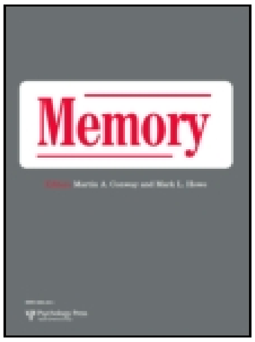

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Strategic processing in long-term repetition priming in the lexical decision task

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In a lexical decision task, faster reaction times (RTs) for old than new items is taken as evidence for an implicit memory involvement in this task. In contrast, the present study shows the involvement of both implicit and explicit memory in repetition priming. We propose a dual route model, in which lexical decisions can be made using one of two parallel processing routes: a lexical route, in which the lexical properties of the stimulus are used to determine whether it is a word or not, and a strategic route that builds on the inherent correlation between "wordness" and "oldness" in the experiment. Eliminating the strategic route by removing this correlation diminishes the priming effect at the slow end of the RT distribution, but not at the fast end. This dissociation is interpreted as evidence for the involvement of both implicit and explicit memory in repetition priming.

Keywords: Implicit memory; Repetition priming; Lexical decision.

Repetition priming is a wide-ranging phenomenon in which processing of an item is facilitated, either in speed or accuracy, by its prior exposure. Throughout this paper, this term will only refer to *long-term repetition priming*, in which this prior exposure reflects a different learning episode that occurred at least several minutes before the test context (see Bowers, 2000). An issue that has figured prominently in research on repetition priming is the extent to which it is influenced by memory processes with and without conscious awareness. The aim of the present study was to examine the possible contribution of explicit memory to repetition priming in the lexical decision paradigm, one of the classic tasks used for its demonstration (e.g. Goshen-Gottstein & Moscovitch, 1995a; 1995b). We propose a dual-route processing account of repetition priming in this task, which identifies two dissociable reaction time (RT) components of priming that reflect two types of processing in this task, which would be mapped to the distinction between implicit and explicit memory.

Over the last two decades, research has shown that repetition priming is observed even in situations in which the prior exposure of the repeated item was very remote from the task in which priming is manifested. Repetition priming was shown to persist over a very long time delay (Mitchell, 2006), and across different tasks (Jacoby & Dallas, 1981). Moreover, it was shown to be independent of the ability to retrieve the primed item explicitly (Tulving & Schacter, 1990). On these grounds, it was suggested that some forms of repetition priming stem from an implicit memory system that is dissociated from explicit memory (Schacter, 1987) whereas others depend on processes associated with explicit memory

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(Schacter, Dobbins, & Schnyer, 2004; Schacter, Wig, & Stevens, 2007). Implicit memory is observed as "facilitation of task performance without conscious recollection" (Schacter, 1987, p. 501), as opposed to explicit memory in which conscious recollection is part of the task requirements.

Lexical decision (Meyer & Schvaneveldt, 1971) is one of the classic tasks used to study implicit memory. In a typical experiment, participants are exposed to words, followed by a lexical decision task, in which they have to indicate whether items are words or non-words. This phase typically includes previously exposed words, new words, and non-words. The standard finding is faster and more accurate responses to pre-exposed ("old") words compared to "new" words. This finding is taken as evidence for implicit memory, since explicit retrieval is not part of the lexical decision task requirement. Importantly, the lexical decision task is typically regarded as being less prone to contamination by explicit memory, as compared to other tests such as stem completion or fragment completion. This claim is based on the quick responses that are required in this task, which makes explicit contamination relatively unlikely (e.g., MacLeod, 2008; Sheldon & Moscovitch, 2010).

In contrast to this claim, the present work shows that the largest part of the repetition effect in lexical decision relies on top-down strategic processing, rather than reflecting bottom-up priming. Specifically, we will demonstrate that contextual information, which is independent of the identity of the specific repeated items, is used to inform the word/non-word decision and provides a useful processing path that facilitates performance. This claim stands in contrast to viewing repetition benefits as reflecting implicit memory alone, and therefore calls for re-evaluation of previous finding in the lexical decision paradigm (Sheldon and Moscovitch, 2010).

Specifically, we propose that lexical decision is carried out by two parallel processing routes. The first process is lexical, and is based on the identity of the stimulus. This process leads to responding "word" if the stimulus is identified as a word, and to responding "non-word" if it is not. Importantly, the lexical route does not necessarily rely on the pre-exposure phase, as it can take place even without it, in principle. Nevertheless, processing along the lexical route can be facilitated by pre-exposure of items, due to enhancing their corresponding values in the dimensions that underlie the decision (e.g. Balota & Chumbley, 1984; Balota & Spieler, 1999; Ratcliff, Gomez, & McKoon, 2004). It should be noted that the notion of a lexical route in our model is accounted for in detail by many different models, which differ in their underlying architecture. However, they all share the property of not having to rely on a previous pre-exposure stage in order to reach a decision. It should be noted that the lexical route in our model is a general term for non-strategic processes. Accordingly, it might even include several sub-routes that compete among themselves (e.g. Balota & Spieler, 1999).

