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Remembering “primed” words: A counter-intuitive effect of repetition on recognition memory

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Abstract

The present study examines the effect of immediate repetition on recognition memory. In a series of 4 experiments, the study phase task was to name aloud a word that was immediately preceded by either the same word (repeated trials) or a different word (not-repeated trials). Across experiments, performance in the study phase demonstrated the anticipated benefit in naming times for repeated trials. More important, performance in the test phase revealed greater sensitivity for not-repeated than repeated trials. This effect was observed even when repetitions at study were separated by an unrelated word (Experiment 3), and was eliminated only when participants named both words in succession at study (Experiment 4). These findings fit nicely with the desirable difficulty principle (R. A. Bjork, 1994), as they demonstrate that items more easily processed at study (i.e., repeated items) are not as well-encoded as items that are more difficult to process at study (i.e., not-repeated items). Furthermore, the current study points to the possibility that attentional orienting in response to processing difficulty may constitute a broadly important cognitive control adaptation that impacts memory encoding.

Keywords: repetition; recognition; desirable difficulty; attentional orienting

Introduction

Experimental psychologists have used stimulus repetition in diverse ways to understand basic principles of perception, learning, and memory. The present study focuses on a tension between two opposing influences of stimulus repetition. On the one hand, it has long been known that stimulus repetition facilitates perceptual identification (e.g., Jacoby & Dallas, 1981; Scarborough, Cortese, & Scarborough, 1977), and that multiple opportunities to encode the same stimulus lead to improved retention (e.g., R. A. Bjork & Allen, 1970; Cuddy & Jacoby, 1982). On the other hand, stimulus repetition impedes the orienting of attention; attention tends to be captured by new rather than old perceptual objects (Yantis & Jonides, 1984), and it shifts preferentially to locations and objects that have not recently been attended (Posner & Cohen, 1984).

The tension between these two well-documented influences of stimulus repetition rests in that they appear not to fit with a third well-documented principle: attention is fundamentally important to memory encoding (e.g., Craik, Govoni, Naveh-Benjamin, & Anderson, 1996). If stimulus repetition impedes attention, and if attention is fundamental to memory encoding, then it seems that stimulus repetition must hurt memory encoding. Yet this prediction runs counter to intuition—there is a general sense that remembering typically benefits from multiple opportunities to engage in memory encoding. The present study examines the relation between immediate stimulus repetition (that is, repetition over a very short temporal interval) and memory performance. To our knowledge, no study to date has demonstrated that immediate stimulus repetition can hurt memory performance. In the present study, we describe several experiments in which this result does indeed occur—superior memory performance for a word presented once is better than for a word presented twice in rapid succession.

This result was discovered as part of a research program that examined the link between cognitive control and recognition memory. Our first study in this line of research tested the influence of selective attention at the time of encoding on recognition memory (Rosner, D'Angelo, MacLellan, & Milliken, 2015), while a subsequent line of research examined the influence of perceptual degradation on recognition memory (Rosner, Davis, & Milliken, 2015). In these studies, we found that items that were difficult to process at study (i.e., incongruent rather than congruent selective attention items, or blurry rather than clear items) were recognized more accurately at test. These results led us to examine whether a related result might occur with a manipulation of stimulus repetition at the time of encoding, and we report here that indeed it did. Although not originally motivated by this idea, we came to appreciate that the results of these studies are a good fit for the desirable difficulty principle introduced long ago by R. A. Bjork (1994).

The Desirable Difficulty Principle

Desirable difficulties are defined as conditions that increase encoding difficulty, but in doing so improve learning (E. L. Bjork & Bjork, 2011; R. A. Bjork, 1994). For example, completing practice tests is typically more difficult than repeated studying of to-be-learned information, but leads to better performance on a final test (Roediger & Karpicke, 2006). Varying the conditions associated with encoding, and intermixing rather than blocking encoding conditions, also increase encoding difficulty but lead to better retention. Perhaps the best example of desirable difficulty is the spacing effect. In spacing effect studies, information is studied (or learned) in either a massed condition (in which study sessions occur in close succession) or a spaced condition (in which study sessions are separated by longer amounts of time). Learning typically occurs more slowly in the spaced than massed condition, but

performance on a final recall test is superior in the spaced condition. Moreover, the longer the interval between study sessions, the better the final performance (Baddeley & Longman, 1978; R. A. Bjork & Allen, 1970).

A nice example of the spacing effect was reported by Bahrick (1979). In a first study session, individuals were presented with English-Spanish word pairs. In subsequent study sessions, participants were presented with English words and asked to provide the Spanish translation. The study sessions continued until all words were correctly translated. Critically, study sessions were separated by an interval of 0, 1, or 30 days. Those in the 0-day interval condition completed all study sessions in one sitting. Performance in the study sessions was best for short inter-session intervals; that is, the shorter the interval, the better individuals were at recalling the Spanish translation. However, in a final retention test that was administered months after the study sessions, individuals in the spaced conditions (1 or 30 days) performed better than those in the massed condition. Moreover, recall was better in the 30 day than the 1 day condition. Even more interesting, a follow up study conducted 8 years later revealed that individuals in the spaced conditions performed better on a test of the learned words than those in the massed condition (Bahrick & Phelps, 1987).

The spacing effect can also be observed with short-term spacing. That is, within a single session, words that are shown in massed presentations (i.e., two successive presentations) are not as well remembered in a following memory test as those in spaced presentations (i.e., with other items separating the two presentations). Again, greater spacing between items at the time of encoding tends to produce larger memory benefits for repeated items (Braun & Rubin, 1998; Cuddy & Jacoby, 1982; Hintzman, 1974; Jacoby, 1978; Kahana & Howard, 2005; Underwood, 1969).

Perceptual Desirable Difficulties

Desirable difficulties are also evident in studies that manipulate perceptual characteristics to alter the ease of identification. For example, words presented in unfamiliar fonts are identified more slowly at encoding but remembered better than words presented in familiar fonts in both laboratory and classroom settings (Diemand-Yauman, Oppenheimer, & Vaughan, 2011). The perceptual interference effect may also constitute an example of a perceptually-based desirable difficulty (Hirshman & Mulligan, 1991; Hirshman, Trembath, & Mulligan, 1994; Mulligan, 1999; Nairne, 1988). In studies of this effect, words are presented briefly at study either with or without a following pattern mask. Of course, masked words are more difficult to identify than unmasked words at study, but are often better remembered during subsequent memory tests.

As noted above, the present study followed from two earlier studies in our lab, both of which produced effects that might be described as perceptual desirable difficulties. In one study, Rosner, Davis, et al. (2015) conducted a series of experiments in which words were presented in a clear or blurry font at the time of study. The study phase task was simply to name the words aloud. Naming times were slower for blurry than clear words. However, the blurry words were better recognized than clear words at the time of test (see also Rosner, Davis, et al., 2015; Yue, Castel, & Bjork, 2013 for limiting conditions of this effect). In another study, item congruency was manipulated using a selective attention method at the time of encoding (Rosner, D'Angelo, et al., 2015). In an incidental study phase, a red and a green word were interleaved and presented to participants, with the task being to read the red word aloud. The two words were either the same (congruent) or different (incongruent). Naming times were about 100 ms slower for incongruent than congruent items, but incongruent items were recognized more accurately than

congruent items on a surprise recognition memory test (see Krebs, Boehler, De Belder, & Egner, 2015 for a similar result in a gender identification task).

The Present Study

The goal of the present study was to examine whether perceptual desirable difficulty effects might be produced by manipulating immediate stimulus repetition at the time of study. The method used by Rosner, D'Angelo, et al. (2015) to study congruency effects on recognition required only a slight adaptation to study this issue. In that study, a red word and a green word were presented simultaneously, and participants were required to name just the red word. In the present study, we modified this procedure simply by offsetting the red word and green word in time; that is, a green word prime was followed shortly after by a red word target, with the task again being to name the red word target. Based on the results observed by Rosner, D'Angelo, et al. (2015), we predicted better memory performance for not-repeated items than for repeated items.

The prediction that stimulus repetition might hurt memory performance is somewhat counter-intuitive; one might expect repeated words to be better remembered than not-repeated words simply by virtue of being seen more often. On the other hand, the idea that stimulus repetition might hurt memory performance is in line with the perceptual desirable difficulties observed in our prior studies, as well as the observation that the orienting of attention is impeded when stimuli are repeated (Klein, 2000; Posner & Cohen, 1984; Spadaro, He, & Milliken, 2012; Yantis & Jonides, 1984). Moreover, immediate stimulus repetition can be thought of as an extreme instance of massed study. As seen in the spacing effect literature, massed presentation of items impedes learning, and it seems conceivable that the mechanism that underlies poor

memory for massed presentation might also contribute to relatively poor memory for immediate repetitions at study.

