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Remembering ‘primed’ words:

The effect of prime encoding demands

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Published in the Canadian Journal of Experimental Psychology

doi: 10.1037/cep0000139

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Acknowledgements

Financial support for this study was provided in part by a Natural Sciences and Engineering Research Council of Canada Discovery Grant awarded to Bruce Milliken. The funding agreement ensured the authors’ independence in designing the study, interpreting the data, writing, and publishing the report. The authors report no conflicts of interest.

Abstract

Rosner, Lopez-Benitez, D'Angelo, Thomson, and Milliken (2017) reported a novel recognition memory effect using an immediate repetition method during the study phase. During each trial of an incidental study phase, participants named a target word that followed a prime word that had the same identity (repeated trials) or a different identity (not-repeated trials). Recognition in the following test phase was better for the not-repeated trials. In the present study, we examined the influence of prime encoding demands on this counter-intuitive effect. In Experiment 1, we instructed one group to simply ignore the prime, as in the original study. A second group completed a divided attention task on prime presentation. Recognition memory was better for not-repeated than repeated words in both groups. In Experiment 2, encoding of the prime varied across three groups: one group named each prime, a second group counted the vowels in each prime, and a third group made a semantic discrimination for each prime. Recognition was better for repeated than for not-repeated words in the semantic group and did not differ across conditions for the other two groups. Finally, in Experiment 3, we assessed memory for not-repeated primes in addition to memory for targets (as in Experiments 1 and 2). The results confirmed that poor memory for the primes plays a significant role in producing the previously described effects. The results are discussed in relation to transient processing adaptations that affect memory encoding.

Introduction

Increases in processing difficulty at study often improve memory on later tests. A variety of such findings have been reported, and collectively they comprise the desirable difficulty principle (R. A. Bjork, 1994). E. L. Bjork and Bjork (2011) discuss four such findings. The spacing effect occurs when massing practice or study sessions within a short period produces poorer long-term retention compared to shorter study sessions distributed over a longer period (Ebbinghaus, 1913; see also Mammarella, Russo, & Avons, 2002; Toppino & Bloom, 2002). The interleaving effect refers to improved memory performance when learners study topics or practice tasks in an interleaved fashion rather than a blocked fashion (Shea & Morgan, 1979). Blocked learning often gives the appearance of better learning when short-term retention is tested, but such short-term gains are often reversed when retention is tested after a longer interval. Finally, the generation effect refers to improved retention when participants must generate a study item using a cue (e.g., the first two letters, or an anagram) rather than simply reading the study item (Jacoby, 1978; Landauer & Bjork, 1978). This effect may also relate to the testing effect, whereby testing memory for studied material produces better retention than additional study opportunities (Goldstein, 2011; Roediger & Butler, 2011). These effects fit with the general principle that difficult processing at encoding, retrieval, or both results in improved long-term retention.

Desirable Disfluency

Bjork (1994) coined the desirable difficulty principle to capture the association between difficulties in cognitive processing and improved retention. In addition to these classic effects, many recent studies also point to an association between perceptual processing difficulties and

improved long-term retention. Diemand-Yauman, Oppenheimer, and Vaughan (2011) demonstrated improved memory for information presented in hard-to-read fonts compared to an unmodified font. Nairne (1988) reported what may be a related effect that involved visual masking. During an initial phase of the experiment, participants identified words presented briefly, either unmasked or pattern masked. Performance on a subsequent surprise recognition test was better for the masked than for the unmasked items (see also Hirshman & Mulligan, 1991). In another example, Rosner, Davis, and Milliken (2015) reported superior recognition memory for words presented in a blurry font than for words presented in a clear font at the time of study (but see Rosner, Davis et al., 2015, and Yue, Castel, & Bjork, 2013 for limiting conditions of this effect). Finally, Rosner, D'Angelo, MacLellan, and Milliken (2015) tested recognition memory for target words paired with interleaved distractor words. Recognition was superior for incongruent targets (i.e., a red target word interleaved with a different green distractor word) than for congruent targets (i.e., a red target word interleaved with the same word in green). Together, these results imply that perceptual difficulties can enhance encoding and retention in a manner that is broadly consistent with E. L. Bjork and Bjork's (2011) desirable difficulty principle.

Of most direct relevance to the present study, Rosner, López-Benítez, D'Angelo, Thomson, and Milliken (2017) followed up on the selective attention study described above by offsetting the target and distractor items in time. That is, rather than a target and distractor presented simultaneously, participants first viewed a single green prime word followed by a single red target word, with the task being to name only the red target word. The key issue addressed in this study was whether repetition affected recognition in the same way as congruency. Indeed, recognition memory was better for not-repeated targets than for repeated

targets just as it was better for incongruent than congruent items in the prior study (Rosner, D'Angelo et al., 2015). This result is noteworthy for two reasons. First, it implies that priming is 'undesirable' in some contexts, as it may impair subsequent encoding. Second and more important, this result constitutes a counterintuitive effect in memory: Better recognition when a word is presented just once at the time of encoding than when a word is presented twice.

The Present Study

The result reported by Rosner et al. (2017) is a curious one because intuition would suggest that stimulus repetition ought to improve memory performance. Indeed, many empirical studies have documented facilitatory effects of stimulus repetition on memory performance (e.g., Lloyd, 2003; Raegh & Yassa, 2014), and it is arguably foundational in learning and education. Clearly, the conditions that led to the result reported by Rosner et al. (2017) require further study. Toward that aim, we examined the contribution of prime encoding demands to this effect by conducting the three experiments reported in this study.

In Experiment 1, we tested two groups of participants. The method for one group constituted a close replication of the method used by Rosner et al. (2017): Two words were presented during each study trial, one after the other. Participants were to attend to and name only the second of the two words. We gave participants no instructions on what to do with the first of the two words, and therefore they were free to process it in any way they liked. The method for the second group was the same with the exception that a divided attention manipulation was implemented for the first of the two words. Specifically, two distractor digits flanked the first word on each study trial, one just left of the first letter and one just right of the last letter of the word. We asked participants to report the sum or product of the two digits as

quickly and accurately as possible. In effect, the aim was to evaluate whether divided attention during encoding of the first of two words would produce the same result as an instruction not to do anything. If participants in the Rosner et al. (2017) study engaged only in relatively low-level perceptual processing, and this was key in driving the effect, then we ought to see identical results in these two groups. Specifically, better memory for not-repeated targets than for repeated targets. In Experiment 2, we examined the role of prime encoding demands further by varying the ‘depth’ of encoding (Craik & Lockhart, 1972). One group counted the vowels in each prime, a second group named each prime, and a third group attended to the meaning of each prime. The key issue addressed in Experiment 2 was whether recognition differences between repeated and not-repeated targets hinge on the encoding requirements for the primes at study. Finally, in Experiment 3, we measured memory for the not-repeated primes that preceded targets, as well as for not-repeated and repeated targets, to examine directly whether superior memory for not-repeated than repeated items hinges on particularly poor memory for primes.