By contrast, the second route is strategic, and relies on the inherent correlation between "oldness" and "wordness" that typically exists in the experimental design. Specifically, in the standard lexical decision paradigm described above, only words appear in the pre-exposure phase. When the participant recognises an item in the lexical decision phase as one that appeared in the pre-exposure part, the response "word" should be selected since only words were pre-exposed. Notably, this strategic route to reaching a "word" decision is non-lexical, since once such a strategy is established, using it does not require lexical access. Hence, the strategic route might serve to bypasses processing in the lexical route. This proposal resembles that of Balota and Spieler (1999), but differs from theirs in that their strategic route is analytic and implemented as a second stage of processing if the output of the lexical route is indeterminate.

The presentation of a stimulus initiates processing along both the lexical and strategic routes that operate in parallel. RT for the "word" response is determined by a horse race between the two, which is terminated—leading to a "word" response—as soon as one of the routes reaches a "word" decision. Accordingly, the advantage of old words stems from two sources. A "non-word" response, on the other hand, can only stem from the lexical route.

The dual route model predicts that the standard repetition effect stems mainly from the upper tail of the RT distribution. The reasoning is that recognition, on which the strategic route is based, is typically slower than lexical processes (e.g. Dewhurst & Conway, 1994). Accordingly, the benefit of the strategic route will be observed in cases when the lexical route is relatively slow. The idea of episodic contamination of lexical decision processing is not new. Forster and Davis (1984) proposed a dual-route model of lexical decision, where the presentation of a target results in the initiation of a short-term lexical process and a long-lasting episodic search process. The episodic component was sensitive to word frequency, and its effect was mitigated using masked priming, making episodic retrieval unlikely. However, this model did not distinguish between the lexical and strategic routes discussed above. The contribution of episodic memory to lexical decision has been examined in detail in other works, in both the short-term and long-term priming domains (e.g., Coane & Balota, 2010; Durgunoglu & Neely, 1987; Oliphant, 1983; Rajaram & Neely, 1992).

The novelty of the present work is twofold. First, we aim to demonstrate the dissociable effects of lexical and episodic routes on different portions of the RT distribution, within the same conditions. Second, we show that the episodic effect is not only sensitive to manipulations affecting the item itself during the study phase, as shown before, but also to the context in which it appears. Unlike previous work, the term ‘‘context’’ is regarded here as the statistical properties of the experiment, namely the contingency between different conditions.

We predicted that the contribution of the strategic route would be eliminated once the correlation between oldness and wordness was removed. In order to test our hypothesis, we presented both words and non-words in the pre-exposure phase of the Experimental Group. In this situation, the explicit recognition of an item does not inform the lexical decision, since it does not provide the correct answer to the lexical decision. Two control groups in which only words were pre-exposed served for comparison.

The experiment included three stages. In the pre-exposure stage, participants had to study stimuli under explicit memory instructions. Note that in usual implicit memory studies, the pre-exposure does not mention any later memory test. However, in our case we used intentional learning in order to show that the repetition effect is attenuated in the Experimental Group even in the extreme condition where memory for the pre-exposed items is optimal. The second stage was a five-minute numerical buffer task. The third stage was the lexical decision task, and the fourth was a recognition test. We administered the recognition test in order to make sure that the effects in the lexical decision tasks did not stem from a difference between the groups in their memory of the items.

METHOD

Participants

Sixty-three students from the University of Toronto participated in the study, in exchange for course credit. All participants reported normal or corrected-to-normal vision, with no previous psychological or neurological dysfunction or learning disabilities. The participants were randomly assigned to three groups.

Apparatus and stimuli

The experiment was conduced on Pentium-V desktops with 17-inch monitors running E-prime (Schneider, Eschman, & Zuccolotto, 2002). Responses were collected using a standard QWERTY keyboard. All the stimuli appeared in white on a black background, using an 18 Courier New font. The word pool was derived from the MRC Psycholinguistic Database[1] (Wilson, 1988), and consisted of 240 monosyllabic nouns with four to six letters, low frequency (between 0.1 to 39.04 occurrences per million words, SubtlexUS corpus; Brysbaert & New, 2009), and highly concrete (400 to 700; Coltheart, 1981). The non-word pool was derived from the ARC Nonword Database[2] (Rastle, Harrington, & Coltheart, 2002), and consisted of 160 monosyllabic non-words, with four to six letters, composed of only orthographically existing onsets and bodies, and only legal bigrams. The stimuli that appeared in each part of the experiments were drawn at random for each participant independently, to avoid any systematic influence of specific items.

