Exploring the Repetition Paradox:

The effect of learning context and massed repetition on memory

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Abstract

While 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. The present work 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 varies depending on learning context.

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 shows 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 its 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 three or thirty seconds before viewing a target that was to be classified as a member of the repeated category or not. Surprisingly, response times were significantly longer when the category was repeated for thirty seconds compared to only three seconds.

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 seconds. Participants then completed an ostensibly unrelated cued-recall task. In results reminiscent of semantic satiation studies, participants who repeated words for 5 or 10 seconds were significantly more likely to use them in the recall task relative to chance level (no repetition). However, words repeated for 20 or 40 seconds were reported no more often than chance level. Kuhl and Anderson (2011) termed this decline in performance with prolonged rehearsal the *massed repetition decrement.*

Although Kuhl and Anderson's 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 is to examine this possibility.

An additional goal of our work was to clarify the impact of prolonged repetition on recall. While Kuhl and Anderson (2011) clearly demonstrated that priming effects faded to approximate 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, as this result would potentially indicate a link between prolonged repetition and active inhibition of repeated material. To address this issue, we extended the duration of the longest repetition period from 40 to 60 seconds.

Experiment 1

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

Participants. Participants were 39 undergraduate students (9 male; mean age = 19.18, SD = 1.97, range = 17-23) recruited at the University of Western Australia in exchange for partial credit towards 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), where participants repeated aloud a list of visually presented words, followed by a test phase (TP), where participants completed a cued recall task designed to elicit words previously repeated in the LP (see Figure 1 for a schematic diagram of the procedure). Participants were not informed of an upcoming memory task, and were thus unaware of the significance of the words repeated in the LP.

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

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 four minutes. Forty words unrelated to those in the LP or TP were hidden in the puzzle. Participants were informed that there was no theme to the puzzle, 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 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. Participants had 4s to respond before the trial finished. The experimenter recorded 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 a “hit” 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 non-responses were scored as a “miss”.

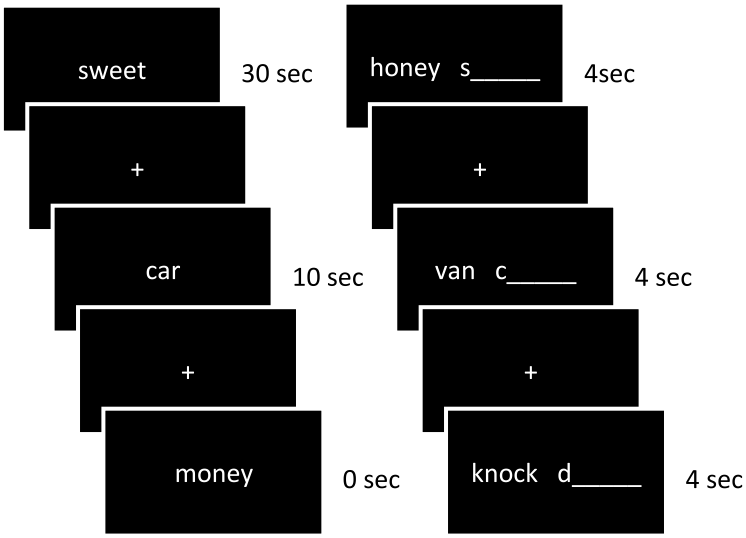

Figure 1. Schematic depiction of repetition and cue words, with the LP and TP on the left and right respectively. LP words designated a 0s repetition duration were never displayed and instead the next word in sequence was presented.

Materials. Twenty-four 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 cueing for the repeated word during the TP. TP words were selected such that they had an approximately 45% chance of successfully cueing their LP-counterpart by chance according to the norms data. Repeated words and their cues were 3-10 letters in length (M = 4.21, for repeated words, M = 5.81 for associates). 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). Members of word pairs were not semantically or phonetically related to any other items in the study.

For the LP, four counter-balanced lists were generated such that across participants, each word was repeated equally often for 0, 10, 30 or 60s. 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 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 (ie. FLOOD - W_____). Several filler word-letter pairs were added to the beginning of the list to enable participants to adjust to the task.