Experiment 1

In the study by Rosner et al. (2017), participants saw two words during each trial in the study phase. For repeated trials the two words were identical, and for not-repeated trials the two words were different. Participants named the second word aloud but were not provided any specific instruction regarding response requirements for the first word. On the following surprise recognition memory test, recognition memory was better for not-repeated target words than for repeated target words. The aim of this experiment was to examine whether inattention to the first word during study was critical to the result reported by Rosner et al. (2017). The general idea is that not providing instructions regarding the primes on each study phase trial may have

led to reduced endogenous attention to those primes. In other words, participants may have opted voluntarily not to pay attention to the primes. Perception of an unattended prime may have resulted in fluent perceptual processing of a repeated target that followed (Jacoby & Whitehouse, 1989), but without an accompanying recapitulation of semantic processing for the repeated words. If stimulus repetition in the absence of access to the meaning of primes is critical to the effect reported by Rosner et al. (2017), then a similar result ought to occur under any set of conditions that limits access to the meaning of primes.

To that end, there were two groups tested in the current experiment. One group followed a procedure that was a close replication of Rosner et al. (2017)—participants were presented two words in succession on each study trial and named only the second of the two words. The second group followed a procedure that involved divided attention for the first of two words on each study trial. For this group, participants attended to two single digit numbers that flanked this first word and reported either the sum or product of these two numbers. The key issue addressed here was whether the repetition effect reported by Rosner et al. (2017) would be observed with this divided attention procedure. If the divided attention task produces a similar result to ignoring the first word, then reduced endogenous attention to the prime may be essential to understanding this effect.

Method

Participants. Forty-eight participants (30 females; mean age = 19 years) from the McMaster University student pool completed the experiment in exchange for course credit or \$10 CAD. All participants had normal or corrected-to-normal vision and spoke English fluently.

A counterbalancing procedure was used to assign twenty-four participants to each group (ignore/divided attention) based on their order of arrival.

Apparatus and stimuli. The experimental program was run on a Mac Mini using the PsychoPy open source experimental software (v1.81.0, Peirce, 2007; 2009). The stimuli were displayed on a 24-in. BENQ LED monitor. The onset of naming responses for the study phase was detected using a Logitech Microphone Headset, while responses for the test phase were recorded using the keyboard. All participants were tested individually, sitting approximately 50 cm from the monitor.

{ INSERT FIGURE 1 HERE }

During the study phase, a green prime word and a red target word were presented centrally on each trial, with the prime word flanked by white digits ranging in value from 2 – 9, as shown in Figure 1. During the test phase, a red word appeared centrally, with response options “OLD” and “NEW” displayed in white in the bottom corners of the screen. In all cases, stimuli were presented with a space between each letter against a black background. Each word subtended approximately 0.8° of visual angle vertically and 5.9° horizontally. A total of 360 five-letter words were used in the experiment, all of which were high-frequency nouns (Thorndike and Lorge, 1944). The exact word lists can be found in Appendix A.

Procedure. The experiment consisted of two phases: An incidental study phase and a test phase. In the study phase, participants saw a green prime flanked by white digits, which was followed by a red target item. The between-subjects manipulation was the prime encoding task. Participants in the ignore group did nothing with the prime. Participants in the divided attention

group reported aloud either the sum or product (a between subject manipulation) of the digits flanking the green prime, as quickly and accurately as possible. In both groups, participants then named the red target word aloud as quickly and accurately as possible. Each trial began with a central fixation cross displayed for 2,000 *ms*, followed by a green prime for 200 *ms*, a blank screen for 1,000 *ms*, and then a red target word for 500 *ms*. Response times (RTs) were recorded from the onset of the target word to the onset of the vocal response to the target word, as detected by a microphone headset worn by participants. Following offset of the target word, a blank screen appeared for a minimum of 1 second or until the experimenter coded the participants' response, after which the next trial began.

The experimenter coded participant's responses in the study phase as correct, incorrect, or a spoil by pressing "1", "2", or "3" on the number pad of the keyboard. Incorrect responses occurred when the participant reported the wrong sum or product, named the prime word, or named the target word incorrectly. Spoils occurred when extraneous or unexpected noise was suspected to have triggered the microphone (e.g., coughing or significant ambient noise during the response window). After completion of the incidental study phase, participants completed a series of math problems for 10 minutes before proceeding to the test phase. These math problems consisted of simple arithmetic and order of operations questions. Participants were then presented with detailed instructions for the test phase both verbally and written on screen. The test phase was a surprise recognition memory task. On each trial in the test phase, a single word was presented, and participants were asked to decide whether the word was a target item from the previous study phase or a new, previously unseen lure. Participants recorded their "old" or "new" decisions via a keyboard response. Following each "old" response, participants made a remember/know classification for the word, once again via keyboard response. The

remember/know instructions included detailed definitions of the difference between “remembering” and “knowing” (Rajaram, 1993). These “remember” and “know” judgments were labelled as “Type A” and “Type B”, respectively. Remember/know data were collected for exploratory purposes and are reported in Appendix B for the interest of the reader, though not discussed in depth here.¹

Trials in the test phase began with the presentation of a central fixation cross for 2000 *ms*, followed by the presentation of a red word. The words “OLD” and “NEW” appeared in the bottom left and right corners of the screen to serve as reminders for which key corresponded to which response. The stimuli remained on screen until a response was provided via a key press: “A” for “OLD” and “L” for “NEW”. If the participant responded “OLD”, the word remained on screen and the words “OLD” and “NEW” were replaced with “TYPE A” and “TYPE B”, respectively. Stimuli remained on screen until participants responded via key press once again: “A” for “TYPE A” (a feeling of remembering) and “L” for “TYPE B” (a sense of knowing).

Design. Three hundred and sixty words were used in the experiment. The 360 words were randomly divided into six lists of 60 words (see Appendix A). For each participant, three of these were “old” word lists and three were “new” word lists. The assignment of word lists to old or new status was counterbalanced across participants. The three old lists served one of the following roles: prime word only (not-repeated trials), target word only (not-repeated trials), or prime and target (repeated trials). These roles were once again counterbalanced across participants. The three new lists were used to generate lure items for the test phase and were randomly assigned to the roles of prime word only (not-repeated trials), target word only (not-repeated trials), and prime and target (repeated trials). Note that because only target words were presented at test, the word list assigned to the new prime word only role was never seen by

participants. Note also this is a dummy coding scheme, as new not-repeated words are undifferentiated from new repeated words to participants at test. The order of presentation of words in both phases was randomly determined. A total of 60 repeated and 60 not-repeated trials were intermixed randomly during the study phase. During the test phase, the 120 old targets were intermixed randomly with 120 previously unseen lures, for a total of 240 recognition test trials.