Procedure

The general procedure will be described first, followed by the specific details of each group. The experiment started with a study phase. In each trial, an item was presented on-screen for 3000ms, followed by a 2000ms intertrial interval (ITI). The participants were instructed to study the items. The next phase of the experiment was an arithmetic filler task that was administered for five

[1] Retrieved from http://websites.psychology.uwa.edu.au/school/MRCDatabase/uwa_mrc.htm

[2] Retrieved from http://www.maccs.mq.edu.au/ ~nwdb/nwdb.html

minutes, in order to prevent any short-term memory involvement in the subsequent parts of the experiment. In this task, the participants saw equations on-screen (such as $1+4+2=7$), and had to decide whether they are correct or incorrect using the keys "/"and "z", respectively. Each equation was presented on-screen until a response was indicated, followed by a 1000ms ITI. The equation was correct with a probability of 50%. Incorrect solutions ranged from -2 to $+2$ of the correct solution. The third part of the experiment was a lexical decision task. In each trial a stimulus appeared on-screen and the participants had to decide whether or it is a word or non-word, using the keys "/" (word) and "z" (non-word). Each stimulus was presented until a response was indicated, followed by a 1000ms ITI. The final part of the experiment was a recognition phase. In each trial, a stimulus appeared on-screen and the participants had to indicate whether it appeared in the first part of the experiment (using the keys "y" or "n"), and how confident they were in their response (using the keys 1 to 3, where 1 = not confident, 2 = somewhat confident and 3 = very confident). Also, if they responded "yes" to the first question, they were asked to indicate whether they remember, know or guess (using the keys "r", "k" and "g", respectively). The instructions to this question were taken from Wais, Mickes, and Wixted (2008), based on Gardiner and Richardson-Klavehn (2000).

Three groups were compared. In the critical Experimental Group, the study phase included 20 words and 20 non-words. In the two control groups, the study phase included words only. This phase included 20 words in the Control-1 Group, to control for the number of words in the Experimental Group, and 40 words in the Control-2 Group, to control for the total number of studied items in the Experimental Group. Table 1 describes the number and type of items in each part of the experiment, for each of the groups. Note that the new items in the recognition phase were different than those that appeared in the lexical decision task. In other words, the items in the recognition test were either old, and hence appeared both in the study and in the lexical decision task, or completely new.

TABLE 1
Experiment 1: Number of items of each type in each part of the experiment

	Experimental Group	*Control-1*	*Control-2*
Study	20 words 20 non-words	20 words	40 words
Lexical decision	Words: 20 old 20 new Non-words: 20 old 20 new	Words: 20 old 20 new Non-words: 40 new	Words: 40 old 40 new Non-words: 80 new
Recognition	Words: 20 old 20 new Non-words: 20 old 20 new	Words: 20 old 20 new	Words: 40 old 40 new

Analysis

For the lexical decision analysis, all the trials for each subject in each condition were sorted by their RT, and binned to four equal-frequency bins (denoted 1 through 4). Then, RTs faster than 100ms or slower than 4000ms, as well as RTs from error trials, were removed from the RT analysis. Three independent variables were of interest in the lexical decision analysis: Group (Experimental, Control-1, Control-2), Type (words, non-words) and Condition (old, new). However, these do not create a full factorial design, since old non-words only appeared in the Experimental Group. Accordingly, the analysis was carried out in two parts: one compared the conditions and included only words, and the other looked at the effects of Condition for non-words, in the Experimental Group only. Alpha was .05 in all the analyses. Error bars in all the figures represent within-subject confidence intervals for the simple contrasts of Condition (Masson & Loftus, 2003).

RESULTS

Lexical decision

RT. Before turning to the distribution analysis, we analysed the mean RT, being the most common central tendency statistic used in the field. An analysis of variance (ANOVA) was conducted for words only, with Group and Condition as independent variables. The main effect of Condition was significant, $F(1,60) = 18.09$, $MSe = 5361.81$, $\eta_p^2 = .23$, but not of Group, $F(2,60) = 1.70$, $MSe = 41{,}674.39$, $p = .19$, $\eta_p^2 = .05$. Importantly, the two-way interaction was significant, *F(2,60)* $= 6.97$, *MSe* $= 5361.81$, $\eta_p^2 = .19$ (see Figure 1). The simple effect of Condition (new minus old) was -1ms in the Experimental Group, *F(1,60)* $= .002$, *MSe* $= 5361.81$, $p = .96$, $\eta_p^2 < .01$; 118ms in Control-1, *F(1,60)* $= 27.17$, *MSe* $= 5361.81$, $\eta_p^2 = .31$; and 50ms in Control-2, *F(1,60)* $= 4.85$, *MSe* $= 5361.81$, $\eta_p^2 = .07$. The difference between new and old words differed between the Experimental Group and the control groups, *F(1,60)* $= 9.41$, *MSe* $= 5361.81$, $\eta_p^2 = .14$. Also, this difference was significantly larger in Control-1 than in Control-2, *F(1,60)* $= 4.53$, *MSe* $= 5361.81$, $\eta_p^2 = .07$, reflecting the effect of the number of studied items on repetition priming. According to this analysis, the experimental manipulation eliminated the repetition effect completely, suggesting that repetition operates only through the strategic route. However, as will be shown in the following binning analysis, this conclusion is premature.

