hence, recollection was enhanced. Interestingly, using a similar contextual manipulation to that used here, Glenberg (1979) found a varied-context advantage in free and cued recall tasks, tasks that are primarily mediated by recollection. That a similar overall enhancement was not evident in the recognition task used in this study reflects the fact that recognition does not necessarily require recollection of study details, but can also be mediated by familiarity, in the absence of recollection. Such familiarity was enhanced equally by same-context and varied-context repetition, both in amnesic and memory-intact individuals, and likely reflects the enhanced trace strength associated with repetition of the target itself.

The validity of our conclusions regarding the processes mediating repetition effects in memory-impaired and memory-intact individuals rests on the assumption that Remember/Know reports can be used to assess recollection and familiarity. While there is good evidence that memory-intact individuals, when properly instructed, can reliably characterize their memorial experience (Gardiner & Richardson-Klavehn, 2000; Rajaram, 1999; Yonelinas, 2002), the ability of memory-impaired individuals to do so may be questioned. Indeed, there is evidence to suggest that in some conditions, amnesic individuals may assign Remember responses more liberally than controls (Rajaram et al., 2002). Although the false alarm rate for Remember responses in the amnesic group in the current study was acceptably low, and comparable with rates reported in the normal literature (e.g., Gardiner, 1988; Rajaram, 1993; Yonelinas & Jacoby, 1995), there was quite a bit of variability, with the rate exceeding .10 in several participants with amnesia. This is problematic, as it suggests that some participants may not have followed instructions to give Remember responses only when they were able to remember specific details (as by definition, no such details exist for nonstudied items). Therefore, we analyzed the performance of a subgroup of seven individuals with amnesia whose Remember false alarm rate was very low (mean=.009) and did not differ from that of controls ( $t < 1$ ). In particular, we were interested in whether Remember responses varied as a function of repetition condition in this subgroup. Remember responses did not differ in the single presentation, same-context repetition, and varied-context repetition conditions. These results suggest that the failure to find effects of repetition on recollection in the amnesic group as a whole was not due to the fact that some participants may have used Remember judgments inappropriately.

Possibly of greater concern, some have argued that even if participants provide Remember/ Know responses according to instructions, these responses cannot elucidate the contribution of recollection and familiarity to performance, because Remember and Know responses merely differ quantitatively, in terms of the strength of the memory trace (Donaldson, 1996; Wixted, 2007). By this view, participants set two decision criteria on a single continuum of trace strength, where the stricter criterion represents the cut-off for Remember responses and the more lenient criterion the cut-off for Know (and overall recognition) responses. Although such a unidimensional model can successfully explain a number of findings, it does not provide an adequate account of the current findings. First, our data indicate that both participant groups benefited from repetition, but only in the control group was such an increase in memory strength associated with enhanced Remember responses. According to the unidimensional strength

model, such an increase should be seen in both groups, as enhanced memory trace strength should translate into increased Remember responses. Second, we found that both groups performed equivalently in the two repetition conditions, but in the control group there was an increase in Remember responses associated with varied repetition, whereas in the amnesic group there was not. By a unidimensional strength account, an increase in Remember responses may come about (1) if there is greater variability in the memory strength distribution of varied-context items than of same-context items; or (2) if participants set a more liberal criterion for Remember responses in that condition<sup>1</sup>. However, this account does not explain why either of these would occur in the control group, but not in the amnesic group.

Thus, our findings can best be understood as reflecting the fact that repetition leads to enhanced familiarity in the amnesic group, and moreover, that it does so to the same extent regardless of whether the context in which the information is presented is kept constant or is changed across repetitions. In the control group, by contrast, repetition enhances both familiarity and recollection, with the enhancement in recollection particularly pronounced given varied-context repetition. These findings highlight the fact that the same manipulation may affect the performance of memory-impaired and memory-intact individuals in qualitatively different ways (for another example, see Verfaellie & Treadwell, 1993).

