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BRIEF REPORT

Exploring the repetition paradox: The effects of learning context and massed repetition on memory

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Abstract Although repetition is generally assumed to enhance the accessibility of memory for rehearsed material, recent research has suggested that prolonged repetition might actually be detrimental under some conditions. In the present work, we manipulated repetition duration and learning condition (intentional vs. incidental) in an effort to clarify the relationship between repetition and memory. Replicating previous findings, memory for repeated items declined with increased repetition under incidental-learning conditions. However, increased repetition had the opposite effect under intentional-learning conditions. Taken together, these results provide evidence for distinctive mechanisms of memory acquisition during repetition that vary depending on learning context.

Keywords Priming · Incidental vs. intentional learning · Cued recall · Massed repetition

For over a century, repetition has been regarded as an important precursor to learning new material, fostering memory encoding and successful retrieval (Ebbinghaus, 1885/1913). An example of this comes from the repetition-priming literature, which has shown that merely repeating a stimulus has widespread beneficial effects, such as faster lexical decision times (Scarborough, Gerard, & Cortese, 1979), more accurate object identification (Jacoby & Dallas, 1981), and enhanced implicit memory in amnesic patients (Cave & Squire, 1992; Jacoby & Witherspoon, 1982; Shimamura & Squire, 1984).

Although continual repetition usually eventuates in diminished returns (Chen & Squire, 1990; Miller, 1978), repetition rarely leads to poorer recall. One example is the phenomenon of *semantic satiation*, in which prolonged exposure to a word invokes a subjective feeling of "loss of meaning," and reduces the word's accessibility in semantic tasks (Balota & Black, 1997; Black, 2001). In one of the first reliable measures of this effect, Smith (1984) asked participants to repeat a category name aloud for 3 or 30 s before viewing a target that was to be classified as a member or not a member of the repeated category. Surprisingly, response times were significantly longer when the category was repeated for 30 s, as compared to only 3 s.

Inspired by semantic-satiation research, Kuhl and Anderson (2011) recently investigated the effects of repetition on short- and long-term memory. Participants were first presented with a series of words to be repeated aloud for 5, 10, 20, or 40 s. The participants then completed an ostensibly unrelated cued-recall task. In results reminiscent of those from semantic-satiation studies, participants who repeated the words for 5 or 10 s were significantly more likely to use them in the recall task, relative to chance level (no repetition). However, words repeated for 20 or 40 s were reported no more often than chance level. Kuhl and Anderson termed this decline in performance with prolonged rehearsal the *massed repetition decrement.*

Although Kuhl and Anderson's (2011) findings might initially appear to clash with much of the previous memory literature, the source of this discontinuity may stem from the nature of learning in their paradigm. Specifically, word learning in their design was entirely incidental in nature, rather than intentional. Intentional learning offers several potential advantages over incidental learning, including the opportunity to use memorization strategies (Eagle & Leiter, 1964) and increased ability to employ deeper levels of information encoding (Craik & Lockhart, 1972). These critical differences may play a key role in determining whether prolonged repetition benefits or impairs later memory. Our chief aim was to examine this possibility.

An additional goal of our work was to clarify the impact of prolonged repetition on recall. Although Kuhl and Anderson

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(2011) clearly demonstrated that priming effects faded to approximately chance levels after 40 s of repetition, it is unclear whether additional repetition might actually drive performance below chance level. This is an important question, since this result would potentially indicate a link between prolonged repetition and the active inhibition of repeated material. To address this issue, we extended the duration of the longest repetition period from 40 to 60 s.

Experiment 1

Experiment 1 replicated the paradigm of Kuhl and Anderson (2011) using a longer repetition duration, in order to verify their results before we compared performance to that from an intentional-learning context in Experiment 2.

Method

Participants The participants were 39 undergraduate students (nine male, 30 female; mean age = 19.18 years, *SD* = 1.97, range = 17–23) recruited at the University of Western Australia in exchange for partial credit toward a psychology course requirement.

Procedure The procedure was based on that of Kuhl and Anderson (2011). The experiment consisted of two phases: a learning phase (LP), in which participants repeated aloud a list of visually presented words, followed by a test phase (TP), in which they completed a cued-recall task designed to elicit the words previously repeated in the LP (see Fig. 1 for a schematic diagram of the procedure). Participants were not informed of an upcoming memory task, and thus were unaware of the significance of the words repeated in the LP.