Experiment 1

The purpose of Experiment 1 was to examine the effect of stimulus repetition on later recognition using an adaptation of the procedure used by Rosner, D'Angelo, et al. (2015). Rather than presenting red and green interleaved words simultaneously, a single green word prime was followed by a single red word target in the study phase. The study phase task was simply to read the red word aloud. At the time of test, the target words from the study phase were intermixed with new words and participants were required to make old/new recognition judgments. Naming times in the study phase were expected to be faster for repeated than not-repeated items. The key issue here is whether recognition would be better for the not-repeated than repeated items as predicted above.

An additional purpose of Experiment 1 was to replicate the aforementioned effect of congruency on recognition memory. As such, Experiment 1 included a second group that completed a direct replication of the selective attention method of Rosner, D'Angelo, et al. (2015). Therefore, participants were assigned to one of two groups: the "congruency group" (the replication of Rosner, D'Angelo, et al., 2015) or the "repetition group". The results from the congruency group replicated the pattern observed in our prior study; recognition was better for incongruent than for congruent items. However, as the results from this group were not directly relevant to the present study of repetition effects on recognition, they are not presented in detail here. The interested reader will find details of the method and results from the congruency group in the supplementary materials section included with this manuscript.

Method

Participants. Twenty-four participants (18 female, mean age = 18, SD = 0.99) were recruited from the McMaster University student pool in exchange for course credit. All participants spoke English fluently and had normal or corrected-to-normal vision. Written consent was obtained from all participants prior to conducting this and all subsequent experiments.

Apparatus. The experimental procedure was run using PsychoPy (Peirce, 2007, 2009) on a Dell computer. Stimuli were presented on a 24 inch BENQ LED monitor.

Stimuli. All stimuli were red and green words presented on a black background, and were presented in Lucida sans console font at the centre of the screen. The words were five-letter, high frequency nouns (Thorndike & Lorge, 1944), and were presented with a space between each letter. Each word subtended 5.95 degrees of visual angle horizontally, and 0.75 degrees vertically. The exact positioning was based on the interleaved stimuli used for the congruency group (see supplementary materials for details), so that the words were slightly offset from one another both vertically and horizontally. This offset was subtle and unlikely apparent to participants, as the red and green words were never on screen at the same time. Examples of the stimuli are presented in Figure 1.

Figure 1: Examples of study phase items for Experiment 1. The left side depicts an example of a repeated item; the right side depicts an example of a not-repeated item.

Procedure. The experiment took place in a well-lit room with participants tested individually. Participants sat 50 cm in front of the monitor, with a standing microphone placed in front of them. This microphone recorded participants' response times for each trial during the study phase from the time of trial onset to the time of voice onset. In the study phase, participants were told that they would see a green word followed by a red word on each trial, and they were to say the red word aloud as quickly and accurately as possible. They were not informed of a later recognition memory test. Each trial began with the presentation of a white fixation cross in the centre of the screen for 2000 ms, followed by a green prime word for 500 ms, a 250 ms blank inter-stimulus interval (ISI), and a red target word for 1000 ms. For half of the trials, the green prime and red target had the same identity (repeated trials). For the other half of the trials, the green prime and red target had different identities (not-repeated trials). Following each naming response, the experimenter coded participants' responses as correct, incorrect, or a spoil by pressing "1", "2", or "3" on the keyboard, respectively. Responses were classified as incorrect if participants said the wrong word, said the wrong word and then corrected their response, or failed to provide a response. Responses were classified as a spoil if participants made a spurious response (e.g., stuttering, throat clearing) that was thought to trigger the microphone early.

Following the study phase, participants completed a 10 minute distractor math task to serve as a filled retention interval, after which they were given instructions for the surprise recognition memory test. Participants were told that they would see a red word on every trial, and they were to indicate whether or not they remembered reading the word during the previous study phase. If they remembered the word, they were to respond "old" by pressing the A key on the keyboard; otherwise, they were to respond "new" by pressing the L key.

The recognition memory test also included a remember/know distinction for items given an “old” response (Rajaram, 1993). However, the labels “Type A” and “Type B” were used in lieu of “remember” and “know”, respectively, as doing so reduces the overall level of false alarms (McCabe & Geraci, 2009). Participants were told that if an item was classified as “old”, they would then be asked to specify if the item provoked a Type A memory (a feeling of remembering) or a Type B memory (a feeling of knowing). After receiving instructions, participants were asked to describe the difference between Type A and Type B memories to the experimenter in their own words, in order to ensure they understood the distinction.

Every trial for the test phase began with a white central fixation cross for 2000 ms, followed by a red word and the words “OLD” and “NEW” on the bottom left and right of the screen, respectively, to serve as reminders for which key corresponded to which response; these stimuli stayed on screen until response. When participants made a “new” response, the next trial began immediately after. When participants made an “old” response, the words “OLD” and “NEW” were replaced by “TYPE A” and “TYPE B”, once again to serve as reminders of the remember/know distinction that was to be made. These stimuli stayed on screen until response, at which point the next trial was initiated.

Design. The stimuli were constructed using six lists of 60 words (see Appendix A). Three of the word lists were assigned to the “old” stimulus set, and the other three were assigned to the “new” stimulus set. These roles were counterbalanced across participants. Within the old stimulus set, one list was used to construct 60 repeated items, with each item in the list used as both a prime and a target. The other two lists were used to construct the not-repeated items, one list for primes and the other for targets. The assignment of lists to these three roles for old items was counterbalanced across participants. Within the new stimulus set, the three lists were

randomly assigned across participants to serve as repeated items, as not-repeated primes, or as not-repeated targets. It should be noted that, because only red target words were presented at test, the word list assigned to the “new not-repeated prime” role for each participant was coded as such, but never actually seen during the experiment. The slight horizontal and vertical offset of prime word relative to target word was counterbalanced across items. There were 120 trials in the study phase (60 repeated and 60 not-repeated items) and 240 trials in the test phase (120 old items and 120 new items). All targets from the study phase were presented during the test phase. The order of presentation of items was randomized in both the study and test phases, with repeated and not-repeated items intermixed during the study phase, and old repeated, old not-repeated, and new items intermixed during the test phase.

Results

Correct naming times in the study phase and recognition sensitivity in the test phase were the key dependent variables here and in all subsequent analyses in this article.

Study phase. Correct response times (RTs) were first submitted to an outlier analysis (Van Selst & Jolicoeur, 1994) that eliminated 2.44% of observations from subsequent analyses. Mean RTs were computed from the remaining observations. These mean RTs and corresponding error rates were submitted to two-tailed paired samples t-tests. Naming times (see Table 1) were faster for repeated (577 ms) than for not-repeated (629 ms) items, $t(23) = 6.45$, $p < .001$, $d = 1.87$, and there was no difference in error rates for repeated (.001) and not-repeated (.002) items, $p > .10$.

Table 1

Mean response times (ms) and error rates for the study phase

Experiment	Repeated	Not-repeated	RT Difference (Rep – Not-rep)
1 – Repetition	577 (.001)	629 (.002)	-52***
2	609 (.008)	638 (.011)	-29***
3			
Lag-0	569 (.002)	594 (.006)	-25***
Lag-1	616 (.006)	640 (.008)	-24***
4			
Lag-0	420 (.001)	452 (.008)	-32**
Lag-1	464 (.001)	477 (.006)	-13

Note 1: Table displays response times with error rates in parentheses.

Note 2: Asterisks next to the RT difference score indicate a significant difference in RTs between the repeated and not-repeated items.

(* $p < .05$; ** $p < .01$; *** $p < .001$)

Test phase. For this and all following test phase analyses, items responded to incorrectly during the study phase were excluded from the test phase analysis. As a single red word was shown at test, a false alarm rate could not be computed separately for repeated and not-repeated items. As such, hit rates were used as a measure of sensitivity when comparing repeated and not-repeated items. The mean proportions of “old” responses are displayed in Figure 2.

Figure 2: Mean proportions of “old” responses for Experiments 1 and 2. Error bars here and on all other graphs represent within-subject error corrected for between subjects variability (Morey, 2008).