A second analysis was conducted on the Experimental Group data only, comparing priming for words and non-words. RTs were 788 and 787ms for old and new words, respectively, and 1158 and 1061ms for old and new non-words, respectively. An ANOVA was conducted with Wordness and Condition as within-subject independent variables. Only the main effect of Wordness was significant, *F(1,20)* $= 9.06$, *MSe* $=$ 240,935.64, $\eta_p^2 = .31$. The main effect for Condition was non-significant, *F(1,20)* $= 1.39$, *MSe* $=$ 35,834.44, $\eta_p^2 = .07$, $p = .25$, as well as the two-way interaction, *F(1,20)* $= 1.81$, *MSe* $=$ 26,398.58, $\eta_p^2 = .08$, $p = .19$.

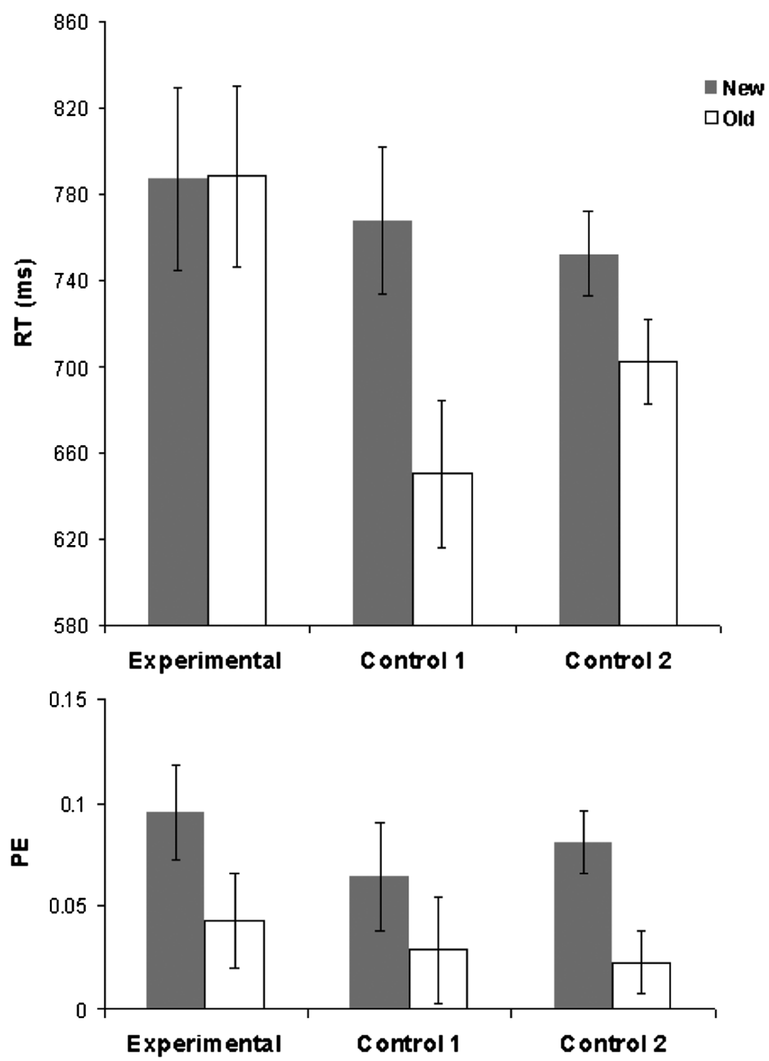

Figure 1. Mean RTs and PEs for the lexical decision task by Condition and Group for words only.