Results

Data from two participants were excluded from 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 (8 male) remaining for analysis.

Figure 2 illustrates 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 10s repetition, as demonstrated by a significant difference in hit rate between the 0s (chance level) and 10s conditions [$t(36) = 2.24$, $p = .031$], but did not occur at the 30s ($p = .87$) or 60s ($p = .68$) repetition durations.

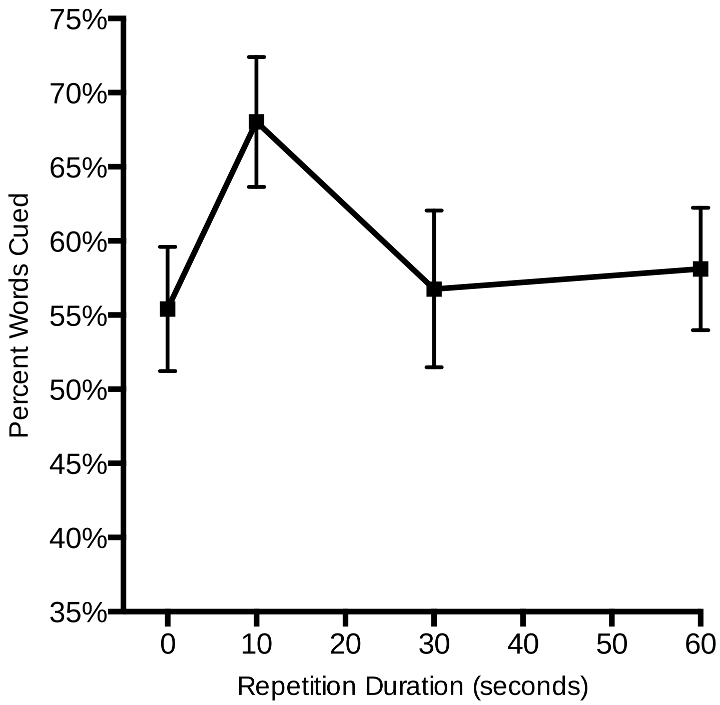

Figure 2. TP performance for participants in Experiment 1. Error bars show *SEM*.

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 seconds from the 40-second duration employed by Kuhl and Anderson (2011) failed to push recall levels below chance. This provides additional evidence that 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 60s. Experiment 2 was identical to Experiment 1, but included explicit instructions to encode the words during LP for later recall. The goal was to determine whether prolonged repetition negatively influences memory in the face of deliberate encoding attempts.

Experiment 2

Participants. Participants were 30 naïve undergraduate students (10 male; mean age = 21.40, SD = 7.29, range = 17-56) recruited using the same procedure as 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

Data from three participants were excluded from analyses. One participant reported falling asleep towards the end of the repetition task, while 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 (8 male) remaining for analysis.

Figure 3 illustrates 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 (0s). Significant differences were obtained at the 30s [$t(26) = 3.780$, $p = .001$] and 60s [$t(26) = 3.55$, $p = .001$] repetition durations, but not at the 10s repetition duration ($p = .28$).