A preliminary analysis was conducted that compared hits to false alarm rates, collapsed across repeated and not-repeated old items. This analysis was conducted simply to confirm that participants recognized items at above chance levels. A two-tailed paired sample t-test confirmed that participants were able to distinguish between old (.631) and new items (.178), $t(23) = 12.3$, $p < .001$, $d = 3.56$. More important, a comparison of the hit rates revealed superior recognition of not-repeated (.667) than repeated items (.596), $t(23) = 4.62$, $p < .001$, $d = 1.33$.

The proportions of “remember” (R) and “know” (K) responses from the test phase were used to estimate the separate contributions of recollection and familiarity to recognition memory performance (Yonelinas, 2002; Yonelinas & Jacoby, 1995). The contribution of recollection is based on R, while the contribution of familiarity is based on K given an R response was not made (1-R). These estimates were obtained separately for hit rates for each item type.

The estimates of recollection and familiarity were analyzed separately using two-tailed paired sample t-tests. The analysis of recollection estimates revealed no difference between repeated (.310) and not-repeated items (.330), $t < 1$. However, the comparison of familiarity estimates revealed higher familiarity for not-repeated (.512) than repeated items (.426), $t(23) = 4.39$, $p < .001$, $d = 1.27$.

Discussion

The results of Experiment 1 were counter to intuition: recognition memory was more sensitive for not-repeated than repeated items, in this case driven by differences in familiarity rather than recollection (but see Collins, Rosner, & Milliken, 2017). This result is noteworthy in that it demonstrates better memory performance for an item presented once than for an item presented twice in succession at study. To our knowledge, no prior published study has reported such a result.

Experiment 2

The results of Experiment 1 are consistent with the desirable difficulty principle: the more difficult to name words at study (i.e., the not-repeated items) were recognized with greater sensitivity than the easier to name words (i.e., the repeated items). As noted in the Introduction, this effect was discovered in the context of a research program focused on the link between adaptations in cognitive control and recognition memory. In particular, we were interested in the possibility that processing difficulty (or disfluency) might lead to an up-regulation of attention, which would in turn improve memory encoding and recognition memory performance. The results of Experiment 1 are consistent with this idea, but of course other theoretical accounts are also tenable.

The purpose of Experiment 2 was to address an alternative account of this result. In particular, at the time of test, participants were instructed to identify words as “old” if they remembered reading them at the time of study. In the repetition group, a participant may have experienced the word “BRICK” as a repeated item at study, meaning that this word would have been presented first in green and then again in red. At test, the word “BRICK” would then appear in red, at which time the participant might remember reading it as a red target, seeing it as a green prime, or both. If the participant was of the mind that words presented in green at study disqualify an item as also having been presented in red, then remembering a green prime would have led participants to classify “BRICK” as a new item. If this were the case, then performance would be systematically negatively affected for repeated relative to not-repeated trials, but not because of the influence of repetition on memory encoding. Instead, this result would be related to an idiosyncratic source memory judgment occurring at test.

Experiment 2 was conducted to rule out this particular source memory account. In Experiment 2, participants again completed an incidental study phase that involved naming the second of two words presented in sequence. However, rather than naming a red target word that followed a green prime word during the study phase, all study phase words (and all test phase words) were presented in white. As such, colour could no longer be used as a basis for differentiating primes and targets at the time of test. If source memory for words of different colour led to the results of Experiment 1, then the memory benefit for not-repeated words should not occur here. On the other hand, if processing difficulty differences related to stimulus repetition led to the results of Experiment 1, then the memory benefit for not-repeated words may be observed here as well.

Method

Participants. Forty-eight participants (37 female, mean age = 19, SD = 1.33) were recruited from the McMaster University student pool in exchange for course credit or \$10. All participants spoke English fluently and had normal or corrected-to-normal vision.

Apparatus, stimuli, procedure, and design. The apparatus, stimuli, procedure, and design were identical to those for Experiment 1 with the following exceptions. All words were presented in white, all words were presented at the centre of the screen (rather than offset slightly as in Experiment 1), and the spaces between the letters in each word that allowed interleaving in the congruency group of in Experiment 1 (see supplementary materials) were removed. During the study phase, participants were instructed to read the second of the two white words.

Results

Study phase. Correct RTs were submitted to the same outlier analysis used in Experiment 1, which removed 2.96% of RTs from further analysis (Van Selst & Jolicoeur,

1994). Mean RTs were computed from the remaining observations, and these mean RTs and error rates were analysed using two-tailed paired sample t-tests (Table 1). RTs were faster for repeated (609 ms) than for not-repeated words (638 ms), $t(47) = 3.72, p < .001, d = 0.759$. No significant difference was observed for error rates, $p > .10$, but the error rates for the not-repeated words (.011) were numerically higher than for repeated words (.008), indicating no speed accuracy trade-off.

Test phase. Two-tailed paired sample t-tests were used to analyze data from the test phase. The overall hit rate, collapsed across the two repetition conditions, was first compared to the false alarm rate. This analysis revealed a higher proportion of “old” responses to old items (.638) than to new items (.214), $t(47) = 18.9, p < .001, d = 3.85$, indicating simply that participants were able to distinguish between old and new items. More important, an analysis of the hit rates revealed better recognition memory performance for not-repeated (.659) than repeated items (.618), $t(47) = 3.49, p = .001, d = 0.712$ (see Figure 2).

Estimates of recollection and familiarity were again compared for repeated and not-repeated items using two-tailed paired sample t-tests. Reminiscent of the results of Experiment 1, familiarity estimates were higher for not-repeated (.481) than repeated items (.434), $t(47) = 3.78, p < .001, d = 0.771$. Again, there was no difference in recollection between repeated (.332) and not-repeated (.348) items, $t(47) = 1.18, p = .243, d = 0.241$.

Discussion

The results of Experiment 2 indicate that recognition sensitivity was higher for not-repeated than repeated items, as observed in Experiment 1. This result is not consistent with a source memory account by which old repeated items are incorrectly classified as “new” simply because they are remembered as being green rather than red at the time of study. Rather, it seems

that the increased fluency experienced when responding to repeated targets may result in poor encoding of those items. As a result, these items are not as well-remembered as the not-repeated targets, as reflected by performance on a recognition memory task. Of course, it remains possible that participants can recall a word as having been either a prime or a target at study when making recognition decisions at the time of test. If so, then these source judgments could still support a source memory account of the superior recognition of not-repeated items. As such, we cannot rule out all possible source memory accounts of the present findings, but can rule out what we think of as an idiosyncratic source memory account related to the colours in which items are presented at study.

Experiment 3

The results of Experiments 1 and 2 demonstrate superior recognition for words presented once at study (not-repeated items) than words presented twice at study (repeated items). This result is surprising in that one might assume multiple opportunities to encode an item would benefit rather than hurt retention. However, in the current procedure, repeated words may not have been given the opportunity to be encoded twice. That is, although there were two physical presentations of the same word on repeated study trials, the short time interval between repetitions may have led the two repetitions to be encoded as a single event (Hommel, 1998, 2004; Kahneman, Treisman, & Gibbs, 1992).

The goal of Experiment 3 was to examine whether the memory benefit for not-repeated words observed in Experiments 1 and 2 is related, at least in part, to the repeated study items being perceived as a single event. To address this issue, participants were separated into two groups: a lag-0 group and a lag-1 group. All participants were presented with three words (two primes and a target) in succession on every study trial (see Figure 3). For not-repeated items,

these three words were all different. For repeated items, two of the three words had the same identity. Repeated items for the lag-0 group contained an identical word in serial positions two and three in each three-word study trial. Given that repetition in this condition was not spaced (i.e., there were no items intervening between the repeated items), the prediction was that performance should be similar to that in Experiments 1 and 2, with better recognition for not-repeated than repeated items. In contrast, repeated items for the lag-1 group contained the same word in positions one and three in each three-word study trial. A different word appeared in serial position two, which in effect spaced the repetitions by a single item. If the results of Experiments 1 and 2 were a by-product of repeated words being encoded as a single event (e.g., Hommel, 2004), then the results from the lag-1 group should differ from those of Experiments 1 and 2. Indeed, if the intervening prime in the lag-1 condition fosters two separate encodings of the same word, then memory performance might well be better for repeated than for not-repeated trials.