We next turned to analyse the repetition effect along the RT distribution. An ANOVA was conducted for words only with Group as a between-subject variable and Condition and Bin (1 to 4) as within-subject variables. Main effects were significant for Condition, $F(1,60) = 23.93$, $MSe = 21{,}587.42$, $\eta_p^2 = .29$, and for Bin, $F(3,180) = 191.51$, $MSe = 47{,}563.17$, $\eta_p^2 = .76$, but not for Group, $F(2,60) = 1.87$, $MSe = 202{,}705.08$, $p = .16$, $\eta_p^2 = .06$. Two-way interactions were observed between Group and Condition, $F(2,60) = 6.89$, $MSe = 21{,}587.42$, $\eta_p^2 = .19$, and between Bin and Condition, $F(3,180) = 4.37$, $MSe = 11{,}306.31$, $\eta_p^2 = .07$. Finally, the three-way interaction between Group, Bin and Condition was significant, $F(6,180) = 5.76$, $MSe = 11{,}306.31$, $\eta_p^2 = .16$, suggesting that the effect of repetition along the RT distribution differs in the three groups (see Figure 2).

We continued by examining the simple contrast between the old and new conditions in each bin, for each group separately. Table 2 describes the results of this analysis. As can be seen in Table 2 and Figure 2, while the priming effect gets larger with the increase of RT in the control groups, the picture in the Experimental Group is opposite. Specifically, the repetition effect in the Experimental Group is observed only in the first two RT Bins, but not in Bins 3 and 4. We will return to this point later.

Finally, we analysed the repetition effect for non-words, in the Experimental Group only. An ANOVA was conducted for the Experimental Group with Condition and Bin as within-subject independent variables. One participant was removed from this analysis due to 0% accuracy in the fastest bin of the old non-words. The main effect of Bin was significant, $F(3,57) = 44.25$,

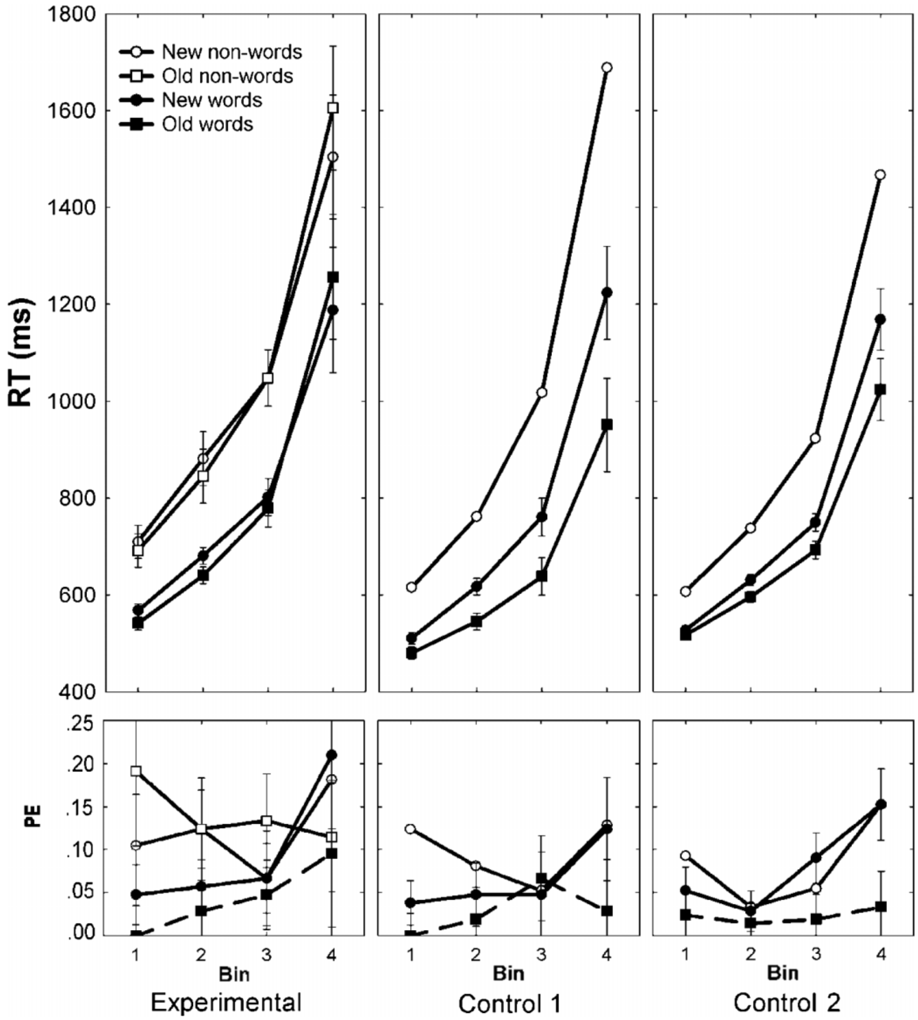

Figure 2. Mean RTs and PEs for the lexical decision task by Group, Condition and Bin.