During the LP, participants were seated a comfortable distance from a 19-in. CRT monitor connected to a PC computer. The participants were presented with single words on the monitor and were required to repeat these words, at a moderate pace of about one repetition per second, until the word was removed from the display. The words were displayed for 10, 30, or 60 s, with the durations randomized throughout the LP. Successive words were separated by a 1-s interval during which a fixation cross was displayed at the center of the display. If a participant's repetitions were too slow or too fast (as assessed by the experimenter), the participant was notified during the first few trials. The LP took approximately 11 min to complete.

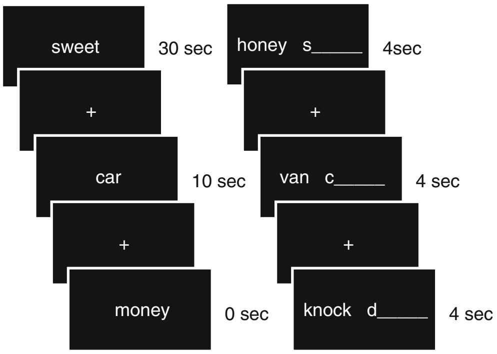

Fig. 1 Schematic depiction of repetition and cue words, with the learning phase (LP) and test phase (TP) on the left and right, respectively. The LP words designated a 0-s repetition duration were never displayed, and instead the next word in the sequence was presented

Following the LP, participants were presented with a short filler task—a word search—in which they were asked to find as many four-letter words as possible within the space of 4 min. Forty words unrelated to those in the LP or TP were hidden in the puzzle. Participants were informed that the puzzle had no theme, and that the words were unrelated to the repeated words.

The final TP was described as a "free association" experiment and consisted of a series of word–letter pairs presented on the display. Participants were informed that there were no "right" or "wrong" answers and that they should simply respond aloud with the first word that came to mind that was related to the presented word and began with the presented letter. The participants had 4 s to respond before the trial finished. The experimenter recorded the responses by hand. After responding, participants initiated the next trial by pressing the spacebar on the keyboard. In keeping with Kuhl and Anderson's (2011) design, a "hit" was recorded if the participant responded with a word previously presented during the LP. Responses that were variations of a studied word were designated as "hits" only if the response had phonetic overlap with the studied word (i.e., STEALS or STEALING would be a match for STEAL, but STOLEN would not be a match). All other responses, as well as nonresponses, were scored as "misses."

Materials A total of 24 word pairs were selected using the University of South Florida's word association norms database (Nelson, McEvoy, & Schreiber, 1998). Each pair consisted of one word that was repeated during the LP and another word to cue the repeated word during the TP. The TP words were selected such that they had an approximately 45 % chance of successfully cueing their LP counterpart by chance, according to the norm data. The repeated words and their cues were 3–10 letters in length ($M = 4.21$ for repeated words, $M = 5.81$ for associates). The pairs were chosen so that the LP word did not strongly prime its TP word counterpart, whereas the TP word did strongly prime its LP word counterpart (i.e., FLOOD primes WATER strongly, but not vice versa). The members of word pairs were not semantically or phonetically related to any other items in the study.

For the LP, four counterbalanced lists were generated, such that across participants, each word was repeated equally often for 0, 10, 30, or 60 s. Several filler words were added to the beginning and end of each list, to reduce primacy and recency effects. The list assigned to a participant in the LP was determined by the order of participant presentation. For the TP, a single list of word–letter pairs was used across participants, with each word–letter pair consisting of the TP word from the LP–TP pair and the first letter of the LP word (i.e., FLOOD W_____). Several filler word–letter pairs were added to the beginning of the list to enable participants to adjust to the task.

Results

The data from two participants were excluded from the analyses. One participant exhibited a chronic cough throughout the study that interfered with repetitions, and another was identified as a multivariate outlier, exceeding the Mahalanobis distance critical value (9.45) across repetition durations (Barnett & Lewis, 1994). This left a sample of 37 participants (eight male, 29 female) remaining for analysis.

Figure 2 illustrates the mean hit rates as a function of repetition duration. A repeated measures analysis of variance (ANOVA) did not reveal a main effect of repetition duration [$F(3, 108) = 2.31$, $p = .08$, $\eta_p^2 = .06$] on hit rates. However, planned paired-samples t tests showed that priming was elicited at 10 s of repetition, as demonstrated by a significant difference in hit rates between the 0-s (chance level) and 10-s [$t(36) = 2.24$, $p = .031$] conditions, but did not occur at the 30-s ($p = .87$) or 60-s ($p = .68$) repetition durations.