Figure 3: Examples of the trial sequence in Experiments 3 and 4. The leftmost sequence is an example of a repeated item for the lag-0 group; the middle sequence is an example of a repeated item for the lag-1 group. The rightmost sequence is an example of a not-repeated item, which was the same across groups.

Method

Participants. Forty-eight participants (29 female, mean age = 20, SD = 1.84) were recruited from the McMaster University student pool in exchange for course credit or \$10, or by

undergraduate students as part of a third year Memory and Cognition Laboratory course. These participants were randomly assigned to either the lag-0 group or the lag-1 group, with 24 participants in each group. All participants spoke English fluently and had normal or corrected-to-normal vision.

Apparatus and stimuli. The apparatus and stimuli were identical to Experiment 1 with the following exceptions. All words were presented at the centre of the screen and the spaces between the letters in each word were removed. Additionally, 4-6 letter high frequency nouns were used to construct the word lists, and can be viewed in Appendix B (Thorndike & Lorge, 1944).

Procedure. The procedure was identical to Experiment 1 with the following exceptions. Every trial during the study phase consisted of the presentation of three words: two green primes, and one red target. Each prime was presented for 500 ms, the target was presented for 1000 ms, and there was an ISI of 250 ms between each word. The participants were instructed to read the red target word only. For the lag-1 group, on repeated trials the first of the two prime words and the target word were the same, while the second prime word differed from the other two words; that is, these repeated trials involved repetition of a word with an intervening different word. On the other hand, for the lag-0 group, the second prime word and the target word were the same, while the first word differed from the other two words. In this case, repeated trials involved repetition of a word with no intervening different word (as in Experiments 1 and 2). Not-repeated trials consisted of three different words, and were identical across the lag-0 and lag-1 groups (see Figure 3). Finally, the test phase required an old/new judgment as in prior experiments, but did not include a remember/know judgement.

Design. The design of Experiment 3 was identical to Experiment 1, with the exception that eight word lists of 60 words were used to construct the stimuli. An additional two word lists were added to create a filler prime word list. The assignment of each list to the repeated word, not-repeated target, not-repeated prime, filler prime, and new roles was counterbalanced across participants.

Results

Study phase. Correct RTs were submitted to an outlier analysis, which excluded 2.87% of observations from further analyses (Van Selst & Jolicoeur, 1994). Mean RTs were computed from the remaining observations, and these mean RTs and corresponding error rates were submitted to a 2 x 2 mixed-factor ANOVA, with group (lag-0/lag-1) as a between subjects factor, and repetition (repeated/not-repeated) as a within subject factor (see Table 1). The analysis of RTs revealed a significant main effect of repetition, $F(1,46) = 30.9, p < .001, \eta_p^2 = .402$, with faster RTs for repeated (592 ms) than not-repeated words (617 ms). Neither the main effect of group nor the interaction between group and repetition were significant, $p > .10$, indicating no difference in repetition effect between groups. The analysis of error rates produced similar results, revealing a repetition effect that approached significance, $F(1,46) = 3.75, p = .059, \eta_p^2 = .075$, with higher error rates for not-repeated (.007) than repeated words (.004). Once again, all other effects were not significant, $p > .10$.

Test phase. To ensure that participants were able to distinguish between old and new items, the mean proportions of “old” responses, collapsed across the two repetition conditions, were submitted to a 2 x 2 mixed-factor ANOVA, with group (lag-0/lag-1) as a between subjects factor and item type (old/new) as a within subject factor. A main effect of item type was observed, $F(1,46) = 229, p < .001, \eta_p^2 = .833$, with a higher proportion of “old” responses for old

(.541) than new items (.208). No other effects in this analysis were significant, all p 's > .10.

Memory sensitivity was analyzed by submitting hit rates for repeated and not-repeated items to a 2 x 2 mixed-factor ANOVA, with group (lag-0/lag-1) once again as a between subjects factor, and repetition (repeated/not-repeated) as a within subject factor (see Figure 4). This analysis revealed a significant main effect of repetition, $F(1,46) = 13.3$, $p < .001$, $\eta_p^2 = .224$, with a higher hit rate for not-repeated (.568) than repeated items (.514). Importantly, neither the main effect of group, nor the interaction between group and repetition were significant, all p 's > .10.

Figure 4: Mean proportions of “old” responses for Experiments 3 and 4.

Although there was no significant interaction between group and repetition, our *a priori* hypothesis that there could well be a difference between the groups led us to examine the effect of repetition separately for the two groups. Hit rates for repeated and not-repeated items were submitted to two-tailed paired sample t-tests for the lag-0 and lag-1 groups separately. For the lag-0 group, a significant effect was found $t(23) = 2.79$, $p = .010$, $d = 0.807$, with a higher hit rate for not-repeated (.547) than repeated items (.485). For the lag-1 group the same result was

observed; the hit rate was higher for not-repeated (.588) than for repeated items (.544), $t(23) = 2.34$, $p = .028$, $d = 0.676$.

Discussion

The results of this experiment were very clear. Recognition sensitivity was higher for not-repeated than for repeated items, and this effect on recognition sensitivity did not depend significantly on whether there was an intervening different word between the two repeated words.

Experiment 4

The results of Experiment 3 demonstrated that the superior recognition for not-repeated over repeated items observed with the present procedure is robust to the presentation of an intervening different item between a repeated prime and target. This result prompted additional thought about factors that were unique to our method that might produce better memory for an item presented once than an item presented twice. We noted that studies of the spacing effect typically involve attentive encoding of the same event twice, either un-spaced or spaced (e.g., Baddeley & Longman, 1978; R. A. Bjork & Allen, 1970; Kahana & Howard, 2005), whereas our procedure required participants to attentively encode only the second of two repeated events. To address this issue in Experiment 4, participants again saw two green prime words and a red target word, and were placed either in the lag-0 or lag-1 group. Importantly however, participants were asked to read aloud all items in the study phase. If the results of previous experiments were in part due to the primes being ignored rather than attended to, then Experiment 4 should produce either a null effect or the opposite result, namely, better memory for repeated than not-repeated words.

Method

Participants. Forty-eight participants (39 female, mean age = 20, SD = 2.54) were recruited from the McMaster University student pool in exchange for course credit or \$10. These participants were randomly assigned to the lag-0 or lag-1 group, with 24 participants in each group. All participants spoke English fluently and had normal or corrected-to-normal vision.

Apparatus, stimuli, procedure, and design. The apparatus, stimuli, procedure, and design were identical to Experiment 3 with the following exceptions. Participants were instructed to read all three words on every trial as they appeared, though RTs were only recorded for the final target words. Additionally, the ISI between words was increased from 250 ms to 500 ms to ensure that participants had enough time to read each word before the next one appeared.

Results

Study phase. Correct RTs were submitted to the same outlier analysis as in previous experiments which eliminated 2.49% of observations from further analyses (Van Selst & Jolicoeur, 1994). Mean RTs were computed from the remaining observations and these mean RTs and corresponding error rates were submitted to the same 2 x 2 mixed-factor ANOVA as in Experiment 3, with group (lag-0/lag-1) as a between subjects factor and repetition (repeated/not-repeated) as a within subject factor (see Table 1). The analysis of RTs revealed a significant main effect of repetition, $F(1,46) = 8.94, p = .005, \eta_p^2 = .163$, with faster RTs for repeated (442 ms) than not-repeated words (464 ms). A significant effect of repetition was also observed in the analysis of error rates, $F(1,46) = 10.3, p = .002, \eta_p^2 = .183$, with higher error rates for not-repeated (.007) than repeated words (.001). All other effects in both analyses were not significant, all p 's > .10.

Test phase. As in Experiment 3, the mean proportions of “old” responses to old items collapsed across the two repetition conditions, and to new items, were submitted to a 2 x 2

mixed-factor ANOVA, with group (lag-0/lag-1) as a between subjects factor and item type (old/new) as a within subject factor. The analysis revealed a main effect of item type, $F(1,46) = 127, p < .001, \eta_p^2 = .735$, with a higher proportion of “old” responses to old (.492) than new items (.205); no other effects were significant, all p 's $> .10$. Next, an analysis of hit rates was conducted using a 2 x 2 mixed-factor ANOVA, with group (lag-0/lag-1) as a between subjects factor and repetition (repeated/not-repeated) as a within subject factor (see Figure 4). This analysis revealed a main effect of repetition, $F(1,46) = 5.45, p = .024, \eta_p^2 = .106$, with a lower hit rate for not-repeated (.476) than repeated items (.508). Note that this result is opposite to those reported in all of the other experiments reported here. No other effects were significant in the analysis, all p 's $> .10$.