TABLE 2
Experiment 1: The repetition effect (new–old) in RT for each bin in each group

Bin	*Experimental Group words*	*Experimental Group non-words*	*Control-1*	*Control-2*
1	**27ms**[*] $F(1,60) = 11.24$ $MSe = 667.62$ $\eta_p^2 = .16$	**18ms** $F(1,19) = .59$[a] $MSe = 5639.84$ $\eta_p^2 = .03$, $p = .45$	**30ms**[*] $F(1,60) = 14.59$ $MSe = 667.62$ $\eta_p^2 = .20$	**10ms** $F(1,60) = 1.66$ $MSe = 667.62$ $\eta_p^2 = .03$, $p = .20$
2	**41ms**[*] $F(1,60) = 15.01$ $MSe = 1158.84$ $\eta_p^2 = .20$	**37ms** $F(1,19) = .89$ $MSe = 14{,}991.09$ $\eta_p^2 = .04$, $p = .36$	**72ms**[*] $F(1,60) = 47.39$ $MSe = 1158.84$ $\eta_p^2 = .44$	**35ms**[*] $F(1,60) = 11.00$ $MSe = 1158.84$ $\eta_p^2 = .15$
3	**24ms** $F(1,60) = 1.11$ $MSe = 5312.99$ $\eta_p^2 = .02$, $p = .30$	**1ms** $F(1,19) = .00$ $MSe = 16{,}281.69$ $\eta_p^2 = .00$, $p = .99$	**123ms**[*] $F(1,60) = 29.97$ $MSe = 5312.99$ $\eta_p^2 = .33$	**57ms**[*] $F(1,60) = 6.42$ $MSe = 5312.99$ $\eta_p^2 = .10$
4	**−68ms**[b] $F(1,60) = 1.01$ $MSe = 48{,}366.90$ $\eta_p^2 = .02$, $p = .32$	**−102ms** $F(1,19) = 1.31$ $MSe = 79{,}000.05$ $\eta_p^2 = .06$, $p = .27$	**273ms**[*] $F(1,60) = 16.16$ $MSe = 48{,}366.90$ $\eta_p^2 = .21$	**145ms**[*] $F(1,60) = 4.54$ $MSe = 48{,}366.90$ $\eta_p^2 = .07$

[*] $p < .05$
[a] The simple contrasts for non-words in the Experimental Group were conducted within an ANOVA that involved the Experimental Group only, hence the difference in *MSe* and the number of degrees of freedom.
[b] One of the participants in this group had an exceptionally outlying negative value of −1250ms in this bin, *which is 3.02 standard deviations below the group mean*. When this participant is removed, the mean effect in this bin is −9ms, *F(1,59) = .02*, *MSe = 36,752.31*, *p = .88*, $\eta_p^2 = .0003$. *All the reported effects still hold when removing this participant from the overall ANOVA*.

MSe = 123,977.35, $\eta_p^2 = .70$, but not the main effect of Condition, *F(1,19) = .09*, *MSe = 62,321.18*, $\eta_p^2 = .004$. Also, the two-way interaction was non-significant, *F(3,57) = 2.14*, *MSe = 17,863.82*, *p = .11*, $\eta_p^2 = .10$. Despite the non-significant interaction, we continued to examine the simple contrast between the old and new conditions in each bin separately, in order to mirror the same analysis that was carried out with words. None of these simple contrasts were significant (see Table 2).

Accuracy (PE). An ANOVA was conducted for words only, with Group and Condition as independent variables. The main effect of Condition was significant, *F(1,60) = 27.00*, *MSe = .0028*, $\eta_p^2 = .31$, but not the main effect of Group, *F(2,60) = 1.43*, *MSe = .0041*, *p = .25*, $\eta_p^2 = .05$, or the two-way interaction, *F(2,60) = .52*, *MSe = .0028*, *p = .60*, $\eta_p^2 = .02$ (see Figure 1). The simple effect of Condition was significant in the Experimental Group, *F(1,60) = 10.37*, *MSe = .0028*, $\eta_p^2 = .15$, as well as in Control-1, *F(1,60) = 4.82*, *MSe = .0028*, $\eta_p^2 = .07$, and Control-2, *F(1,60) = 12.86*, *MSe = .0028*, $\eta_p^2 = .18$. The repetition effect did not differ between the Experimental Group and the control groups, *F(1,60) = .07*, *MSe = .0028*, $\eta_p^2 = .001$, *p = .79*, or between Control-1 and Control-2, *F(1,60) = .97*, *MSe = .0028*, $\eta_p^2 = .02$, *p = .33*.