These results replicated Kuhl and Anderson’s (2011) principal finding, with repetition leading to improved memory only at the shortest repetition duration. Additionally, increasing the repetition duration to 60 s from the 40-s duration employed by Kuhl and Anderson failed to push recall levels below chance. This provides additional evidence that the mechanisms underlying reduced recall following rehearsal do not inhibit memory accessibility for repeated items below their baseline level—although, of course, we cannot rule out that this might occur with repetition beyond 60 s. Experiment 2 was identical to Experiment 1, but it included explicit instructions to encode the words during the LP for later recall. The goal was to determine whether prolonged repetition negatively influences memory in the face of deliberate encoding attempts.

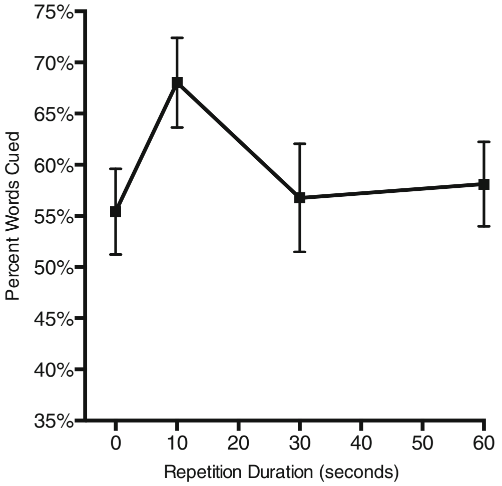

Fig. 2 Test phase (TP) performance for participants in Experiment 1. Error bars show *SEM*s

Experiment 2

Method

Participants The participants were 30 naïve undergraduate students (10 male, 20 female; mean age = 21.40 years, *SD* = 7.29, range = 17–56) recruited using the same procedure as for Experiment 1.

Procedure The procedure was identical to Experiment 1, except that prior to beginning the LP repetition task, participants were informed of an unspecified subsequent task related to the about-to-be-repeated words and were encouraged to memorize as many of the words as possible.

Materials The word lists were identical to the ones used in Experiment 1.

Results

The data from three participants were excluded from the analyses: One participant reported falling asleep toward the end of the repetition task, and two others were identified as multivariate outliers, exceeding the Mahalanobis distance critical value (9.45) across repetition durations. This left a sample of 27 participants (eight male, 19 female) remaining for analysis.

Figure 3 illustrates the mean hit rates as a function of repetition duration. A repeated measures ANOVA (Greenhouse–Geisser corrected) revealed a main effect of repetition duration, $F(1.89, 49.10) = 4.34$, $p = .020$, $\eta_p^2 = .14$. Planned paired-samples t tests were conducted to compare the effects of different repetition durations to chance level (0 s). Significant differences were obtained at the 30-s [$t(26) = 3.780$, $p = .001$] and 60-s [$t(26) = 3.55$, $p = .001$] repetition durations, but not at the 10-s repetition duration ($p = .28$).

The results of Experiment 2 indicate that recall increased steadily with repetition, before asymptoting after 30–60 s of repetition. A comparison of Figs. 1 and 2 suggests that intentional-learning instructions led to a very different outcome than when no such instructions were presented. Confirming this impression, a 2 (experiment) × 4 (repetition duration) mixed ANOVA showed a significant interaction, $F(2.59, 160.70) = 3.57$, $p = .02$, $\eta_p^2 = .05$.

Although the results of Experiments 1 and 2 suggest that the impact of repetition on recall is mediated by whether learning is

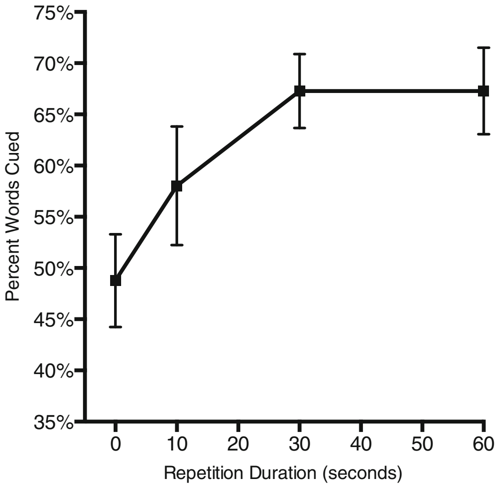

Fig. 3 Test phase (TP) performance for participants in Experiment 2. Error bars show *SEM*s