Our results also have important practical implications for efforts at memory training in individuals with severe amnesia. They reinforce that while repetition can enhance memory performance, such efforts have clear limitations, in that the resulting memories remain impoverished and devoid of the contextual detail that recollection affords. Yet, on a more positive note, our findings also suggest that individuals with severe memory impairment can take advantage of repetitions both when these are highly fixed and invariant, and when they vary such that the same information is repeated in semantically different contexts. While the former may be more characteristic of formal laboratory settings, the latter no doubt more closely approximates conditions in which information is typically encountered in everyday life. Neither of these appears to be inherently more beneficial (or, for that matter, harmful) for individuals with severe amnesia. Thus, acknowledging that the effects of repetition are qualitatively different in amnesic patients and in memory-intact individuals, we nonetheless infer that remedial measures can be designed without excessive concern about how repetition is implemented.

In drawing this conclusion, it is important to keep in mind that our recognition test did not require participants to use the studied information flexibly, but rather, assessed memory for the target information precisely as it had been studied. A similar situation in everyday life may arise when learning a person's name or a fact about that person – instances in which the to-be-remembered information is in itself fixed, regardless of the context in which it is encountered. Many other situations, however, make demands on memory in such a way that newly acquired information needs to be extended to novel situations or applied in different settings. An example of this may be the acquisition of novel concepts, which then can be used flexibly in different domains. As expected, normal individuals who are exposed to concepts in a variety of contexts at study are better able to recognize broad applications of these concepts than are individuals who are exposed to them in a restricted range of contexts (Di Vesta & Peverly, 1984). Future research will need to determine whether, under such circumstances, encoding in variable contexts can benefit individuals with amnesia as well.

---

<sup>1</sup>Because the repetition conditions were intermixed at study, a criterion shift explanation of the increase in Remember judgments associated with the different-context condition is unlikely. This is because previous research has demonstrated that participants are highly reluctant to shift criterion from trial to trial (Stretch & Wixted, 1998).

Finally, it is worth emphasizing the severity of the memory disorder in the patients who participated in this study, and the fact that despite reasonably good overall recognition they exhibited very poor recollection ability. In patients with milder memory impairment, in whom recollection is impoverished but not absent, attempts to enhance recollection have been found to be successful (Jennings & Jacoby, 2003). In those individuals, repetition in variable contexts may provide another useful means to do so. More generally, these findings underscore the need for future research evaluating the usefulness of different strategies for memory enhancement, taking into account the extent to which residual memory abilities are mediated by familiarity versus recollection.

### Acknowledgements

This research was supported by NIH grants MH57861 and MH71783 and by the Office of Research and Development, Medical Research Service, Department of Veterans Affairs.

The authors have no financial or other relationships that could be interpreted as a conflict of interest affecting this manuscript.

### References

- Cermak LS, Verfaellie M, Lanzoni S, Mather M, Chase K. Effect of spaced repetitions on amnesia patients' recall and recognition performance. *Neuropsychology* 1996;10:219–227.
- Chalfonte BL, Verfaellie M, Johnson MK, Reiss L. Spatial location memory in amnesia: Binding item and location information under incidental and intentional encoding conditions. *Memory* 1996;4:591–614. [PubMed: 8934456]
- Ciccone DS, Brelsford JW, Tullis T. The effects of stimulus variability on response latency in a continuous recognition task. *Bulletin of the Psychonomic Society* 1975;5:456–458.
- Dewhurst SA, Hitch GJ. Cognitive effort and recollective experience in recognition memory. *Memory* 1999;7:129–146. [PubMed: 10645376]
- Di Vesta FJ, Peverly ST. The effects of encoding variability, processing activity, and rule-examples sequence on the transfer of conceptual rules. *Journal of Educational Psychology* 1984;76:108–119.
- Donaldson W. The role of decision processes in remembering and knowing. *Memory and Cognition* 1996;24:523–533.
- Fazio F, Perani D, Gilardi MC, Colombo F, Cappa SF, Vallar G, Bettinardi V, Paulesu E, Alberoni M, Bressi S, Franceschi M, Lenzi GL. Metabolic impairment in human amnesia: A PET study of memory networks. *Journal of Cerebral Blood Flow and Metabolism* 1992;12:353–358. [PubMed: 1569132]
- Francis, WN.; Kucera, H. *Frequency Analysis of English Usage: Lexicon and Grammar*. Boston: Houghton Mifflin Co; 1982.
- Gardiner JM. Functional aspects of recollective experience. *Memory and Cognition* 1988;16:309–313.
- Gardiner JM, Kaminska Z, Dixon M, Java RI. Repetition of previously novel melodies sometimes increases both remember and know responses in recognition memory. *Psychonomic Bulletin and Review* 1996;3:366–371.
- Gardiner JM, Radomski E. Awareness of recognition memory for Polish and English folk songs in Polish and English folk. *Memory* 1999;7:461–470.
- Gardiner, JM.; Richardson-Klavehn, A. Remembering and knowing. In: Tulving, E.; Craik, FIM., editors. *The Oxford Handbook of Memory*. New York: Oxford University Press; 2000. p. 229–244.
- Glenberg AM. Component-levels theory of the effects of spacing of repetitions on recall and recognition. *Memory and Cognition* 1979;7:95–112.
- Heiss WD, Pawlik G, Holthoff V, Kessler J, Szeliess B. PET correlates of normal and impaired memory function. *Cerebrovascular Brain Metabolism Review* 1992;4:1–27.
- Huppert FA, Piercy M. The role of trace strength in recency and frequency judgements by amnesics and control subjects. *Quarterly Journal of Experimental Psychology* 1978;30:346–354.
- Jacoby LL, Jones TC, Dolan PO. Two effects of repetition: Support for a dual-process model of know judgments and exclusion errors. *Psychonomic Bulletin and Review* 1998;5:705–709.

