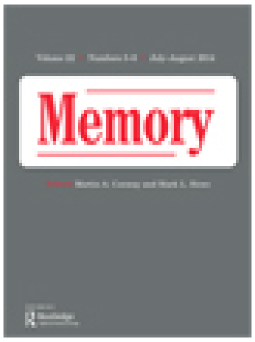

MEMORY

Routledge
Taylor & Francis Group

ISSN: 0965-8211 (Print) 1464-0686 (Online) Journal homepage: https://www.tandfonline.com/loi/pmem20

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To cite this article: Signy A. M. Sheldon & Morris Moscovitch (2010) Recollective performance advantages for implicit memory tasks, MEMORY, 18:7, 681-697, DOI: 10.1080/09658211.2010.499876

To link to this article: https://doi.org/10.1080/09658211.2010.499876

MEMORY, 2010, 18 (7), 681–697

Psychology Press
Taylor & Francis Group

Recollective performance advantages for implicit memory tasks

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A commonly held assumption is that processes underlying explicit and implicit memory are distinct. Recent evidence, however, suggests that they may interact more than previously believed. Using the remember–know procedure the current study examines the relation between recollection, a process thought to be exclusive to explicit memory, and performance on two implicit memory tasks, lexical decision and word stem completion. We found that, for both implicit tasks, words that were recollected were associated with greater priming effects than were words given a subsequent familiarity rating or words that had been studied but were not recognised (misses). Broadly, our results suggest that non-voluntary processes underlying explicit memory also benefit priming, a measure of implicit memory. More specifically, given that this benefit was due to a particular aspect of explicit memory (recollection), these results are consistent with some strength models of memory and with Moscovitch's (2008) proposal that recollection is a two-stage process, one rapid and unconscious and the other more effortful and conscious.

Keywords: Implicit memory; Explicit memory; Recollection; Familiarity; Priming.

Long-term memory is traditionally divided into declarative, explicit memory and non-declarative, implicit memory (Graf & Schacter, 1985; Schacter, 1987; Squire, 2004). Although past research focused on their independence, recent studies suggest that explicit and implicit memory may interact more than was previously believed (Kinoshita & Wayland, 1993; Schacter, Dobbins, & Schnyer, 2004). The present article will examine how aspects of explicit memory, specifically processes associated with recollection, are related to performance on implicit memory tasks.

Initial support for a distinction between implicit and explicit memory came from several studies that reported dissociations between the two types of memory at a functional, behavioural level in healthy participants (for review, see Roediger & McDermott, 1993). At a neuropsychological level, there was evidence of preserved performance on implicit memory tasks by individuals with amnesia, despite their impaired performance on explicit memory tests (for reviews, see Bowers & Schacter, 1993; Moscovitch, Vriezen & Goshen-Gottstein, 1993; Shimamura, Salmon, Squire, & Butters, 1987). These findings led to the suggestion that the medial temporal lobes (MTL) and related structures in the diencephalon that support explicit memory are not necessary for normal performance on implicit memory tasks.

This dissociation was questioned by a number of investigators (see review in Butler & Berry, 2001) with much of the early criticism being

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The authors would like to thank Keith Horton for graciously providing us with the stimuli used in Experiment 2 and Marilyne Ziegler for her help with programming. The authors would also like to thank NSERC for funding.

http://www.psypress.com/memory DOI:10.1080/09658211.2010.499876

concerned with the methods used to assess implicit and explicit memory (e.g., Hintzman & Hartry, 1990; Ostergaard & Jernigan, 1993; Shimamura, 1985). Some investigators noted that priming was impaired in patients with amnesia on a variety of measures (e.g., Schacter, Church, & Bolton, 1995; Squire, Shimamura, & Graf, 1987) such as perceptual-identification tasks (Yang et al., 2003), stem-completion tasks (Graf & Schacter, 1987), and stimulus-specific priming (e.g., Kinoshita & Wayland, 1993; Schacter et al., 1995) under some but not all conditions (Cermak, 1993; Gabrieli et al., 1994: Goshen-Gottstein, Moscovitch, & Melo, 2000; Musen & Squire, 1992). To reconcile these discrepant findings, Schacter, Wig, and Stevens (2007; see also Shacter, et al., 2004) proposed two different types of priming: one that relies on cortical-perceptual representations, independent of the MTL or explicit memory, and another that relies on MTL-based operations which are involved in establishing new associations.