intentional or incidental, several questions remained unanswered. First, we did not verify whether the intentional or incidental learners followed the task instructions, nor whether any attempts were made to explicitly recall LP items during the TP. This raises questions about whether performance differences were mediated only by the learning instructions, and whether explicit retrieval strategies, which could have been more likely to occur for intentional learners, might also modulate recall performance (Graf & Schacter, 1985; Schacter & Graf, 1986; Tulving, Schacter, & Stark, 1982). Additionally, we did not assess whether satiation experiences, such as loss of word meaning, occurred, or whether this might be related to the dissociation in performance between learning groups. To examine these questions, we conducted a high-powered replication of Experiments 1 and 2, and included a postexperiment questionnaire that surveyed participants' use of encoding and retrieval strategies, as well as their subjective experiences of satiation.

Experiment 3

Method

Participants Naïve participants were recruited using the same procedure as in the previous experiments. To achieve a sufficiently powerful replication, we aimed to recruit 48 participants[1] (24 incidental learners, 24 intentional learners). However, an additional consideration was the potential use of recall strategies during the TP. Because, unlike in the previous experiments, we could assess this possibility using the postexperiment questionnaire (see below), we opted to control for recall strategy by excluding participants from the main analysis who indicated that they had attempted explicit retrieval. To accomplish this and still obtain our target sample size, new participants were recruited to replace those who indicated explicit retrieval attempts. As a result, a total of 68 participants (18 male, 50 female; mean age = 20.74 years, *SD* = 6.88, range = 17–46) completed the experiment.

Procedure The procedure was identical to that of the earlier experiments, with two key differences. First, we removed the 60-s repetition duration, because performance did not differ significantly from the 30-s repetition duration in either Experiment 1 or 2. This change allowed us to add the items from this repetition duration to the 0-, 10-, and 30-s repetition durations, in order to decrease variability. Second, participants completed a short questionnaire at the end of the study that assessed (a) whether (and how) memorization was attempted during the LP; (b) whether explicit retrieval was attempted during the TP; and (c) what subjective experiences were felt during the LP (e.g., loss of the repeated words' meanings). We then used these responses as the basis for creating our comparison groups. The main analysis included 48 participants (12 male, 36 females; mean age = 19.60 years, *SD* = 5.31, range = 17–46) who did not report explicitly attempting to retrieve the LP words during the TP, divided into two equal-sized groups on the basis of their self-reported attempts to memorize items during the LP. This required swapping three participants who reported actively trying to memorize items, despite incidental-learning instructions, with three participants who did not attempt to memorize items, despite intentional-learning instructions.

An additional 20 participants (six male, 14 female; mean age = 23.45 years, *SD* = 9.28, range = 17–45) reported using explicit retrieval strategies during the TP. We excluded these participants from the main analysis so that we could focus on the key issue of how intentional and incidental learning moderate the effect of repetition on recall, while controlling for differences in recall strategy. However, we will consider their data separately in the analyses below, to make a preliminary investigation of whether explicit retrieval attempts yield different outcomes.

Materials A total of 23 additional word pairs were added to those used in the earlier experiments, selected according to the criteria described in Experiment 1. The repeated words and their cues were 3–10 letters in length (*M* = 4.36 for repeated words, *M* = 5.98 for associates). The word pairs were arranged into three counterbalanced lists for the 0-, 10-, and 30-s repetition durations.

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[1] A preliminary estimate of the sample size was determined via statistical power analysis software (G*Power 3.1; Faul, Erdfelder, Lang, & Buchner, 2007), using an effect size ($f = .22$) derived from the significant interaction found between learning conditions and repetition instructions across Experiments 1 and 2 (corresponding to a small effect size, according to Cohen, 1988), an alpha level of .05, and a desired power of approximately .80. This estimate was considered, along with the requirement to fully counterbalance participants across three different word lists, in order to arrive at the final target sample size.

Results

We began by analyzing data only from the 48 participants who did not report using explicit recall strategies. No outliers were identified. Figure 4 illustrates the mean hit rates as a function of repetition duration and learning condition. A Learning Context (incidental, intentional) × Repetition Duration (0, 10, 30 s) mixed ANOVA revealed a main effect of repetition duration, $F(2, 47) = 11.95, p < .001, \eta_p^2 = .21$, and a Learning Context × Repetition Duration interaction, $F(2, 92) = 3.22, p = .04, \eta_p^2 = .07$, but no main effect of learning context ($p = .14$).