A second ANOVA was conducted on the Experimental Group data, with Wordness and Condition as within-subject independent variables. Overall PE was 4% and 10% for old and new words, respectively, and 14% and 12% for old and new non-words, respectively. The main effect of Wordness was marginally significant, *F(1,20) = 4.08*, *MSe = .0190*, $\eta_p^2 = .17$, *p = .06*. The main effect of Condition was non-significant, *(1,20) = 2.56*, *MSe = .0020*, $\eta_p^2 = .11$, *p = .13*. However, the two-way interaction was significant, *F(1,20) = 5.28*, *MSe = .0054*, $\eta_p^2 = .21$. We investigated this interaction by looking at the simple effect of Condition within each level of Wordness. Performance was better with old words than with new words, *PE = 4%* vs. *10%*, respectively, *F(1,20) = 7.32*, *MSe = .0039*, $\eta_p^2 = .27$. The trend was opposite in non-words, *PE = 12%* vs. *14%* for new and old non-words, respectively, but the effects were non-significant, *F(1,20) = 1.40*, *MSe = .0034*, $\eta_p^2 = .07$, *p = .25*.

Recognition

Although recognition memory performance was not our main focus of interest in the present study, it is important to show that the differences observed in the lexical decision data do not reflect differences in overall recognition. For the old/new decisions, performance was measured as p(Hit) - p(FA), in order to correct for guessing. This measure was .64 in the Experimental Group, .76 in Control-1 and .65 in Control-2. A one-way ANOVA revealed a significant difference between the groups, $F(2,60) = 4.28$, $MSe = .0223$, $\eta_p^2 = .12$. This effect reflected a difference between Control-1 (who had 20 items in the study phase) and the other two groups (who had 40 items in the study phase), $F(1,60) = 8.45$, $MSe = .0223$, $\eta_p^2 = .12$, but not between the Experimental Group and Control-2, $F(1,60) = .11$, $MSe = .0223$, $p = .74$, $\eta_p^2 = .002$. This result shows that the difference between the groups in their lexical decision performance does not reflect differential memory for the items. The results of the confidence ratings and remember/know/guess decisions do not undermine these results, and were omitted for brevity.

GENERAL DISCUSSION

The major finding is that the portion of the repetition effect, which stemmed from the upper tail of the RT distribution in the control group, was completely absent in the high bins in the Experimental Group. This finding shows that the effect in the upper tail of the RT distribution mainly stems from using the strategic route, as hypothesised above.

The idea that fast and slow responses in lexical decision stem from different processes resembles Balota and Spieler's (1999) two-stage model. This model assumes that fast "word" or "non-word" responses are made when the familiarity/meaningfulness of the stimulus is judged to be very low (for non-words) or very high (for words). A second stage of more analytic processing is required when the familiarity/meaningfulness is intermediate. In these cases, the upper tail of the RT distribution is prolonged. Accordingly, our hypothesised strategic route could have been regarded as a new special case of analytic processing.

However, unlike Balota and Spieler's model, we claim that processing along the strategic route runs independently, in parallel to the lexical processing, rather than depending on its outcome. The parallel processing assumption is supported by two aspects of the data. First, if moving to strategic processing was contingent on unresolved lexical processing then RTs in the Experimental Group would have been faster overall than in the control groups. This finding would have been obtained because the strategic, recollection-based stage is ineffective in the Experimental Group and thus is not expected to take place at all, leading to shorter RTs compared to the conditions in which strategic processing could benefit the decision. In contrast to this prediction, overall RTs in the Experimental Group were slower, or at most equal, to those of the control groups (see Figures 1 and 2). Second, RTs for new words were about the same in all three groups, whereas RTs for old words were overall faster in the control groups compared to the Experimental Group (Figure 2). This pattern suggests that strategic processing results in speeding up performance, which fits nicely with the idea of parallel, self-terminating processing routes. On a more theoretical level, the parallel processing assumption is based on the idea of multiple memory systems that can work in parallel. While the lexical route is based on the implicit memory system, the strategic route is based on explicit memory. However, more work is still required in order to establish this point, as well as to examine the role of word frequency in the proposed model.

An important aspect of the results was that the repetition effect was preserved in the short bins of the Experimental Group. Namely, quick "word" responses are faster for old words than new words, in a situation where only the lexical route can lead to correct stimulus classification. Accordingly, this finding demonstrates automatic priming in early processing stages via the lexical route, which probably reflects implicit memory. Interestingly, the repetition effect in Bin 2, where it is the largest in the Experimental Group, was equal in the Experimental Group and Control-2, both having 40 items in the study phase, and larger in Control-1, having only 20 items to study. This finding shows that this component of repetition priming is sensitive to memory load, namely the number of items in the study list, and hence relies on a capacity-limited memory resource. At first glance, this seems to be at odds with studies showing implicit memory even after weeks, months or years (Mitchell, 2006), which lead to regarding implicit memory as unlimited. However, our results support recent theorising, claiming that implicit and explicit memory do not differ in their capacity limits (Lustig & Hasher, 2001; Reder, Park, & Kieffaber, 2009). Another interpretation regarding the difference in repetition effect in Bin 2 is that processing is faster along the strategic route in Control-1, leading to an earlier and larger repetition effect as compared to Control-1. Accordingly, while the repetition effect in Bin 2 reflects only automatic priming in the Experimental Group and Control-2, it reflects, in addition, some strategic processing in Control-1.