Building on this proposal, Moscovitch (2008) suggested that all forms of priming can also be influenced by some explicit memory processes mediated by the MTL at an unconscious, automatic level. Supporting this more interactive view are neuro-imaging studies that have shown that similar brain regions, including the MTL and the hippocampus in particular, are active during both implicit and explicit memory tasks (e.g., Kirchoff, Wagner, Maril, & Stern, 2000; Turk-Browne, Yi & Chun, 2006). Consistent with this neuro-imaging evidence, Westmacott and Moscovitch (2002, 2003) used behavioural procedures to show that processes associated with recollection contribute to tests that are seemingly semantic and lexical, both of which figure prominently in studies of implicit memory. They asked healthy participants to perform tests of fame judgement and speeded reading of names of famous people that were associated pre-experimentally with either high or low recollective experience (R). For example, the name of Princess Diana was associated with a memory of where the participants were and how they felt when they heard of her fatal accident. By contrast, George Bush Sr, though equally familiar, evoked no recollection in most participants. Westmacott and Moscovitch found that not only was the performance on tests of recall and recognition (episodic based tests) better for high R names than low R names, but performance was also better (faster and more accurate) for high R names than low R names on the tests of fame judgement and speeded reading, which can be considered as conceptual and perceptual implicit memory tasks, respectively. In a later study, Westmacott, Black, Freedman, and Moscovitch (2004) found that the advantage for high R names was absent in patients with focal MTL lesions or degeneration (Alzheimer's disease), whose recollection is severely compromised, but not in patients with semantic dementia whose MTLs, and recollections, are relatively preserved. They concluded that the contribution of recollection on these tasks is dependent on the MTL (for reviews, see Aggleton & Brown, 1999; Eichenbaum, Yonelinas, & Ranganath, 2007).

Based on these findings, Tulving's (1983) description of ecphory and retrieval, and the component process model (Moscovitch, 1992), Moscovitch (2008) proposed that recollection is a two-stage process: The first stage (ecphory) is fast, relatively automatic, operates outside conscious awareness, and is hippocampus dependent; the second stage is slower, requires conscious awareness, and depends on the interaction of the prefrontal and parietal cortices with the hippocampus (see reviews by Cabeza, Ciaramelli, Olson, & Moscovitch, 2008; Ciaramelli, Grady, & Moscovitch, 2008). According to this proposal, a target associated with a prior event is broadcast to all systems, including those that support recollection. The interaction between the stored information and its output occurs rapidly, automatically and outside conscious awareness (ecphory), and can influence other ongoing processes related to the target. At a later stage, conscious awareness of the output results in the experience of recollection. Thus the initial, rapid process reflects access to recollected information. Subsequent, slower processes make that content available to consciousness.

According to this two-stage model, the recollection advantage evident on tests of semantic memory and lexical processing should be observed not only for memories acquired pre-experimentally as in the Westmacott and Moscovitch studies (2002, 2003), but also for memories acquired in traditional laboratory settings. Thus we conjecture that processes that support rapid recollection should influence performance on a variety of implicit memory tasks (Moscovitch, 1992; Moscovitch et al., 1993; Schacter et al., 2004). An alternative possibility is that the strength of the memory trace influences performance on both explicit and implicit tests of memory. Since recollection is typically associated with greater memory strength than is familiarity, the underlying trace may also contribute to performance on implicit tests. For ease of exposition, we focus on the two-stage model and will return to the strength account in the General Discussion.

Of note, the two-stage model is similar to the concept of fluency reprocessing proposed by Jacoby and Dallas (1981), which states that an initial experience with a stimulus will result in more efficient processing when the stimulus is encountered later, both in terms of implicit and explicit decisions. In later work, Jacoby (1991) developed the process dissociation procedure (PDP) that enabled researchers to separate the later strategic, conscious recollection component from the non-conscious aspects of memory. However, in doing so, the possibility was not considered that using the PDP may preclude the discovery that early, non-strategic stages of recollection can influence implicit memory as suggested by the two-stage model of recollection (see General Discussion for an elaboration of this point).

It is also important to note here that, according to this proposal, implicit memory is not *contaminated* by explicit memory in the sense that voluntary, conscious retrieval of information influences performance on implicit tests (see MacLeod, 2008; see also Gardiner, Richardson-Klavehn, Ramponi, & Brooks, 2001, for a treatment of this issue), but rather that automatic processes associated with recollection benefit performance on such tests. Indeed, the influence of these rapid processes should be evident on the very implicit tests that have been shown to be immune to the deliberate, contaminating effects of explicit memory.

To test our hypothesis that processes underlying recollection benefit performance on implicit memory tasks, we performed two experiments using the type of implicit memory tests that have been shown to be relatively resistant to contamination by voluntary retrieval of explicit memory (Goshen-Gottstein, & Moscovitch, 1995: Horton, Wilson, & Evans, 2001).