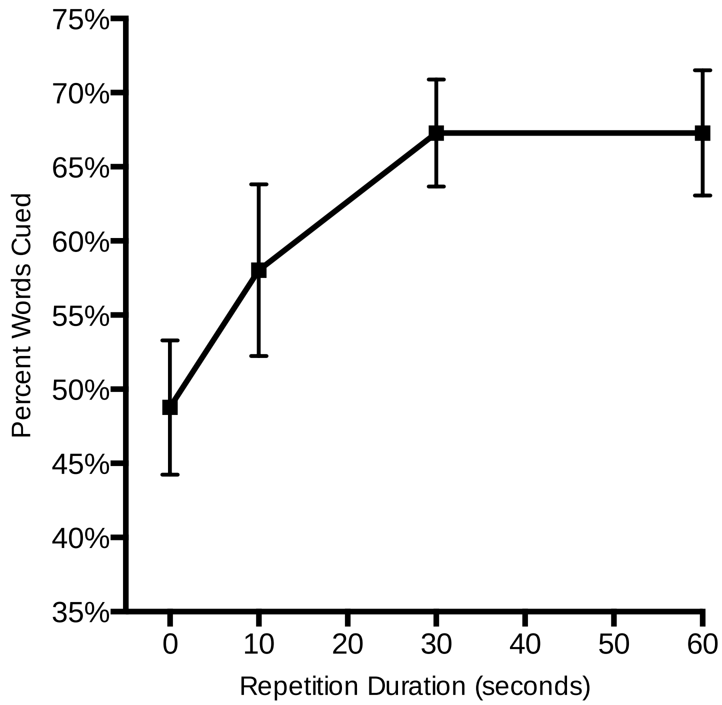

Figure 3. TP performance for participants in Experiment 2. Error bars show *SEM*.

The results of Experiment 2 indicate that recall increased steadily with repetition, before asymptoting after 30-60s of repetition. A comparison of Figures 1 and 2 suggests that intentional learning instructions led to very different outcomes compared to what occurred when no such instructions were presented. Confirming this impression, a 2 (Experiment) x 4 (Repetition Duration) mixed ANOVA showed a significant interaction, F(2.59, 160.70), = 3.57, p = .02, η_p^2 = .05.

While the results of Experiments 1 and 2 suggest that the impact of repetition on recall is mediated by whether learning is intentional or incidental, several questions remain unanswered. First, we did not verify whether intentional or incidental learners followed 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 learning instructions, and whether explicit retrieval strategies, which may 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 post-experiment questionnaire that surveyed participants' use of encoding and retrieval strategies, as well as subjective experiences of satiation.

Experiment 3

Participants. Naïve participants were recruited using the same procedure as 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 previous experiments, we could assess this possibility using the post-experiment questionnaire (see below), we opted to control for recall strategy by excluding participants from the main analysis who indicated that they 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; mean age = 20.74, SD = 6.88, range = 17-46) completed the experiment.

Procedure. The procedure was identical to that of earlier experiments, with two key differences. First, we removed the 60s repetition duration because performance did not differ

[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.

significantly from the 30s 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 30s 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) if explicit retrieval was attempted during the TP; and c) what subjective experiences were felt during the LP (e.g., loss of repeated-word meaning). We then used these responses as the basis for creating our comparison groups. The main analysis included 48 participants (12 male; mean age = 19.60, SD = 5.31, range = 17-46) who did not report explicitly attempting to retrieve 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; mean age = 23.45, 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 moderates 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. Twenty-three additional word pairs were added to those used in earlier experiments, selected according to the criteria described in Experiment 1. Repeated words and their cues were 3-10 letters in length (*M* = 4.36, for repeated words, *M* = 5.98 for associates). Word pairs were arranged into three counterbalanced lists for the 0, 10, and 30s repetition durations.

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 mean hit rates as a function of repetition duration and learning condition. A Learning Context (Incidental, Intentional) x Repetition Duration (0, 10, 30s) mixed ANOVA revealed a main effect of Repetition Duration, $F(2, 47) = 11.95$, $p < .001$, $\eta_p^2 = .21$, and a Learning Context x Repetition Duration interaction, $F(2, 92) = 3.22$, $p = .04$, $\eta_p^2 = .07$, but no main effect of Learning Context ($p = .14$).