Results

We conducted two mixed-factor ANOVAs to examine whether the nature of the divided attention task, addition or multiplication, impacted naming times in the study phase or proportion of old responses in the test phase. Neither the main effect of divided attention task type nor any interactions involving this factor were significant in either analysis (all p 's > .10). Therefore, we collapsed across the two divided attention tasks in all subsequent analyses.²

{ INSERT TABLE 1 HERE }

Naming phase. Following data collection, we learned that about 60% of the correct naming times for the divided attention condition were less than 200 *ms*, suggesting that responses to the divided attention arithmetic task often overlapped with onset of the target word, which in turn stopped the timing of response to the target word prematurely. Moreover, some proportion of the correct RTs greater than 200 *ms* were also likely influenced spuriously by this problem. As such, naming times were excluded from analysis in the divided attention condition.

For the ignore condition, we eliminated from analysis RTs for incorrectly named trials and correct RTs less than 200 *ms* (2.8% of observations). The remaining RTs were submitted to an outlier elimination procedure (Van Selst & Jolicoeur, 1994) that excluded 1.5% of trials from further analysis. Mean RTs were computed from the remaining observations. These means were submitted to a paired sample *t*-test that compared the not-repeated and repeated conditions.

Table 1 lists the mean RTs and error rates in each condition collapsed across participants. The analysis revealed a significant effect of repetition, $t(1,23) = 10.80, p < .001, d = 4.50$, with faster RTs for repeated ($M = 457\text{ ms}, SD = 90\text{ ms}$) than not-repeated trials ($M = 512\text{ ms}, SD = 98\text{ ms}$).

{ *INSERT FIGURE 2 HERE* }

Test phase. Spoil trials and items responded to incorrectly during the naming phase were excluded from the analysis of the recognition test phase for this and all following experiments.³ The primary dependent measure in all analyses was the proportion of “old” responses. Figure 2 displays mean hit (“Old” responses to old words) and false alarm (“Old” responses to new words) rates collapsed across participants.

In the first analysis, we collapsed proportion of targets judged old across the repetition factor and then submitted the resulting values to a 2 x 2 mixed-factor ANOVA with group (ignore/divided attention) treated as a between-subjects factor and item-type (old/new) treated as a within-subject factor. The purpose of this analysis was simply to evaluate whether participants responded old more often to old items than to new items, and whether this recognition sensitivity differed for the two groups. This analysis revealed a main effect of group, $F(1,46) = 5.40, p = .025, \eta_p^2 = .105$. Participants in the ignore group ($M = .436, SD = .131$) responded “old” more

often than did participants in the divided attention group ($M = .345$, $SD = .110$). There was also a main effect of item-type, $F(1,46) = 295.40$, $p < .001$, $\eta_p^2 = .865$, with more hits (“old” responses to old items; $M = .567$, $SD = .158$) than false alarms (“old” responses to new items; $M = .225$, $SD = .141$). Finally, the interaction was significant, $F(1,46) = 17.88$, $p < .001$, $\eta_p^2 = .280$. To examine this interaction further, separate analyses were conducted for the ignore and divided attention groups. For the ignore group, the hit rate ($M = .649$, $SD = .153$) was higher than the false alarm rate ($M = .224$, $SD = .156$), $t(23) = 12.80$, $p < .001$, $d = 5.34$. For the divided attention group, the hit rate ($M = .484$, $SD = .115$) was also higher than the false alarm rate ($M = .227$, $SD = .128$), $t(23) = 11.81$, $p < .001$, $d = 4.92$. Together, these analyses suggest that participants in both groups produced better than chance level recognition performance, but that sensitivity was higher for the ignore group.

In a second analysis, we assessed the effect of repetition by analyzing the hit rates only. In this analysis, group (ignore/divided attention) was again treated as a between-subjects factor and repetition (not-repeated/repeated words) was treated as a within-subject factor. This analysis revealed a main effect of group, $F(1,46) = 17.95$, $p < .001$, $\eta_p^2 = .281$, with a higher hit rate for the ignore than divided attention group. More important, there was also a main effect of repetition, with a higher hit rate for not-repeated words ($M = .591$, $SD = .153$) than for repeated words ($M = .543$, $SD = .172$), $F(1,46) = 16.09$, $p < .001$, $\eta_p^2 = .259$. The interaction was not significant, $F(1,46) = .61$, $p = .439$, $\eta_p^2 = .013$. Our a priori interest in whether the repetition effect would be significant for each of the groups led us to conduct separate analyses for the two groups. In the ignore group, participants had higher hit rates for not-repeated words ($M = .678$, $SD = .143$) than for repeated words ($M = .621$, $SD = .170$), $t(23) = 3.93$, $p < .001$, $d = 1.64$. Performance in the divided attention condition was similar, with more hits for not-repeated ($M =$

.503, $SD = .107$) than for repeated words ($M = .465$, $SD = .138$), though in this case the effect was only approached significance, $t(23) = 2.04$, $p = .054$, $d = 0.85$. The results suggest similar effects of repetition on recognition memory occur in the two groups.

Discussion

The goal of Experiment 1 was to determine whether inattention to the prime is critical to producing superior recognition for not-repeated than repeated words (Rosner et al., 2017). To address this issue, we introduced a divided attention manipulation. In the divided attention group, participants attended to the prime presentation but diverted their attention to the numbers on either side of the prime word rather than attending to the prime word itself. In contrast, in the ignore group, we gave participants no instructions for the prime word but asked them to simply name the target word that followed the prime. Importantly, the effect of repetition on recognition memory was similar across the ignore and divided attention groups, suggesting that ignoring a word produces comparable effects to divided attention.

One interpretation of these results is that processing of unattended primes can facilitate the naming of repeated relative to not-repeated targets in the study phase, without also strengthening representations that drive recognition performance at test. This might occur if participants processed unattended primes perceptually but not semantically. Perceptual processing may serve to speed naming of identical targets, but provides an inadequate basis for remembering either the prime itself or any interactive consequences of processing the prime and an identical target. Of course, to explain why memory performance is superior (rather than merely equivalent) for not-repeated than repeated trials requires an additional mechanism. To capture this property of the results, we assume that the processing discrepancy between primes

and targets on not-repeated study phase trials triggers some form of exogenous (involuntary) attention shift that strengthens encoding. We discuss the nature of the processing discrepancy that produces this exogenous shift of attention in the General Discussion.