Incidental learners showed significant benefits at both the 10-s [$t(23) = 4.00, p = .001$] and 30-s [$t(23) = 2.17, p = .04$] durations, relative to chance level (0 s). As in Experiment 1, performance dropped between the 10- and 30-s durations, although this effect was now marginally significant ($p < .08$, one-tailed). Also replicating our earlier result, intentional learners showed significant repetition benefits at the 30-s duration [$t(23) = 5.64, p < .001$], but not at the 10-s duration ($p = .12$). Across the learning groups, performance was comparable at baseline (0 s) and the 10-s duration ($p > .05$). Importantly, however, at the 30-s repetition duration, the intentional group performed significantly better than the incidental group, $t(46) = 2.39, p = .02$.

The postexperiment questionnaire revealed that 15 intentional learners had used a strategy that consisted of associating words with themselves or with other words in the study. These associations were created by linking words together in a sentence or story, or by using mental imagery. Nine others used some form of inner rehearsal as they repeated the currently displayed word. The questionnaire also revealed that the majority of participants, across both learning conditions, reported subjective experiences associated with semantic satiation during the LP. Fourteen of the participants (eight incidental learners) reported that words tended to lose their meaning at longer repetition durations, and four (one incidental learner) reported that word pronunciation difficulty increased at longer durations. A further 21 (12 incidental learners) reported both types of experience during the LP. Only eight participants (three incidental learners) reported no satiation-related experiences. In sum, satiation experiences were the norm across participants in both groups, suggesting that they cannot explain the differences in memory performance.

Finally, we examined the data from the 20 participants (seven incidental learners) who attempted explicit recall during the TP. Although the relatively small number of participants makes any strong conclusions premature, examination of Fig. 5 suggests that trends emerged that were similar to those in the main analysis (Fig. 4). A Learning Context × Repetition Duration mixed ANOVA revealed only a main effect of repetition duration, $F(2, 19) = 3.27, p = .05, \eta_p^2 = .15$. However, whereas paired-samples t tests revealed no significant differences between any of the repetition durations for the incidental learners, intentional learners showed significant performance differences between the 0- and 10-s durations [$t(12) = 2.35, p = .02$, one-tailed] and the 0- and 30-s durations [$t(12) = 2.08, p = .03$, one-tailed]. Additionally, the intentional learners showed marginally greater recall than the incidental learners at the 30-s repetition duration, $t(18) = 1.45, p = .08$, one-tailed].

In summary, Experiment 3 replicated the principal effects reported in Experiments 1 and 2, while verifying differences in learning strategies and controlling for the contribution of recall strategies. The results of the postexperiment questionnaire also indicated that memory differences across the incidental and intentional learning conditions were unrelated to experiences of satiation. Finally, our results provide some preliminary evidence that explicit retrieval strategies do not mediate the impact of learning instructions on the massed repetition decrement, although further investigation will be required to verify this claim.

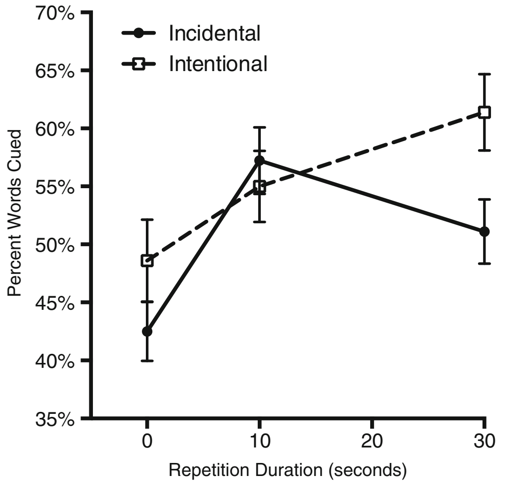

Fig. 4 Test phase (TP) performance for the participants in Experiment 3 who reported not using an explicit recall strategy. Error bars show *SEM*s