- Jennings JM, Jacoby LL. Improving memory in older adults: Training recollection. *Neuropsychological Rehabilitation* 2003;13:417–440.
- Klein K, Saltz E. Specifying the mechanisms in a levels-of-processing approach to memory. *Journal of Experimental Psychology: Human Learning and Memory* 1976;2:671–679.
- O'Connor, MG.; Verfaellie, M. The amnesic syndrome: Overview and subtypes. In: Baddeley, A.; Wilson, B.; Kopelman, M., editors. *Handbook of Memory Disorders*. 2. Chichester, UK: Wiley; 2002. p. 145-166.
- Paivio A. Spacing of repetitions in the incidental and intentional free recall of pictures and words. *Journal of Verbal Learning and Verbal Behavior* 1974;13:497–511.
- Parkin, AJ. Functional significance of etiological factors in human amnesia. In: Squire, LR.; Schacter, DL., editors. *Neuropsychology of Memory*. 3. New York: Guilford Press; 1993. p. 122-129.
- Parkin AJ, Gardiner JM, Rosser R. Functional aspects of recollective experience in face recognition. *Consciousness and Cognition* 1995;4:387–398. [PubMed: 8750414]
- Parkin AJ, Russo R. On the origin of functional differences in recollective experience. *Memory* 1993;1:231–237. [PubMed: 7584270]
- Postman L, Knecht K. Encoding variability and retention. *Journal of Verbal Learning and Verbal Behavior* 1983;22:133–152.
- Rajaram S. Remembering and knowing: Two means of access to the personal past. *Memory and Cognition* 1993;31:89–102.
- Rajaram, S. Assessing the nature of retrieval experience. In: Challis, BH.; Velichkovsky, BM., editors. *Stratification in Cognition and Consciousness*. Amsterdam: John Benjamins; 1999. p. 255-275.
- Rajaram S, Hamilton M, Bolton A. Distinguishing states of awareness from confidence during retrieval: Evidence from amnesia. *Cognitive, Affective and Behavioral Neuroscience* 2002;2:227–235.
- Schacter DL, Verfaellie M, Anes MD, Racine C. When true recognition suppresses false recognition: Evidence from amnesic patients. *Journal of Cognitive Neuroscience* 1998;10:668–679. [PubMed: 9831736]
- Soraci S, Carlin MT, Chechile RA, Franks JJ, Wills T, Watanabe T. Encoding variability and cuing in generative processing. *Journal of Memory and Language* 1999;41:541–559.
- Strauss ME, Weingartner H, Thompson K. Remembering words and how often they occurred in memory-impaired patients. *Memory and Cognition* 1985;13:507–510.
- Stretch V, Wixted JT. On the difference between strength-based and frequency-based mirror effects in recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition* 1998;24:1379–1396.
- Sullivan EV, Marsh L. Hippocampal volume deficits in alcoholic Korsakoff's syndrome. *Neurology* 2003;61:1716–1719. [PubMed: 14694035]
- Tulving E. Memory and consciousness. *Canadian Psychology* 1985;26:1–12.
- Verfaellie M, Cermak L. Acquisition of generic memory in amnesia. *Cortex* 1994;30:293–303. [PubMed: 7924352]
- Verfaellie M, Treadwell J. Status of recognition memory in amnesia. *Neuropsychology* 1993;7:5–13.
- Wechsler, D. *Wechsler Adult Intelligence Scale--III*. San Antonio, TX: The Psychological Corporation; 1997.
- Weingartner H, Eckardt M, Grafman J, Molchan S, Putnam K, Rawlings R, Sunderland T. The effects of repetition on memory performance in cognitively impaired patients. *Neuropsychology* 1993;7:385–395.
- Winograd E, Geis MF. Semantic encoding and recognition memory: A test of encoding variability theory. *Journal of Experimental Psychology* 1974;102:1061–1068.
- Wixted JT. Dual-process theory and signal-detection theory of recognition memory. *Psychological Review* 2007;114:152–176. [PubMed: 17227185]
- Yonelinas AP. The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language* 2002;46:441–517.
- Yonelinas AP, Jacoby LL. The relation between remembering and knowing as bases for recognition: Effects of size congruency. *Journal of Memory and Language* 1995;34:622–643.