Experiment 2

We proposed that superior recognition for not-repeated items in Experiment 1 hinged at least in part on participants not having attended to the prime during the study phase. Because of inattention to primes, recognition performance for repeated targets would depend predominantly on how participants processed repeated targets on their own, rather than any joint semantic processing associated with encoding an identical prime and target. If we further assume that an exogenous shift of attention strengthens memory encoding on not-repeated trials, then one can begin to see how recognition might be better for not-repeated words.

We tested this explanatory framework in Experiment 2 by manipulating the encoding of primes, as in studies that have examined the levels of processing principle (Craik & Lockhart, 1972). Three groups participated in Experiment 2: In the vowel count group, participants focused on orthographic processing of the primes; in the naming group, participants simply named aloud the prime; and in the semantic group, participants focused on a semantic property of the prime. As in Experiment 1, participants in all groups named the target word aloud and later completed a surprise recognition test. Inattention during prime processing may limit semantic processing, resulting primarily in processing at the perceptual level. If limited semantic processing is critical to producing better memory for not-repeated than for repeated targets, increasing ‘depth’ of processing should eliminate the effect. Indeed, it seems possible that semantic processing of primes would lead to a reversal of the effect.

Method

Participants. Seventy-two participants (51 females; mean age = 19 years) from the McMaster University student pool completed the experiment for course credit or a small cash remuneration of \$10 CAD. All participants had normal or corrected-to-normal vision and spoke English fluently. Participants were assigned to one of three groups (name/vowel count/semantic) using a counterbalancing scheme based on their order of arrival, with 24 participants in each group.

Apparatus, stimuli, and design. The apparatus, stimuli, and design used in Experiment 2 were identical to Experiment 1 with the following exception: during the study phase, no white numbers were displayed flanking the green prime stimulus.

Procedure. The procedure used in Experiment 2 was like Experiment 1 with two exceptions during the study phase. First, the prime was displayed for 500 *ms* instead of 200 *ms*, in part to avoid the potential response overlaps observed in Experiment 1. Second, participants completed different prime encoding tasks depending on their group assignment, with methods borrowed from the depth of processing literature (Craik & Lockhart, 1972; Lockhart, Craik, & Jacoby, 1976; Craik, 2002). Participants in the vowel count group were required to report aloud the number of vowels in the prime word. In the name group, participants simply named the prime aloud. Finally, participants in the semantic group were required to answer a simple semantic question about the prime (“Can you touch this?”). RTs to the prime task were recorded in this experiment, along with naming RTs to the target word. The math distractor and test phases were identical to Experiment 1.

Results

Naming phase. RTs for correctly named targets that were greater than 200 *ms* were included in the analyses. These RTs were submitted to an outlier analysis that removed 2.4% of trials from further analysis. Mean RTs were computed from the remaining observations. The mean RTs were submitted to mixed-factor ANOVAs that treated group (vowel count/name/semantic) as a between-subjects factor and repetition (not-repeated/repeated) as a within-subject factor. Table 1 displays the means of the mean RTs and error rates collapsed across participants.

The analysis of RTs revealed a significant main effect of group, $F(1,69) = 8.46, p < .001, \eta_p^2 = .197$. Fisher's LSD tests on the RTs for the three groups revealed that naming times were faster for the name group ($M = 552\text{ ms}, SD = 61\text{ ms}$) than for the vowel count group ($M = 638\text{ ms}, SD = 109\text{ ms}$), $p < .001$, and semantic group ($M = 639\text{ ms}, SD = 72\text{ ms}$), $p < .001$, but did not differ between the latter two groups, $p = .960$. More important, there was a significant main effect of repetition, $F(1,69) = 87.59, p < .001, \eta_p^2 = .559$, with faster naming responses for repeated ($M = 581\text{ ms}, SD = 76\text{ ms}$) than not-repeated ($M = 639\text{ ms}, SD = 113\text{ ms}$) trials. The interaction between group and repetition was also significant, $F(1,69) = 5.30, p = .007, \eta_p^2 = .133$. Subsequent analyses revealed that the priming effect was significant in all three groups, $p < .001$. A follow up Fisher's LSD test on the difference scores suggests the effects was larger in the vowel count group ($M = 86\text{ ms}, SD = 73\text{ ms}$), than in either the semantic ($M = 52\text{ ms}, SD = 48\text{ ms}$), $p = .028$, and name ($M = 37\text{ ms}, SD = 28\text{ ms}$) groups, $p = .002$, but the latter two groups did not differ from one another, $p = .357$ (see Table 1).

Test phase. As with Experiment 1, the proportion of "old" judgments served as the primary dependent variable in the analysis of recognition performance. This measure was

subjected to the same two mixed-factor ANOVAs as with the test phase in Experiment 1, albeit with three groups (vowel count/name/semantic) for the between-group factor. Figure 2 displays the mean proportions of “old” judgments in each condition, collapsed across participants.

The first analysis treated item type (old/new) as a within-subject factor and collapsed across the repetition factor, to assess overall recognition performance, and whether this performance differed between groups. There was a significant main effect of item type, $F(1,69) = 736.38, p < .001, \eta_p^2 = .914$, with more hits ($M = .674, SD = .162$) than false alarms ($M = .216, SD = .149$). The interaction was also significant, $F(2,69) = 21.82, p < .001, \eta_p^2 = .387$. To examine this interaction further, we compared hits and false alarms separately for each group using two-tailed paired sample t-tests. Hits exceeded false alarms in all three groups, $p < .001$. A follow up Fisher’s LSD of the corrected hit rates (hits minus false alarms) determined sensitivity was highest in the semantic group ($M = .606, SD = .143$), which was superior to both the name group ($M = .432, SD = .154$) and ignore group ($M = .337, SD = .132$), both p ’s $< .001$. Between the latter two groups, there was also a significant difference in favour of the name group, $p = .024$ (see Figure 2).