Although the interaction between group and repetition was not significant, the effect of repetition was analyzed separately for the two lag groups for the sake of consistency with the analyses reported for Experiment 3. For both the lag-0 and lag-1 groups, hit rates for repeated and not-repeated items were analyzed using two-tailed paired sample t -tests. For the lag-1 group, the effect of repetition approached significance, $t(23) = 1.96, p = .062, d = 0.567$, with a higher hit rate for repeated (.531) than not-repeated items (.491). For the lag-0 group, the hit rate difference between repeated (.486) and not-repeated (.462) items was not significant, $t(23) = 1.31, p = .204, d = 0.378$.

Discussion

The results of Experiment 4 were opposite to all others reported in the current study: recognition memory sensitivity was greater for repeated than not-repeated items. This result points to the idea that superior recognition for not-repeated over repeated items may hinge on inattention to primes (see also Collins et al., 2017). Also of note is that the benefit of repetition in

the present experiment was not a particularly strong one; hit rates were only about 3% higher for repeated than not-repeated words. Together with the results of previous experiments, this result is consistent with an opponent process view; that is, the results in this experiment may reflect the joint benefit of repetition associated with attending to primes and a cost of repetition that is unrelated to attending to primes.

General Discussion

The goal of the current study was to examine the effect of immediate repetition on recognition memory. In Experiment 1, a green word prime followed by a named red word target produced poorer recognition for repeated than not-repeated words. To our knowledge, this specific finding has not previously been reported, yet it is a result we observed reliably across several experiments. In Experiment 2, the same result occurred with identically colored white prime and target words, demonstrating that the original effect was not an artifact of source memory for word colour at study. Another possible explanation for these counter-intuitive findings was that repeated words were not given a proper chance to be encoded as two separate events. This account was ruled out in Experiment 3, in which better memory was found for not-repeated than repeated words even when there was an intervening different word between the two repeated words. Finally, in Experiment 4, when both the prime and target words were named aloud, better memory was found for repeated than not-repeated items, demonstrating that immediate repetition effects on recognition depend on how primes are encoded. An important objective now and going forward will be to consider the broader implications of these findings for our understanding of the influence of stimulus repetition on perception, learning, and memory.

Our preferred view of the key new result reported here makes reference to the role of attentional orienting in event encoding; we orient preferentially to new events rather than old events (Klein, 2000; Posner & Cohen, 1984; Yantis & Jonides, 1984)¹. Preferential shifts of attention to novel events may lead to better event encoding of target words that mismatch the preceding primes than for target stimuli that match preceding primes. This core idea offers a possible foundation for explaining the results reported here, but of course there are other possibilities as well. In the remainder of the article we discuss alternative interpretations of the results, and point to future research paths that appear promising.

The Role of Prime Encoding

One result worth discussing is that immediate repetition effects on recognition memory depended on how primes in the study phase were encoded. There are at least two distinct ways of thinking about this result. By one view, the dependence of repetition effects on prime encoding focuses on whether the prime encoding demands match or mismatch those of the following target, whereas the other view focuses on the extent to which attention is actively allocated to the primes. These two ideas are unpacked in more detail below.

A transfer appropriate processing account. One account of the dependence of immediate repetition effects on prime encoding focuses on the transfer appropriate processing principle (Morris, Bransford, & Franks, 1977). When applied to prime-target procedures like that used here (Neill & Mathis, 1998; Wood & Milliken, 1998), this principle states that transfer of processing from prime to target depends on the specific correspondence between how prime and target are encoded. Thus, when participants were asked to ignore a prime and then name a following target, the processing requirements from prime to target mismatched. As a consequence, on repeated prime-target study trials, the match in word identity together with the

mismatch in processing requirement (i.e., ignore and then name) would be expected to produce inefficient transfer of processing from prime to target (see also Hommel, 1998, 2004). It follows that this “transfer inappropriate processing” on repeated study phase trials may have disrupted memory encoding for targets and produced poor recognition at test. In line with this view, when participants named both the prime and target in Experiment 4, transfer from prime to target would instead be “appropriate”, which accounts for why recognition sensitivity was higher for repeated than not-repeated trials.

A challenge for this account of the present results is that naming times in the study phase were faster for repeated than for not-repeated trials regardless of how the prime was encoded. For the transfer appropriate processing account to hold, one would have to argue that test phase recognition is subject to transfer appropriate processing during the study phase, while study phase naming times are driven by some other process. Another notable implication of the transfer appropriate processing account is that poor recognition is attributed to processing difficulties at the time of target encoding, which runs counter to the desirable difficulty principle. Recall that the desirable difficulty principle instead attributes good rather than poor memory performance to processing difficulties at the time of target encoding.

An opponent process account. An alternative account of the prime encoding effects observed in the present study focuses on the degree to which participants attend to the identity or meaning of the primes. When participants attend to primes, memory for the prime itself might support recognition of repeated items as old at the time of test. For example, naming the prime word CLOUD prior to naming an identical target word CLOUD could result in participants making an “old” response to CLOUD at test either because they remember the target episode or because they remember the prime episode. From this perspective, attending to primes introduces

an additional source of evidence that favours a correct “old” response at test for repeated items from the study phase, and helps explain the results observed in Experiment 4 of this article. In contrast, ignoring primes makes it more likely that “old” responses for repeated items are driven only by memory of the target episode (i.e., ignoring a word at study is an ineffective way to remember it at test). If we also assume that memory for target episodes benefits from more robust attention orienting to not-repeated than repeated targets during the study phase, then this would account for the recognition results observed in Experiments 1-3 of this article.

Furthermore, the opponent process account is consistent with the desirable difficulty principle (R. A. Bjork, 1994), which may help to explain the results of Experiments 1-3, in which recognition sensitivity was higher for not-repeated than repeated trials. According to the desirable difficulty principle, greater encoding difficulty in the study phase resulted in better recognition memory in the test phase, an effect consistent with other reported perceptual desirable difficulties (e.g., Diemand-Yauman et al., 2011; Hirshman & Mulligan, 1991; Nairne, 1988; Rosner, Davis, et al., 2015). On the other hand, when primes were actively attended to (i.e., by reading them, as in Experiment 4), the results were not in line with the desirable difficulty principle. These results are easily accommodated by the opponent process account, which suggests that the desirable difficulty principle was still operative, but that recognition performance was also controlled by a second process related to attention to the primes that pushed performance in the opposite direction.

Evaluating the role of prime encoding. Collins et al. (2017) recently conducted a series of experiments to address prime encoding issues with a procedure similar to the one used in the present study. In some conditions, participants viewed the prime passively (either by being told explicitly to ignore the prime, or by dividing attention during prime presentation); in others, the

prime was actively encoded (either by reading or semantically encoding the prime). In all conditions, participants were asked simply to read the red target words, which were then later seen in a recognition memory task. In the passive encoding conditions, not-repeated words were better remembered than repeated words, as in Experiments 1-3 reported here. In the active conditions, particularly so with semantic encoding, the opposite effect was found, with better memory for repeated than not-repeated words. Overall, together with the results reported here, it seems that the memory benefit for not-repeated items hinges on poor encoding of, and therefore poor subsequent memory for, the prime episode. This conclusion fits well with the opponent process account proposed here. Furthermore, Collins et al. reported results that were inconsistent with the transfer appropriate processing account, as substantially better memory for repeated than not-repeated items was observed when processing of the prime and target differed (i.e., semantically encode the prime and read the target).

There are a variety of additional ideas related to prime encoding that remain to be tested. For example, in the present study we contrasted performance in a repeated and not-repeated condition, and have proposed that performance may benefit both from attentional orienting to the encoding of not-repeated targets and from actively attending to repeated primes. This opponent process proposal may benefit from further tests that include a neutral condition, perhaps one in which participants name a single red word that follows a meaningless string of prime characters. This method may help to distinguish between benefits and costs of repetition on recognition performance, as well as how these benefits and costs vary as a function of changes in prime encoding.

Another issue that has yet to be examined is whether briefly presented and masked primes would produce a similar pattern to ignored primes presented for a longer duration, as in

the present study. The opponent process account rests on the idea that attention orients more robustly to novel objects than familiar objects, which improves memory encoding for not-repeated relative to repeated targets. If this preferential orienting to novelty is driven by a comparison of perceptual representations of the target and preceding prime, then we would predict that not-repeated items would be better recognized than repeated items even if the primes were presented too quickly to be consciously perceived. However, the effect observed in the current set of experiments may require higher-level representations of primes, which may not be accessible in a study in which primes are quickly presented and masked (Henson & Gagnepain, 2010). This is an issue well worth future study.