- Yonelinas AP, Kroll NEA, Dobbins I, Lazzara M, Knight RT. Recollection and familiarity deficits in amnesia: Convergence of remember-know, process dissociation, and receiver operating characteristic data. *Neuropsychology* 1998;12:323–339. [PubMed: 9673991]
- Young B, Bellezza FS. Encoding variability, memory organization, and the repetition effect. *Journal of Experimental Psychology: Learning, Memory and Cognition* 1982;8:545–559.

Table 1

Demographic and neuropsychological characteristics of the amnesic patients

Patient	Etiology	Age	Edu	WAIS-III			WMS-III			WM
				VIQ	GM	VD	AD	WM		
MTL01	anoxia	51	12	83	52	56	55	85		
MTL02	anoxia	71	18	113	75	72	80	102		
MTL03	anoxia	63	20	111	52	56	64	83		
MTL04*	anoxia	50	16	111	81		69	107		
MTL05	anoxia	37	16	86	49	53	52	93		
MTL06	encephalitis	46	14	92	45	56	55	85		
MTL07	encephalitis	73	18	135	45	53	58	141		
DN01	Korsakoff	51	18	111	69	72	64	81		
DN02	Korsakoff	80	14	105	66	62	64	121		
DN03	Korsakoff	74	14	99	59	65	58	115		
DN04	Korsakoff	82	9	100	72	75	74	91		
DN05*	Korsakoff	70	12	83	66		50	99		

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

\* For these patients, WMS-R scores are provided because WMS-III scores were not available. WMS-R provides a single Delayed Memory score, rather than separate visual and auditory scores.

**Table 2**

Overall endorsement rates as a function of participant group and study condition are broken down in to R and K responses. R responses provide a measure of recollection. Familiarity estimates are based on IRK scores (K/1-R) and provide a measure of familiarity-based recognition. Standard deviations are indicated between parentheses.

	Overall/R	IRK
Amnesic		
Single	.46 (.23)/ .20 (.20)	.36 (.23)
Same-context repetition	.57 (.22)/ .23 (.22)	.44 (.21)
Different-context repetition	.60 (.19)/ .26 (.24)	.47 (.22)
Nonstudied	.27 (.18)/ .08 (.10)	.22 (.14)
Control		
Single	.40 (.20)/ .18 (.16)	.27 (.15)
Same-context repetition	.73 (.14)/ .48 (.19)	.50 (.24)
Different-context repetition	.78 (.15)/ .55 (.19)	.53 (.26)
Nonstudied	.05 (.06)/ 0 (.01)	.04 (.06)