The second analysis observed only the hit rates, with group treated as a between-subject factor and repetition (repeated/not-repeated) treated as a within-subject. This analysis produced both a main effect of group $F(2,69) = 12.47, p < .001, \eta_p^2 = .266$, and a main effect of repetition, $F(1,69) = 35.95, p < .001, \eta_p^2 = .343$. For the group effect, Fisher’s LSD tests showed superior hit rates for the semantic group than both the name and vowel count groups ($p < .001$ for both comparisons), though the latter two did not differ from one another ($p = .276$). For the repetition effect, participants recognized repeated words ($M = .711, SD = .200$) better than not-repeated words ($M = .637, SD = .152$). This effect was qualified by an interaction between group and

repetition, $F(2,69) = 35.83, p < .001, \eta_p^2 = .510$. The significant interaction led us to analyse the effect of repetition separately for each group, again using two-tailed paired sample t-tests. For the semantic group, the hit rate was higher for repeated targets ($M = .898, SD = .102$) than for not-repeated targets ($M = .678, SD = .679$), $t(23) = 8.94, p < .001, d = 3.73$. In contrast, for the name and vowel count groups the effect of repetition was not significant, $p > .10$. These results are in line with our prediction that the effect of repetition depends on prime encoding demands.

Discussion

In contrast to Experiment 1, in Experiment 2 we instructed participants to attend to the primes, with the specific encoding requirements for the prime varying across three groups. The purpose of the experiment was to examine whether the repetition effect on recognition memory would vary as a function of processing of the primes. Indeed, there were null effects of repetition on recognition performance in the vowel count and name groups, and greater sensitivity for repeated than for not-repeated targets in the semantic group. These results demonstrate the counter-intuitive finding reported by Rosner et al. (2017) does not always occur with the repetition method used here. Specifically, when primes are encoded in such a way that participants are likely to remember them at test (according to the levels of processing principle), recognition performance is better for repeated than for not-repeated targets.

Experiment 3

The results from Experiments 1 and 2 are consistent with the proposal that relatively poor recognition performance for repeated targets hinges on poor memorability of primes that accompanies inattention to the semantic properties of those primes. However, the evidence

favouring this proposal to this point has been indirect. In the present experiment, the aim was to directly evaluate this idea by measuring how well participants could remember the primes from the study phase. To do this, we tested recognition of not-repeated primes in addition to targets (note that recognition of repeated primes could not be tested separately from recognition for repeated targets). Three prime encoding groups were included in this experiment: an ignore group like that in Experiment 1, a name group like that in Experiment 2, and a semantic group like that in Experiment 2. Two hypotheses related to prime recognition were of interest.

The first hypothesis was straightforward: The repetition effect in recognition observed for targets ought to closely mirror recognition of primes, with the worst prime recognition in the ignore group and the best prime recognition in the semantic group. The second hypothesis relates to the relative recognition sensitivity for not-repeated primes and repeated targets. The rationale for examining this contrast is that recognition of primes could conceivably drive recognition for repeated targets despite the nominal task being to recognise the named targets from the study phase. For instance, participants could respond “old” to the repeated item TRUCK not because they remembered encoding the word TRUCK as a named target, but because they remembered encoding the word TRUCK as a prime. In this sense, it is useful to consider recognition performance for repeated targets in the context of how well participants recognise primes on their own.

Method

Participants. Seventy-two participants (60 females; mean age = 19 years) from the McMaster University student pool completed the experiment for course credit or a small cash remuneration of \$10 CAD. All participants had normal or corrected-to-normal vision and spoke

English fluently. Participants were assigned to one of three groups (ignore/name/semantic) using a counterbalancing scheme based on their order of arrival, with 24 participants in each group.

Apparatus, stimuli, and design. The apparatus, stimuli, and design used in Experiment 3 were identical to Experiment 2 with the following exceptions during the test phase. First, words were presented in white. Second, the proportion of new and old words at test was altered such that there were now 60 new words and 180 old words. The 180 old words consisted of 60 not-repeated primes, 60 not-repeated targets, and 60 repeated targets. To accommodate this change in experimental design, the size and number of word lists were altered, but the global word pool remained the same. As in prior experiments, the counterbalancing constraints ensured that each word in the global word pool occurred equally often as a not-repeated prime, a not-repeated target, and a repeated target.

Procedure. The procedure used in Experiment 3 was similar to Experiment 2 with the following exceptions. There were three groups tested in this experiment: an ignore group like that tested in Experiment 1, a name group like that tested in Experiment 2, and a semantic group like that tested in Experiment 2. Participants in the ignore group simply named the red word aloud on each study phase trial. Participants in the name group named both the prime and target word aloud. Finally, in the semantic group, participants answered a simple semantic question about the prime (“Can you touch this?”). During the study phase, we collected only naming RTs for target words. Finally, and most importantly, the test phase was altered to include the not-repeated primes in addition to not-repeated and repeated targets.

Results

Naming phase. RTs for correctly named targets that were greater than 200 *ms* were included in the analyses. These RTs were submitted to an outlier analysis that removed 1.7% of trials from further analysis (Van Selst & Jolicoeur, 1994). Mean RTs were computed from the remaining observations, and these mean RTs were submitted to a mixed factor ANOVA that treated group (ignore/name/semantic) as a between-subjects factor and repetition (not-repeated/repeated) as a within-subject factor. The means of participants' mean RTs and error rates in each condition are displayed in Table 1.

The analysis of RTs revealed a significant main effect of group, $F(2,69) = 16.21, p < .001, \eta_p^2 = .320$. Fisher's LSD tests on the RTs for the three groups revealed that naming times were slower for the semantic group ($M = 644\text{ ms}, SD = 105\text{ ms}$) than for the ignore ($M = 497\text{ ms}, SD = 113\text{ ms}$) and name groups ($M = 508\text{ ms}, SD = 73\text{ ms}, p < .001$ for both comparisons), but did not differ between the latter two groups, $p = .691$. More important, there was a significant main effect of repetition, $F(1,69) = 45.04, p < .001, \eta_p^2 = .395$, with faster naming responses for repeated ($M = 533\text{ ms}, SD = 114\text{ ms}$) than for not-repeated ($M = 564\text{ ms}, SD = 125\text{ ms}$) trials. The interaction between group and repetition was not significant, $F(2,69) = 2.31, p = .107, \eta_p^2 = .063$.

{ INSERT FIGURE 3 HERE }

Test phase. The mean proportions of "old" judgments in each condition, collapsed across participants, are displayed in Figure 3. The analysis strategy for the recognition test phase had four components. The first two components involved analyses of recognition memory that

corresponded to those conducted in Experiments 1 and 2. In effect, we were interested in whether the results from this experiment offered a close replication of the recognition results in our prior experiments. The third component of our analysis examined recognition performance for the not-repeated primes across the three groups. As noted above, the straightforward prediction is that repetition effects revealed in the first analysis ought to mirror closely the overall recognition performance for not-repeated primes in this second analysis. Finally, the fourth component of our analysis strategy involved a comparison of recognition performance for not-repeated primes and repeated targets across the three groups. This comparison allowed us to evaluate whether recognition for primes always improved with a repeated naming event.