Issues of Spacing

In Experiments 3 and 4 of the current study, spacing between repetitions was manipulated in order to ensure that repeated items were experienced as two separate instances. It could be argued, however, that the results of Experiments 3 and 4 constitute a failure to find the well-known spacing effect, in which spaced repetitions are better remembered than massed repetitions (Kahana & Howard, 2005). According to the spacing effect principle (Baddeley & Longman, 1978; R. A. Bjork & Allen, 1970), at least in so far as a single intervening item constitutes an effective manipulation of spacing, the repeated words in the lag-1 group should have been better remembered than the repeated words in the lag-0 group. Yet, in both experiments, there was no effect of this spacing manipulation.

This lack of a spacing effect may seem troubling, although there are a few reasonable explanations for why these experiments did not show such an effect. First, most spacing effect studies (e.g., Cuddy & Jacoby, 1982; Hintzman, 1974; Jacoby, 1978; Kahana & Howard, 2005; Underwood, 1969) tend to look at larger intervals between repetitions (i.e., more than one

intervening item). As such, it may be that a spacing effect was not found here simply because the interval between repetitions was too short. Second, some studies have shown that even with intervening items between repetitions, engaging in the same task (e.g., reading) for those repetitions results in little or no memory benefit (Cuddy & Jacoby, 1982; Jacoby, 1978). Therefore, it is possible that even if there were larger intervals between repetitions in the current study, the memory benefit afforded by increased spacing may be minimal. A systematic study of this issue that compares immediate repetition effects as measured here, to repetition effects across larger spacing intervals, is certainly warranted.

It should also be noted that few spacing effect studies have compared memory for single presentations of words to massed repeated presentations of words, as was the case here². Those studies that have addressed this issue have provided mixed results. Some experiments have produced better memory for massed (i.e., repeated) than single (i.e., not-repeated) presentation items, whereas experiments in the same set of studies have produced equivalent memory performance for the two conditions (Braun & Rubin, 1998; Cuddy & Jacoby, 1982; Underwood, 1969). Additionally, these studies did not explicitly examine immediate repetition effects (e.g., repetition over an interval of less than a second), making it unclear how stimulus repetition effects in those studies compare to those in the present study. Although to this point we have been unable to set our result (superior memory for not-repeated over repeated items) precisely in the context of the broader literature on spacing effects, our result does point to an important gap in the literature that requires further study.

The Repetition Effect and the Word Frequency Effect

Recognition sensitivity is typically higher for low frequency words than for high frequency words (Gregg, 1976; see also Gillund & Shiffrin, 1984; Glanzer & Adams, 1985;

Higham, Perfect, & Bruno, 2009; Joordens & Hockley, 2000; Kinoshita, 1995; Kinsbourne & George, 1974). This well-studied regularity of recognition may be relevant to the results reported here. Although all of the items used in our study were high-frequency words, and therefore the repetition effects observed here are not procedurally equivalent to word frequency effects, it is worth discussing possible similarities in the underlying mechanisms that may produce the repetition and word frequency effects.

An interesting possibility is that study phase naming of repeated targets in our experiments is more efficient than for not-repeated targets because of the high accessibility of a compatible memory representation from the immediately preceding prime. Similarly, high frequency words may be named more efficiently than low frequency words because of more readily accessible memory representations for words that occur more frequently in natural language. In other words, the same fundamental constraint of memory search for an appropriate target representation could underlie both the repetition and word frequency effects. Expanding this idea a step further, when a memory representation is not immediately accessible (i.e., for low frequency or not-repeated targets) additional processing may be required that involves refining the target representation, so that a search of memory is successful despite the memory representation being of relatively low accessibility (see Hintzman, 1988; Jamieson, Holmes, & Mewhort, 2010). As such, processes related to refining the target representation may result in attention orienting that is more robust for not-repeated than for repeated targets. Future research that examines the immediate repetition effects reported here within this general framework is certainly needed.

Another interesting focus for future research is whether the immediate repetition effects observed here are specific to recognition or if they generalize to other memory tasks. Although

low frequency words are better recognized than high frequency words, the opposite is typically observed in free recall tests (Gregg, 1976; see McDaniel & Bugg, 2008 for a review). If the repetition effect reported here is related to the word frequency effect, then recall performance may be better for repeated than not-repeated words. This result would offer important converging evidence in favour of the view that repetition and word frequency effects have the same underlying cause.

Time-On-Task

One other account for the present findings is the possibility that the more time spent processing an item, the better it is remembered. In other words, better recognition memory performance for not-repeated than repeated items in the current study may simply be a direct result of longer processing times for not-repeated than repeated targets. That is, the more time spent processing an item directly results in that item being better remembered. It is important to note that this explanation is inconsistent with the results of Experiment 4, in which not-repeated targets were processed more slowly than repeated targets, and yet recognition sensitivity was greater for repeated than not-repeated items. Nevertheless, it is still possible that time-on-task may explain the results of Experiments 1-3, in which the not-repeated targets required more processing than repeated targets, and were also better remembered at test.

To address this concern, we compared RTs for remembered and forgotten items separately for repeated and not repeated targets. If time-on-task is responsible for the results of the present study, then RTs should be slower for remembered than forgotten items. One-tailed *t*-tests indicated that this was not the case for both repeated and not-repeated items, both *t*'s < 1. More critically, we also compared RTs for remembered repeated targets and forgotten not-repeated targets. Again, if time-on-task is a key issue in this study, then RTs should be slower for

remembered repeated targets than for forgotten not-repeated targets. Further analyses revealed that this was not the case, as RTs for remembered repeated targets (595 ms) were *faster* than for forgotten not-repeated targets (620 ms), $t(118) = 4.76, p < .001$. These analyses demonstrate that more time spent processing an item does not directly lead to that item being well-encoded.

Conclusions

The present study describes a novel finding in which an immediate repetition method at study revealed better recognition for not-repeated than repeated items at test. This result was observed across multiple experiments, and has been replicated in our laboratory numerous times subsequently (see also Collins et al., 2017). We propose that this effect points to a fundamental issue at the interface between attention and memory encoding that merits additional study: Is this effect related to the well-known spacing and word frequency effects in the memory literature (Baddeley & Longman, 1978; R. A. Bjork & Allen, 1970; Joordens & Hockley, 2000)?; Is this effect related to attention orienting phenomena that implicate more robust orienting to novel than familiar events (Posner & Cohen, 1984; Yantis & Jonides, 1984)? These issues converge on a central theme that perceptual encoding is adapted flexibly in response to how well-predicted external events are by memory representations of prior experiences (Henson & Gagnepain, 2010). Critically, our findings indicate that encoding may potentially be negatively impacted by repetition, and may be related to other literatures in which poor performance is observed in response to repetitions (Milliken, Joordens, Merikle, & Seiffert, 1998; Posner & Cohen, 1984; Spadaro & Milliken, 2013; Tipper, 1985; Yantis & Jonides, 1984).

Footnotes

¹Although the inhibition of return effect is most often measured with respect to shifts of attention in space, a similar mechanism may be responsible for slow responses to repetitions of non-spatial stimulus dimensions, such as colour (Klein, 2000; Law, Pratt, & Abrams, 1995; Spadaro et al., 2012). Thus, we view it as possible that inhibition of return mechanisms are operating here, where effects of repetition for stimulus identity rather than stimulus location are the focus. Furthermore, it should be noted that inhibition of return is observed with long ISIs, whereas the current experiment uses short ISIs (250 and 500 ms). However, it is possible that the mechanism that responds to novelty (leading to inhibition of return effects) is still operative with short ISIs. That is, even at short ISIs a response to novelty may still occur, though this response may not be observed in RTs at short ISIs due to an opposing mechanism producing facilitation for repetitions (Klein, 2000).