Two other findings are worth noting. RTs for non-words show a reversal of the ‘‘old’’ advantage in Bins 3 and 4, which is what would be expected if participants use ‘‘wordness’’ and ‘‘oldness’’ interchangeably in the strategic route. RTs to non-words likely reflect the inhibition participants need to exert to prevent themselves from responding ‘‘word’’ to previously seen (‘‘old’’) non-words (see Wagenmakers, Zeelenberg, Steyvers, Shiffrin, & Raaijmakers [2004] for similar ideas).

The other is the increasing old minus new difference in absolute RTs between the two control groups (or maintaining the proportion difference) from Bin 1 onwards. This finding suggests that the capacity limited memory resource operates very early in processing, and continues even at the long end of the distribution.

Finally, the priming effect in mean accuracy was still observed in the Experimental Group. More importantly, the repetition effect in accuracy did not differ among the groups. This finding might suggest that accuracy in this task reflects mechanisms other than, or in addition to, the ones responsible for priming in RTs. This possibility complicates the RT binning data, since it could be that the processes contributing to accuracy operate in a specific time window and affect RT accordingly. Another possibility is that the groups differed in speed–accuracy trade-off strategies. This account still needs to explain what caused the strategy differences, and how it affected the RT distribution data. Unfortunately, due to the small number of items in each bin, a full speed–accuracy analysis could not be conducted. Accordingly, it is advisable to deal cautiously with the accuracy data due to the relatively low statistical power in the error analysis.

The present work is the first, to the best of our knowledge, that systematically examines the consequences of adding non-words to the study phase, and how that influences the RT distribution. In doing so, as we noted earlier, it complements and advances previous work on the effects of non-word repetition in lexical decision in general (e.g. Meade, Watson, Balota, & Roediger, 2007; Ratcliff, Hockley, & McKoon, 1985; Wagenmakers et al., 2004) and on non-word priming in particular (e.g. Balota & Spieler, 1999; Forster & Davis, 1984; Logan, 1990).

In a broader perspective, several authors suggested that the terms ‘‘direct’’ and ‘‘indirect’’ memory tests should be used to distinguish between tasks that do and do not require memory retrieval (Johnson & Hasher, 1987; Merikle & Reingold, 1991; Moscovitch, 1984; Richardson-Klavehn & Bjork, 1988). These terms are neutral with regards to the type of memory process used in the task, as opposed to the terms ‘‘implicit’’ and ‘‘explicit’’. Specifically, indirect memory tests are defined as tasks ‘‘requiring the subject to engage in some cognitive or motor activity, when the instructions refer only to the task at hand, and do not make reference to prior events’’ (Richardson-Klavehn & Bjork, 1988, p. 478). The lexical decision task clearly falls into this category. However, as shown in the present study, ‘‘indirect’’ does not necessarily mean ‘‘automatic’’. Rather, we showed that the larger part of repetition priming in lexical decision should be regarded as a result of incidental processing (Perlman & Tzelgov, 2006), in which explicit retrieval benefits processing indirectly, although it (*namely, explicit retrieval*) is not explicitly required. The degree in which explicit retrieval strategies contribute to other indirect memory tests, and the time course of this contribution, are subject for important future study (see Sheldon & Moscovitch, 2010), as well as examining the dual-route model in situations involving incidental, rather than intentional, learning.

Taken together, our results suggest, consistent with Balota and Spieler (1999), that the larger part of the typical repetition priming effect observed in lexical decision tasks stem from an additional strategic process rather than from implicit memory in isolation. Our model differs from theirs in that our strategic process emphasises using explicit recognition for performing the task in parallel with implicit ones, whereas their strategic process is implemented as a second stage if the initial meaningfulness analysis does not yield a definite result. Our experimental manipulation demonstrated that when this explicit recognition strategy is rendered ineffective, repetition priming effects are eliminated at the mean level, and observed only in the fastest trials of the RT distribution, reflecting the residual, "real" contribution of implicit memory that is done via the lexical route. Importantly, our results suggest that the implicit memory contribution to repetition priming on the lexical decision task is much smaller than previously suggested and is expressed only in fast RTs. These finding have implications both for memory and for existing models of lexical decision.

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