Analysis of overall recognition performance. The first analysis used proportion of “old” judgments as the dependent variable, with group (ignore/name/semantic) as the between-subjects factor, and item type (old/new) as the within-subject factor. The goal was to assess recognition sensitivity overall, and whether sensitivity differed across these groups.

The analysis revealed a significant main effect of item type, $F(1,69) = 882.95, p < .001, \eta_p^2 = .928$. Participants produced more hits ($M = .610, SD = .159$) than false alarms ($M = .240, SD = .147$). The interaction between group and item type was also significant, $F(2,69) = 23.65, p < .001, \eta_p^2 = .407$, suggesting recognition performance varied across groups. As with Experiment 2, we compared group corrected hit rates using Fisher’s LSD to examine the interaction. Sensitivity was greater in the semantic group ($M = .489, SD = .125$) than either the ignore group ($M = .290, SD = .097$) or the name group ($M = .332, SD = .092$), both p ’s $< .001$. Performance did not differ between the ignore and name group, $p = .167$ (see Figure 3). These results are predictable from and consistent with expectations generated from Experiments 1 and 2.

Analysis of repetition effects. The second analysis used hits as the dependent variable, with group (ignore/name/semantic) serving as a between-subjects factor, and repetition (not-repeated/repeated target) as a within-subject factor. The purpose was to analyse the impact of prime encoding demands on recognition memory sensitivity for repeated and not-repeated targets across the three groups.

The main effect of repetition was significant, $F(1,69) = 44.22, p < .001, \eta_p^2 = .391$, with a higher hit rate for repeated words ($M = .673, SD = .179$) than for not-repeated words ($M = .590, SD = .169$). However, this main effect was qualified by a significant interaction between group and repetition, $F(2,69) = 46.31, p < .001, \eta_p^2 = .571$. To examine the interaction further, we compared the two repetition conditions separately for each group. In the ignore group, the repetition effect was similar to that in Experiment 1, with a higher hit rate for not-repeated ($M = .637, SD = .164$) than for repeated words ($M = .601, SD = .148$), though in this case the effect only approached significance, $t(23) = 1.91, p = .069, d = 0.40$. In the name group, the repetition effect resembled that observed in Experiment 2, with a higher hit rate for repeated ($M = .584, SD = .177$) than for not-repeated words ($M = .548, SD = .162$) that approached significance, $t(23) = 1.78, p = .089, d = 0.37$. For the semantic condition, however, the hit rate was higher for repeated words ($M = .795, SD = .148$) than for not-repeated words ($M = .548, SD = .174$), $t(23) = 10.28, p < .001, d = 2.14$. Broadly speaking, the repetition effects observed here were similar to those observed in our prior experiments.⁴

Recognition of primes. To compare the recognition of not-repeated primes across groups, one-way ANOVAs were conducted on hit rates that treated group (ignore/name/semantic) as the lone between-subject factor. The purpose was to assess whether

recognition of not-repeated primes produced a ‘depth of processing’ effect, and whether these effects can explain observed repetition effects.

The analysis resulted in a main effect of group, $F(2,69) = 35.89, p < .001, \eta_p^2 = .571$. Post-hoc Fisher’s LSD tests revealed recognition memory in the semantic group ($M = .763, SD = .136$) was superior to both the ignore ($M = .393, SD = .155, p < .001$) and name group ($M = .548, SD = .163$, both $p < .001$). The memory for primes also differed between the latter two groups, with the name group performing better than the ignore group ($p = .001$). This pattern of prime recognition corresponds closely to the repetition effects reported in our prior analysis, where there was a substantial repetition benefit for the semantic group, a modest repetition benefit for the name group, and a repetition cost for the ignore group.

Recognition of repeated targets relative to not-repeated primes. To compare recognition performance for repeated targets to that of not-repeated primes, we subjected hit rates to a 3 x 2 mixed-factor ANOVAs that treated group (ignore/name/semantic) as a between-subjects factor, and item type (not-repeated prime/repeated target) as a within-subject factor. The purpose of this analysis was to assess whether the diverse types of prime encoding led to repetition effects above and beyond what can be explained by differences in prime encoding itself.

The analysis of hit rates revealed a main effect of group, $F(2,69) = 23.60, p < .001, \eta_p^2 = .406$. Fisher’s LSD revealed that hit rates were higher for the semantic group ($M = .779, SD = .134$) than both the name ($M = .585, SD = .161$) and ignore groups ($M = .497, SD = .140$), $p < .001$ in both cases. The latter two groups also differed from one another, $p = .041$. Returning to the main analysis, there was also a main effect of item type, $F(1,69) = 67.86, p < .001, \eta_p^2 = .496$, that was qualified by a significant interaction between group and item type, $F(1,69) = 17.36, p < .001, \eta_p^2 = .335$. To analyse this interaction further, we compared the two item types separately

for each prime encoding group. For the ignore group, hit rates were significantly higher for repeated targets than for not-repeated primes, $t(23) = 8.79, p < .001, d = 1.83$. This result again demonstrates that memory for primes was particularly poor for the ignore group. For the name group, hit rates were also higher for repeated targets than for not-repeated primes, $t(23) = 3.17, p = .004, d = 0.66$. This result suggests that naming a word twice on a single study phase trial improved recognition beyond the level achieved for a word named just once as a prime. Finally, for the semantic group, there was a trend favouring higher hit rates for repeated words than for not-repeated primes that approached significance, $t(23) = 1.73, p = .098, d = 0.36$. Considered together, these results suggest that encoding a prime and then producing a naming response to an identical target typically improves recognition performance above and beyond recognition of the prime itself.⁵

Discussion

The purpose of the present experiment was to examine recognition memory for primes in the context of the repetition effects measured in prior experiments. Indeed, the repetition effects observed here were like those observed in prior experiments. First, as reported by Rosner et al. (2017), and as observed in Experiment 1, recognition was better for not-repeated than repeated targets when participants ignored the primes in the study phase. Although this result only approached significance in the present experiment, the reliability of this effect across six similar variants of this procedure (Rosner et al., 2017; Experiment 1 of the present study) offers plenty of supporting evidence that there is a real and replicable difference in recognition memory between not-repeated and repeated target conditions. Second, recognition was just slightly better for repeated than not-repeated targets when participants read the primes in the study phase.

Again, this effect only approached significance here, but several similar variants of this procedure have consistently pointed to a small benefit for repeated items when participants read primes aloud (Rosner et al., 2017, Experiment 4; Experiment 2 of the present study). Third, recognition was substantially better for repeated than not-repeated targets when participants processed the primes semantically. This result corresponds closely to that observed in Experiment 2. Altogether, the repetition effects observed here constitute close replications of those seen in prior experiments.