²Studies of the spacing effect compare memory performance for repetitions of study items spaced closely (massed) or spaced further apart, whereas the effect we report here compares memory for items presented just once to that for repetitions of items spaced closely together at study. As such, there is something fundamentally different between the spacing effect and the effect we report here. However, studies examining immediate serial recall for simple stimuli (such as numbers or letters) have compared memory for an item presented once with memory for repeated items. Specifically, spacing of repetitions in immediate serial recall makes memory worse rather than better, producing the opposite of the spacing effect. This finding is known as the Ranschburg Effect (Crowder & Melton, 1965; Jahnke, 1969b; Lee, 1976). In these studies, participants see a string of 8-10 items; control strings contain all different items, whereas

repetition strings contain one repeated item. Immediate serial recall for the repeated items is worse than for comparable control items when the repetitions are spaced but not when they are unspaced. Although this effect demonstrates a memory cost for repeated items, it appears to be different from the effect examined in the current study, as it is presumed to be due to processes at the time of recall such as output interference (Jahnke, 1969a) or guessing strategies (Greene, 1991) rather than to attention orienting to novel items and an up-regulation of attention in response to processing difficulty. (See also repetition blindness for a related effect; Kanwisher, 1987).

Appendix A

Word lists: Experiments 1 and 2

Word list 1: CURVE, MONEY, TOWER, WHEEL, TABLE, CHAIR, GRATE, GROUP, STEEP, STERN, DAILY, TOTAL, WATCH, PILOT, WATER, SHORT, NOVEL, MONTH, SHEER, CABLE, GUIDE, CATCH, BRIDE, CLEAN, TITLE, SPRAY, SOLID, MAJOR, CLIMB, THROW, COAST, OLIVE, RIVAL, TRUTH, IDEAL, GLOVE, STAMP, JEWEL, ADULT, PURSE, GUARD, SWIFT, WORST, CHARM, UNCLE, SIGHT, FLASH, STORY, JUICE, TRADE, PITCH, SAUCE, FANCY, SHOCK, STRIP, BLIND, BROOK, START, GLARE, OPERA

Word list 2: TOUGH, CLERK, PEACH, PHONE, KNOCK, OFFER, GLEAM, WOUND, SPEED, PUPIL, LIGHT, VALUE, EVENT, CREEK, RANCH, CRASH, TRACE, MOTOR, SHAPE, SMART, EXTRA, SHIRT, VOICE, ANGLE, STAKE, RADIO, MATCH, TODAY, BRICK, SLOPE, BREAD, SWEAR, PARTY, BREAK, CHILL, TRAIN, UPPER, WORLD, GLASS, MOVIE, PROOF, NOBLE, STRAW, SCORE, BASIS, CLASS, EMPTY, STATE, AGENT, MAGIC, FRONT, FROWN, CABIN, BIRTH, FLOOR, CIGAR, PIANO, CHOKE, SLIDE, COUNT

Word list 3: TWIST, FEVER, TRICK, DELAY, TOAST, SPOON, DREAM, CHEST, STUFF, CRAWL, LUNCH, INNER, TASTE, BENCH, NURSE, CHAIN, NERVE, RANGE, ISSUE, CLOUD, CHASE, HONEY, HORSE, PLANE, OWNER, LIMIT, PRESS, ROUND, PAINT, PRIZE, ASIDE, CANDY, TREAT, BLANK, SHAME, STOOP, MOUTH, FLAME, ANKLE, BATHE, LAUGH, MUSIC, SCALE, POUND, OCEAN, MIGHT, CLAIM, FAINT, YIELD, CHIEF, HEART, ONION, CHEER, BRAND, PLANK, SLEEP, STUDY, TENSE, GUESS, LEAST

Word list 4: STOLE, SHAKE, CHILD, ROUGH, CLIFF, ORDER, REBEL, DRESS, ELBOW, WAGON, SHARP, QUOTE, TIMER, TRAIL, CROWN, STAGE, JELLY, LINEN, DRAIN, STALK, HURRY, PORCH, RIGHT, STEEL, BRUSH, TRUNK, BUNCH, PENNY, BLOCK, SERVE, STONE, SHARE, BRAIN, EARTH, SCENE, FLOUR, CHEEK, GRASS, PLANT, JUDGE, CRUMB, PRINT, SPOIL, SPOKE, SHELL, OTHER, COURT, SHEET, PAUSE, SUGAR, STICK, BLOOM, TEETH, PRIDE, WHILE, SKIRT, BLAZE, GLORY, TRACK, SPELL

Word list 5: CORAL, FRAME, SHORE, GRAIN, STORE, BOAST, DOUBT, SATIN, REACH, SLICE, PEARL, GRASP, PRICE, ORGAN, TRUCK, STOCK, PASTE, CRACK, COVER, SWING, WHIRL, CLOCK, RIVER, SPACE, STEAL, LEVEL, DEPTH, STILL, ROUTE, SPLIT, SCARE, FENCE, KNIFE, ACTOR, POINT, THING, FLOAT, SALAD, GRIEF, SHINE, SMELL, QUIET, SHIFT, SCENT, LEMON, ELECT, FRUIT, GUEST, MIDST, FLUSH, PIECE, DRIVE, GRADE, SWEET, QUICK, NOISE, SMALL, CROSS, STAND, TROOP

Word list 6: VISIT, APPLE, STYLE, FIELD, BOUND, SWEAT, METAL, LEAVE, DRINK, WRIST, THUMB, MORAL, DANCE, STARE, GRANT, POISE, STOVE, GROAN, SOUND, HOUSE, SHOUT, DRIFT, SENSE, CLOTH, CROWD, LAYER, STORM, WASTE, SMILE, ROAST, SHRUG, PLATE, TRUST, BLUSH, CRUSH, COACH, HOTEL, PAPER, YOUTH, CHECK, SAINT, WRECK, SPORT, EQUAL, SMOKE, STAFF, BURST, BOARD, LOCAL, STEAM, FORCE, ALARM, SHADE, NIGHT, WOMAN, MODEL, UNDER, WHEAT, BRIEF, TOUCH

Appendix B

Word lists: Experiments 3 and 4

Word list 1: JAZZ, CLOSE, WINDOW, FOREST, FATHER, MEANS, LEAST, TRADE, SIDE, SECRET, SENSE, NOVEL, SORT, VISIT, SWEET, EFFECT, CHANCE, DESIGN, SOFT, VOICE, PARTY, BRIDGE, BLOOD, DESK, FEEL, APRIL, FAMILY, STILL, DOCTOR, INCOME, WRONG, COLD, MODERN, ORDER, SOUTH, VOLUME, FINE, BLOCK, LACK, EXTENT, FRIDAY, RIGHT, FILM, IMPACT, CHECK, SOURCE, COUNTY, GROUND, SHARE, PAST, REACH, BEAUTY, PARK, THING, FLAT, MARCH, SIGNAL, SHORE, LEAD, SHAPE

Word list 2: FOOT, CLAIM, GOAL, PRICE, SEARCH, FIRM, LIVING, DINNER, HOLD, MOUTH, BODY, CHARGE, SHOT, FACE, ANIMAL, CARE, ISSUE, WORLD, CAREER, SONG, BATTLE, DEEP, MANY, PAPER, CHILD, VALLEY, ROSE, CORNER, TIME, APPEAL, BALL, ROLE, LIGHT, COMMON, SIZE, THEORY, IMAGE, SOVIET, JUDGE, HALF, LEAVE, YOUTH, FELL, PASS, IDEAL, VIEW, NATURE, FACT, TRAVEL, ASIDE, PART, LAST, WHILE, SHORT, PUBLIC, MIDDLE, SLEEP, DRIVE, MASS, STAFF

Word list 3: YEAR, GLASS, TOWN, DEGREE, THICK, DANCE, TITLE, MUST, FIELD, SECOND, SAFE, LINE, NOTICE, IDEA, PLAN, FIND, HEAD, MONTH, FEED, NONE, PAGE, FEAR, PHASE, UNDER, HOUSE, OFFICE, BOOK, LETTER, WANT, MOTHER, NORTH, SNOW, CIRCLE, ENERGY, FRIEND, PLANT, CLOSER, DRESS, FORM, NARROW, TYPE, FAST, BLUE, DOWN, MEET, BEACH, ARMY, WATER, WOMEN, UPPER, MIGHT, FELLOW, CHIEF, MISS, WARM, STREET, CITY, HEART, HAIR, RISE

Word list 4: POINT, LOSS, SPIRIT, MOON, FALL, QUIET, START, STOP, SCHOOL, VALUE, DUTY, INSIDE, BUDGET, TODAY, CATTLE, PERSON, QUICK, ROUND, MIND,