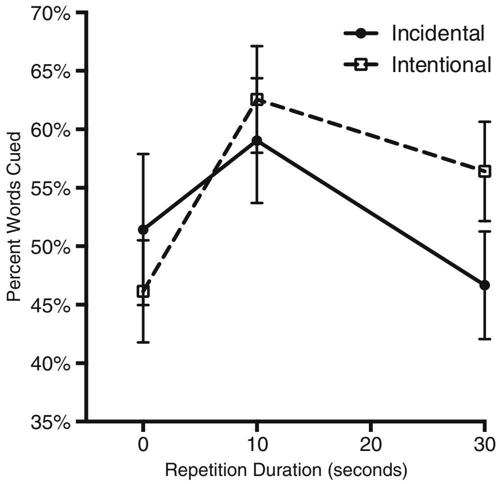

Fig. 5 Test phase (TP) performance for the participants in Experiment 3 who reported using an explicit recall strategy. Error bars show *SEM*s

General discussion

In the present study, we investigated Kuhl and Anderson's (2011) novel finding that prolonged repetition leads to a decline in recall. In Experiment 1, we successfully replicated this result and found that even with a further increase in repetition duration, cued-recall performance did not decrease below chance levels. By comparison, in Experiment 2, we showed that explicit instructions to remember repeated items led to the oft-reported positive relationship between repetition duration and cued recall. Finally, in Experiment 3, we verified that learning condition modulated the effect of repetition on recall, and that performance was determined by whether or not an individual engaged in memorization, regardless of instruction. The results also provided preliminary evidence that this relationship holds whether or not participants attempt to explicitly recall repeated items. Together, these findings place important boundary conditions around the repetition decrement, indicating that it does not occur when there is an intention to learn the material.

It remains unclear why massed repetition during implicit learning initially improves recall, only to see a rapid dissipation of this benefit, or why this did not occur during intentional learning. Kuhl and Anderson (2011) suggested that repetition compromises semantic activation, forcing individuals to focus increasingly on phonetic information to preserve word articulation. However, our own investigations suggest that semantic meaning loss cannot be the only determinant of memory performance. In the postexperiment questionnaire, the majority of participants in Experiment 3 reported subjective feelings of loss of meaning. Nevertheless, this only led to a repetition decrement in the implicit-learning condition. Additionally, if competition between semantic and phonological representations were the only explanation for the repetition decrement, it would be expected to be larger for participants in the intentional-learning condition, who would have been more likely to activate semantics in order to facilitate learning (Neill, Beck, Bottalico, & Molloy, 1990).

An alternative explanation is that intentional learners were actively engaging in memorization strategies, a cognitively effortful process known to increase subsequent recall (Hyde & Jenkins, 1973; Neill et al., 1990; Rose & Rowe, 1976). This is consistent with the participant reports in Experiment 3. It is also likely that using such strategies would foster deeper levels of encoding (Craik & Lockhart, 1972). Incidental learners, on the other hand, were unlikely to have engaged in learning strategies, as was confirmed by Experiment 3. To the extent that this explanation is accurate, it also implies that encoding processes that improve memory are independent from those that lead to subjective experiences like "loss of meaning."

One other notable aspect of our results was that repetition-based improvements in memory reliably appeared earlier for incidental than for intentional learners. One interpretation of this finding is that incidental learning is initially a more efficient process than effortful memorization strategies. Researchers who have observed similar differences between incidental- and intentional-learning conditions have postulated that effortful processing can impede the memorization process (Bugelski, 1974). On the other hand, given that different strategies and representations underlie memory performance in the intentional- and incidental-learning conditions, variations in the apparent rate of learning may simply be attributable to these factors.

In summary, it appears that our understanding of learning through repetition may not be as straightforward as had originally been thought. The present study suggests that, for verbal material at least, changes in long-term memory are most reliably achieved when repetition is paired with the deliberate use of memorization strategies and deep encoding. However, further investigation will be required to better understand the massed repetition decrement and determine why incidental- and intentional-learning contexts elicit such performance disparities. Such investigations should involve explicit attempts to modulate the level of processing employed by learners, in order to confirm whether this modulates recall. An additional consideration is the impact of the recall task on the repetition decrement. Whereas the present study and Kuhl and Anderson (2011) used a largely implicit cued-recall task, real-word scenarios often require explicit recall. Moreover, previous studies have suggested significant dissociations between the performance on implicit and explicit recall tasks (Graf & Schacter, 1985; Schacter & Graf, 1986; Tulving et al., 1982). This suggests a clear need for further investigations, and in particular, a fully crossed experimental design manipulating learning and recall instructions, as well as type of recall task.

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