Given the similar pattern of repetition effects observed here and in prior studies, the analysis of prime recognition was noteworthy on two counts. First, the pattern of prime recognition across the three groups closely mirrored the pattern of repetition effects across groups. Memory for primes was especially poor in the ignore group, predictably better in the name and semantic groups, with the best memory for primes occurring when participants encoded semantically. Second, comparison of recognition for not-repeated primes and repeated targets suggests that repetition did benefit recognition for the name and semantic groups beyond prime memory alone. This result suggests that at least some component of the advantage for repeated over not-repeated targets in these conditions relates to encoding the same word twice, rather than being a spurious consequence of particularly good recognition of the primes alone.

General Discussion

The purpose of the present study was to examine how prime encoding demands influence memorability of targets using an immediate priming method. We were particularly interested in the influence of prime encoding demands on the counter-intuitive result reported by Rosner et al. (2017): better recognition for not-repeated targets than for repeated targets. Experiment 1

produced two notable results. First, the ignore group replicated the pattern of results reported by Rosner et al. (2017), with better recognition for not-repeated than repeated targets. Second, the divided attention group produced a similar result. Attention to digits that flanked the prime word rather than to the prime word itself also produced better recognition for not-repeated words than repeated words. These results confirm that not-repeated targets in an immediate priming method produce a similar desirable difficulty effect to that observed with incongruent word pairs in a selective attention method (Rosner, D'Angelo et al., 2015). Further, the results suggest inattention to primes is critical to the counter-intuitive repetition effect reported here and in Rosner et al. (2017).

In Experiment 2, we examined how 'depth' of prime encoding (Craik & Lockhart, 1972) affected recognition memory for repeated targets. Prime encoding tasks that directed attention to orthographic qualities of the prime produced recognition that was no better for repeated than not-repeated targets. In contrast, an encoding task that directed attention to phonological and semantic qualities of the prime produced superior memory for repeated than not-repeated targets. Considered together, the results of Experiments 1 and 2 demonstrate clearly that immediate repetition effects in recognition memory depend on how participants process primes.

In Experiment 3, we assessed the influence of prime encoding on recognition of repeated items by testing recognition of not-repeated primes. If recognition of repeated targets hinges closely on memory for primes, then recognition of not-repeated primes ought to parallel the repetition effects, with particularly poor recognition of ignored not-repeated primes and particularly good recognition of semantically processed not-repeated primes. Indeed, this is precisely what we observed. Further, if recognition of repeated items is driven by processing of both targets and primes, rather than primes on their own, then recognition of repeated targets

ought to be superior to the recognition of not-repeated primes. Repeated targets were generally recognised more successfully than not-repeated primes. Participants recognised words presented as both prime and target better than words presented only as a prime, though in the case of the semantic condition the effect only approached significance.

The results confirm that when participants encode primes in a manner that supports later remembering (e.g., semantically processing the prime), encoding a word twice in rapid succession produces superior recognition to encoding a word just once. However, when participants encode primes in a manner that does not support later remembering (e.g., when ignoring the prime), encoding a word just once as a target can produce superior recognition than encoding a word twice in rapid succession (Rosner et al., 2017). As noted earlier, superior recognition for not-repeated than repeated items may imply that an exogenous shift of attention to not-repeated targets up-regulates encoding in a manner that facilitates later recognition. The following section discusses this possibility in more detail.

Exogenous Attention, Memory Encoding, and Recognition Memory

The superior recognition for not-repeated than repeated targets observed in Experiments 1 (ignore and divided attention groups) and 3 (ignore group) is a curious result that requires an explanation. A straightforward account of this effect attributes it simply to differences in ‘time-on-task’. According to this view, faster naming times for repeated targets imply that participants processed these targets to a lesser degree, which in turn accounts for their relatively poor recognition. Put differently, naming times could offer a measure of extensiveness of encoding, which in turn directly impacts the likelihood of recognition. To address this possibility for each of our experiments, we compared response times for remembered and forgotten items using a

two-tailed paired sample t -test. None of these comparisons proved significant ($p > .10$), suggesting that naming time on its own does not offer a measure of the extensiveness of encoding that predicts memory performance (see Rosner et al., 2017 for other related analyses).

An alternative view assumes that processing difficulty encountered on not-repeated trials cues attention exogenously in a manner that up-regulates encoding, which in turn results in improved recognition. Here we discuss two possible processing difficulties that might drive these shifts in exogenous attention: (1) difficulties in lower-order perceptual processing, and (2) differences in higher order event encoding.

Perceptual processing difficulty. Experiencing difficulty in ongoing perceptual processing may pull exogenous attention automatically to the encoding of a target item. One might think of this process as a form of cognitive control operation that up-regulates the resources dedicated to encoding in accord with the need for such resources. This up-regulation of resources allocated to encoding could, in turn, affect the quality and depth of encoding. This idea resembles the ‘hedonic marking’ principle (Winkielman et al., 2003). By this view, ongoing evaluation of processing fluency is an adaptive means by which organisms assess the valence of experiences and the need for additional encoding, with the allocation of attentional resources up-regulated to encode unfamiliar information, and perhaps down-regulated to conserve energy for information that is already well represented. Thus, in the context of the present experiments, participants encode repeated words ‘undesirably’, in the sense that their familiarity down-regulates their encoding.

Although none of our current results uniquely favour this explanation, future research that directly manipulates the perceptual processing difficulty associated with repeated target words may be prudent. Mammarella et al. (2002) found that changing the font between repeated

presentation of non-words was sufficient to reduce short-term perceptual priming of those stimuli. If changing the font for repeated target words eliminates or reverses our observed deficit in recognition memory for repeated words, this result would provide compelling evidence for the perceptual processing difficulty account proposed here. Evidence suggests that attentional adaptations that accompany increased processing difficulty do not always result in improved memory performance (Richter & Yeung, 2012; Chiu & Egner, 2015), but at least one does. We must sort out which types of difficulties do and do not provide recognition memory benefits in subsequent work.

New event encoding. Kahneman, Treisman and Gibbs (1992; see also Hommel, 1998; 2004) proposed that onset of a stimulus rapidly and automatically cues a process aimed at determining whether the current stimulus corresponds to an existing event representation. If so, an updating process occurs integrating the current stimulus with the previous event representation. If not, a new event representation is created. Zacks and colleagues describe a related set of ideas focusing on the importance of event segmentation processes (Zacks & Swallow, 2007; Zacks & Tversky, 2001). The basic idea underlying both theoretical frameworks is that identification of the boundaries between events is critical to perception and memory. In the present experiments, the transition between prime and target on not-repeated trials might well serve as an event boundary, whereas no such event boundary exists for the transition between prime and target on repeated trials. If processing that occurs at event boundaries provides a basis for remembering items on a recognition test, then this would explain why recognition is superior for not-repeated than repeated targets.