GOOD, TEST, CALL, SPACE, SHIP, ROOF, EVENT, SHOP, HELP, FILE, TONE, FEET,
ISLAND, SOUND, CHAIR, MONEY, COURSE, MOMENT, POST, GAIN, HORSE, HOME,
CENT, AMOUNT, SAVE, PIECE, MONDAY, SPREAD, JOIN, WELL, GROWTH, TOTAL,
FAIR, DETAIL, DREAM, LONGER, CELL, COLUMN, DEMAND, KING, STAY

Word list 5: WIDE, INDEX, STOCK, STRESS, TALK, HAND, SUNDAY, TRIP, STUDY,
FACTOR, VOTE, CRISIS, LOOK, EARTH, BELIEF, JUNE, STAND, SUMMER, JUNIOR,
HOUR, ROCK, MATTER, MAKE, EDGE, COST, HAVE, BOARD, FRAME, LIKE, WEEK,
GIRL, ROAD, SPEED, BOTTLE, HALL, CREDIT, BREAK, DRINK, TURN, RACE,
BETTER, DOUBT, MAJOR, HEALTH, BIRTH, SUPPLY, WIND, SIGHT, MEMORY,
LAND, SPRING, LIST, PRESS, SERIES, TRAIN, NOTE, SEASON, STEP, BASIS, RATE

Word list 6: NEWS, SCALE, SPEECH, MEMBER, DATE, SERVE, LEVEL, CAUSE, MOVE,
JACK, AREA, HOPE, FRONT, SCENE, MAIN, SITE, LOCAL, TEETH, METHOD,
LENGTH, NOSE, NOBODY, STYLE, MARKET, EFFORT, POLICY, WORK, DROVE,
ROOM, WORD, JURY, FARM, CHANGE, BOAT, CENTER, TRUTH, HEAT, SIGN,
RELIEF, EAST, MUSIC, STATE, WALK, PEOPLE, ACTION, DEAL, POLICE, FORMER,
DANGER, DESIRE, SENATE, RISING, WEIGHT, KNOW, GROUP, RESULT, WINE,
BACK, STATUS, COOL

Word list 7: NECK, ESCAPE, TERM, NAME, COFFEE, FIRE, TREE, WALL, LONG,
RECORD, SCORE, STORE, CHINA, SHOW, CASE, FORCE, WAIT, TABLE, NATION,
COUPLE, MORAL, EVEN, WEST, BEAT, WATCH, BILL, RAIN, POET, LEADER,
CHOICE, COVER, PLAY, DOING, LORD, OFFER, REASON, WINTER, DOOR, RADIO,
TOUCH, CLASS, PLUS, MARK, BASE, STAGE, TASK, ANSWER, LIFE, BANK,

BOTTOM, WISH, RULE, OTHER, DAILY, CLAY, SPOKE, NEED, NIGHT, REGARD,
MASTER

Word list 8: LOVE, NUMBER, SQUARE, UNITY, PLANE, DATA, KEEP, FELT, FIGHT,
PEACE, DUST, FLOOR, TRIAL, CLEAN, MEAN, EMPTY, FUTURE, FIGURE, COURT,
EQUAL, LADY, REST, WRITER, BABY, MANNER, CLUB, SOLID, MODEL, FOOD,
RANGE, TASTE, OBJECT, MINE, PERMIT, WOMAN, SHARP, REMOVE, EDITOR, UNIT,
HOTEL, POETRY, MIKE, LEAGUE, STORY, HOLE, REPORT, TEXT, TEAM, HILL,
COAST, REAL, BRIEF, CAMP, FLOW, SYSTEM, WILL, WIFE, RIVER, FUND, POOL

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Supplemental Material: Experiment 1 Congruency Group

Method

Participants. Twenty-four participants (20 female, mean age = 18, SD = 0.82) were recruited from the McMaster University student pool in exchange for course credit. All participants spoke English fluently and had normal or corrected-to-normal vision.

Apparatus and stimuli. The apparatus and stimuli were identical to Experiment 1 with the following exceptions. Stimuli consisted of pairs of red and green interleaved words presented at the centre of the screen. Like in Experiment 1, each word subtended 5.95 degrees of visual angle horizontally, and 0.75 degrees vertically. Together, both words subtended 6.52 degrees horizontally and 1.03 degrees vertically. Examples of the stimuli are presented in Figure S1.

Figure S1: Examples of study phase items for the congruency group. The left side depicts an example of a congruent item; the right side depicts an example of an incongruent item.

Procedure. The procedure was identical to Experiment 1 with the following exceptions. On every study trial, participants saw a white fixation cross in the centre of the screen for 2000 ms, followed by a pair of red and green interleaved words for 1000 ms. Additionally, at the time of test, participants saw a pair of red and green interleaved words, rather than a single red word. It should be noted that old items were presented in the same manner at test as they were at study—that is, old items were presented with the same target-distractor pairing.

Design. The design was identical to Experiment 1 with the following exception. Rather than words being assigned to “repeated”, “not-repeated prime”, or “not-repeated target” roles, they were assigned to “congruent”, “incongruent distractor”, or “incongruent target” roles.

Results

Study phase. Correct response times (RTs) were first submitted to the same outlier analysis as Experiment 1 (Van Selst & Jolicoeur, 1994), which eliminated 2.34% of observations from subsequent analyses. Mean RTs were computed from the remaining observations. These mean RTs and corresponding error rates were submitted to two-tailed paired sample t-tests. Naming times were faster for congruent (678 ms) than for incongruent (827 ms) items, $t(23) = 12.6$, $p < .001$, $d = 3.65$, and error rates were lower for congruent (.003) than for incongruent (.022) items, $t(23) = 3.29$, $p = .002$, $d = 0.949$.

Test phase. Congruent and incongruent items were compared using d' as a measure of sensitivity and beta as a measure of bias. The mean proportions of “old” responses are displayed in Figure S2.

Figure S2: Mean proportions of “old” responses for the congruency experiment. Error bars here represent within-subject error corrected for between subjects variability (Morey, 2008).

Both d' and beta were analysed using two-tailed paired sample t-tests. For values of d' , the analysis revealed better recognition sensitivity for incongruent (1.37) than congruent items

(1.11), $t(23) = 3.27, p = .003, d = 0.945$. A similar analysis of beta values indicated a criterion difference between incongruent (2.27) and congruent items (1.73) that approached significance, $t(23) = 2.05, p = .052, d = 0.593$, indicating a more conservative criterion to respond “old” to incongruent than congruent items.

Contributions of recollection and familiarity to memory performance were obtained separately for hit rates and false alarm rates, and the hit minus false alarm difference scores were calculated for each item type. The analysis of recollection and familiarity estimates revealed a pattern similar to Experiment 1. There was no difference in recollection between congruent (.276) and incongruent items (.283), $t < 1$, whereas estimates of familiarity were greater for incongruent (.291) than congruent items (.215), $t(23) = 2.92, p = .008, d = 0.843$.

Discussion

The present data constitute a nice replication of the congruency experiments reported in Rosner, D’Angelo, MacLellan, and Milliken (2015), in that incongruent items were better remembered than congruent items. The different performance across conditions was restricted to the false alarm rates here, rather than occurring for both hit rates and false alarm rates as in the experiments reported in Rosner, D’Angelo, et al., but this result has a straightforward explanation. In particular, if we assume that congruency at the time of test increases processing fluency, which in turn is attributed to familiarity (Jacoby & Whitehouse, 1989), then the equivalent hit rates for the congruent and incongruent conditions must be a joint product of better recognition of old incongruent than old congruent items, together with a bias to respond “old” to the fluent congruent items. In any case, these results indicate that stimulus congruency has an impact on recognition memory, and that this effect produces results similar to those found when item repetition is manipulated.

It is also worth considering whether the inclusion of distractor words at test in this congruency experiment (but that did not occur in the present repetition experiments) could have contributed to the improved recognition for incongruent items. For example, two different words at study for incongruent items may offer an opportunity for associative encoding between the two words (e.g., the word BRICK interleaved with TRUCK may have led to the image of a truck carrying bricks) that is not available for congruent items. When two words appear at test, an associative cue is then available for incongruent items, but not for congruent items, which might explain the effect that we observed. However, theoretical accounts such as this one were ruled out by Rosner, D'Angelo, et al. (2015) in two ways. First, better recognition for incongruent than congruent study items was also demonstrated in an experiment that presented only single words at test (Experiment 2). Second, recognition was shown to be superior for an incongruent condition in which two different words were interleaved at study than for an incongruent condition in which two different words were spatially separated (Experiment 3).

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