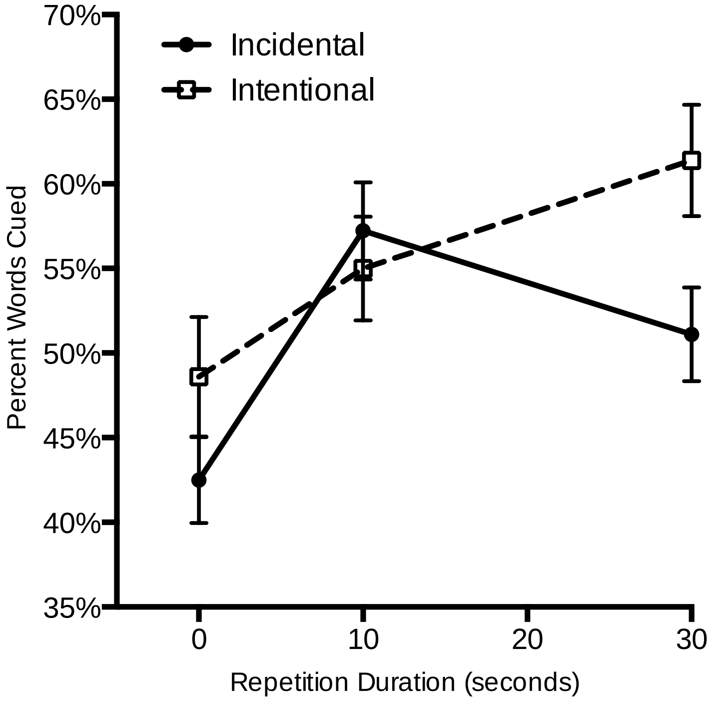

Figure 4. TP performance for participants in Experiment 3 who reported not using an explicit recall strategy. Error bars show *SEM*.

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

The post-experiment questionnaire revealed that 15 intentional learners used a strategy that consisted of associating words with themselves or other words in the study. 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 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 (twelve 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 differences in memory performance.

Finally, we examined 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 Figure 5 suggests similar trends emerged as in the main analysis (Figure 4). A Learning Context x Repetition Duration mixed ANOVA revealed only a main effect of Repetition Duration, $F(2, 19) = 3.27$, $p = .05$, $\eta_p^2 = .15$. However, while 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 0-10s durations [$t(12) = 2.35$, $p = .02$, one-tailed] and the 0-

30s durations [$t(12) = 2.08$, $p = .03$, one-tailed]. Additionally, intentional learners showed marginally greater recall than incidental learners at the 30s repetition duration, [$t(18)=1.45$, $p = .08$, one-tailed].

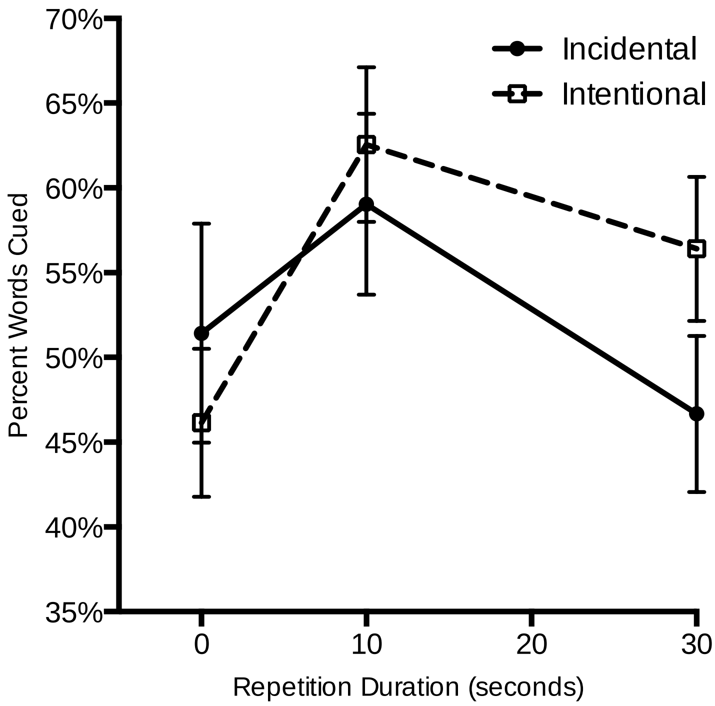

Figure 5. TP performance for participants in Experiment 3 who reported using an explicit recall strategy. Error bars show *SEM*.

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 post-experiment questionnaire also indicate that memory differences across the incidental and intentional learning conditions are 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 is required to verify this claim.

General Discussion

The present study investigated Kuhl and Anderson's (2011) novel findings 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 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 post-experiment 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, then 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 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 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 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 learning condition compared to the incidental learning condition, 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 originally 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 deliberate use of memorization strategies and deep encoding. However, further investigation is 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 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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