Henson and Gagnepain (2010) forward a related proposal. They suggest that memory encoding and retrieval are driven primarily by ‘prediction errors’. By this view, when the

forward transmission of bottom-up sensory information conflicts with semantic and episodically generated expectations, there is an up-regulation of encoding and improvement to subsequent retrieval (Henson & Gagnepain, 2010). This proposal is like that described above on event encoding in that a mismatching signal triggers the up-regulation of encoding, in this case between contextually specific expectations and experience.

Relation to the Spacing Effect in Remembering

In the experiments reported here, stimulus repetition was immediate; that is, the interval between prime and target was just one second. As such, one might reasonably ask whether the results observed here (see also Rosner et al., 2017) relate to the distributed practice principle (Baddeley & Longman, 1978; Ebbinghaus, 1913) or more specifically to the spacing effect (R. A. Bjork & Allen, 1970). Contemporary theories of the spacing effect fall roughly into two classes: deficient processing theories and contextual variability theories (Russo, Parkin, Taylor, & Wilks, 1998).

Deficient processing theories propose that the spacing effect is due to diminished processing of the second occurrence of a target item when it occurs shortly after a first occurrence. For recognition memory, which Hunt and Einstein (1981) argue depends heavily on item-specific memory, Challis (1993) suggests that the spacing effect may be driven by deficient processing of immediate compared to spaced repetitions brought on by short-term perceptual priming. In contrast, contextual variability theories propose spaced repetitions provide more distinct contextual cues than immediate repetitions, affording an advantage for later remembering. Both classes of theory predict that memory for repetitions improves with the forgetting that accompanies longer intervals between repetitions (Greene, 1989). However, only

the deficient processing theories have a mechanism that directly targets poor encoding of repetitions. In this sense, deficient processing theories of the spacing effect seem best equipped to explain superior recognition for not-repeated than repeated items observed in this study (see also Rosner et al., 2017). We propose here that more robust exogenous orienting of attention for novel than familiar events may underlie this deficient processing of repeated items. Critically, this interpretation provides a potential mechanism to explain desirable difficulty effects observed for not-repeated targets.⁶

Conclusion

To the best of our knowledge, the findings reported by Rosner et al. (2017) and replicated here in Experiments 1 and 3 constitute a novel effect- a deficit in recognition memory for words processed twice compared to words processed once. Specifically, recognition memory can be superior for a target preceded by a different prime than for a target preceded by an identical prime. The present study provides evidence that this effect depends on inattention to the primes. When participants attended to and encoded primes semantically, recognition was substantially better for repeated than for not-repeated targets. A key issue for future research to address is the relation between the mechanism that produces inferior memory for repeated items in the present experiments and the mechanism that underlies well-studied spaced repetition and distributed learning effects.

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Footnotes

¹ In both conditions of Experiments 1, and in the ignore condition of Experiment 3, our remember/know data produced higher recollection for not-repeated than for repeated words (see Appendix B), but no effect for familiarity. In contrast, Rosner et al. (2017) report two experiments in which familiarity was higher for not-repeated than for repeated words, with no effect of recollection. The reason for the different effects across these two studies is unclear at this point, but we present the results in the Appendix nonetheless for the interested reader.

² We initially suspected the multiplication task was too difficult, motivating the switch to the addition task. As there was no indication task difficulty had any effect on the variables of interest, we collapsed across this manipulation in all subsequent analyses.

³ Note that the technical problem that influenced naming times for the divided attention group did not affect the recognition analysis for the divided attention group. In other words, correct naming times that were incorrectly recorded as being lower than 200 ms did not compromise analysis of subsequent recognition of those items, as participants were blind to the naming time problem.

⁴ The borderline significance of repetition effects in both the ignore and name groups led us to compare their difference scores using Fisher's LSD. Performance significantly differed, $p = .017$, providing additional evidence that the directionality of the effect in each group differs.

⁵ Indeed, this result fits well with studies of the production effect (MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010; Putnam, Ozubko, MacLeod, & Roediger, 2014). We thank Mike Humphreys for identifying the connection between our current work and the production effect.

⁶Of course, it is equally valid to consider the results an ‘undesirable advantage’ for processing of repeated targets. The current design does not allow us to discriminate between benefits of novelty and costs of familiarity.

Appendix A

Word lists: Experiments 1 and 2

Word list 1:

CURVE, MONEY, TOWER, WHEEL, TABLE, CHAIR, DROVE, 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, DRIVE

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, OPERA, 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, PLAIN, 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

Exp.	Group	Recollection		Familiarity		
		Not-repeated		Not-repeated		Repeated
		Prime	Target	Prime	Target	Target
1	Ignore		.367		.268	.232
	Div. Attention		.150		.187	.172
2	Vowel Count		.238		.236	.221
	Name		.273		.276	.278
	Semantic		.251		.391	.544**
3	Ignore	.077	.272	.091	.254	.231
	Name	.178	.194	.201	.234	.245
	Semantic	.481	.204	.314	.224	.363***

Estimates of recollection and familiarity derived from the Independence/remember-know procedure (Yonelinas, 2002; Yonelinas & Jacoby, 1995). Asterisks represent contrasts of within-subject repetition effects. (* $p < .05$; ** $p < .01$; *** $p < .001$)

Table 1 Mean response times (*ms*) and error rates for naming target words in the study phase

Experiment	Group	Not-Repeated Targets	Repeated Target
1	Ignore	512(.007)	457(.002)
	Divided Attention	-	-
2	Vowel Count	681(.021)	595(.017)
	Name	571(.002)	534(.001)
	Semantic	665(.004)	613(.003)
3	Ignore	506(.001)	488(.001)
	Name	525(.010)	490(.006)
	Semantic	664(.024)	621(.024)

Note: Error rates are presented in parentheses.

Figure 1 Depiction of stimuli in Experiment 1. The *green* word is the prime, and the *red* word is the target. In the ignore group, participants simply named the target word on each trial. In the divided attention group, participants reported either the sum or product of the two white digits and then named the red target aloud.

Figure 2 Mean proportion of “old” responses to old and new items as a function of repetition.

Error bars reflect 95% confidence intervals (CI) corrected for between-subject variability

(Morey, 2008).

Figure 3 Mean proportion of “old” responses to old and new items as a function of item type.

Error bars reflect the 95% confidence intervals (CI) corrected for between-subject variability (Morey, 2008).