The procedure used in both experiments had four phases: A study phase in which words were presented, a phase in which a distractor task was presented, an implicit memory test for those words, and a subsequent recognition test phase that used the remember–know procedure (R/K; Tulving, 1985). In the first experiment the implicit test was lexical decision, whereas in the second experiment it was speeded stem completion. In both cases we investigated whether performance on the implicit test varied according to whether the words were subsequently judged to be recollected, familiar, or new via the R/K procedure (Tulving, 1985). We predicted that words that were subsequently recollected would be associated with greater priming effects (faster performance to previously studied items) on the implicit memory tasks than would words that were subsequently given a familiarity rating or those that had been studied but not recognised (misses). All of the words in the above categories, of course, would be expected to elicit better performance than new words.

We are mindful that the remember–know procedure is controversial at both a methodological and theoretical level (e.g., see Dunn, 2004). As we noted earlier, dual- or single-strength models have been proposed to account for the data derived from studies using the remember–know procedure without appealing to threshold dual process accounts of familiarity and recollection (e.g., Rotello & Macmillan, 2006; Wixted, 2007). Before we consider which of the various theories best accounts for the data, it is important to establish empirically that a relation exists between performance on implicit memory tasks and recollection as indexed by remember responses. For ease of exposition we adopted the dual-stage framework to provide a theoretical rationale for our studies, but have tried to be as operational as possible in describing the procedures and results. We defer a discussion of alternative interpretations of our findings to the end of the paper.

EXPERIMENT 1A

In this experiment we used the remember–know procedure (Gardiner, 1988; Tulving, 1985) and a lexical decision task to examine the influence of the processes underlying recollection and familiarity on tests of implicit memory. We chose the lexical decision task because it is likely that the rapidity of making such decisions precludes the possibility of contamination by voluntary, explicit retrieval. Although the R/K procedure does not map directly onto recollection and familiarity, it was chosen because it provides a tolerable first approximation of these processes by capturing the subjective experiences of recognition: participants classify old items as *remember* (R) if they consciously recollect details or the context of their occurrence during the study phase, or as *know* (K) if they cannot recollect specific information associated with the occurrence of the item. According to the dual-process model of recognition memory, R responses are based on the process of recollection in episodic memory, whereas K responses are based on the process of familiarity (Tulving, 1985). According to the two-stage model of recollection (Moscovitch, 2008), we hypothesised that words that are later recollected (R responses) will be associated with faster lexical decision response times (greater priming) and, by inference, better implicit memory than words that are later recognised on the basis of familiarity (K responses).

An important note is that we refer to familiarity (K responses) as explicit because, as measured by the R/K procedure, participants are stating that they explicitly recognise an item as old when they give it a K response. Further, we consider the possibility that processing fluency underlies this decision in the discussion to Experiment 1a and test it in Experiment 1b.

Method

Participants. A total of 18 people between the ages of 19 and 28 years ($M = 21.4$) participated in this study in exchange for course credit or an honorarium of $10. Of the participants, 11 were female. All were right-handed, had normal or corrected to normal vision, and were free from neurological or psychiatric illness, and English was their primary language.

Stimuli. The stimulus set consisted of two lists of 120 words. All of the words were monosyllabic nouns, four to six letters long, low frequency (between 2 and 10 occurrences per million words; Kucera & Francis, 1967), and highly concrete (400–700; Coltheart, 1981).

Procedure. Each list was used in an experimental cycle that consisted of four phases: study phase, distractor phase, lexical decision phase, and recognition test phase. All words were presented in 25-point Courier font in the centre of a computer screen, approximately 60 cm away from the participant.

For the study phase participants were instructed to study 40 words that appeared one at a time for 2000 ms. A 500-ms fixation cross appeared during the inter-word interval. During the distractor phase participants completed 3 minutes of a task in which they were to decide which of two mathematical equations would result in a larger value. Participants completed as many sets of this problem as possible within the time limit. Participants then completed the lexical decision phase, in which they were instructed to indicate by a key press whether the stimulus that appeared in the centre of the computer screen was a real word. The words were presented one at a time with an inter-word 250-ms fixation cross. The 40 words from the study phase, 40 new words, and 80 nonwords made up the stimulus set. The nonwords were taken from the ARC nonword database (Rastle, Harrington, & Coltheart, 2002). The participants were told to respond by pressing the “1” button if what they saw was a word and the “2” button if it was not. They were told to use only their dominant hand and to respond as quickly and as accurately as possible. Finally, participants completed the recognition test phase. Participants were told that words would be presented one at a time in the centre of the computer screen and they were to decide whether the word was one that they recollected from the study phase, was one they knew from the study phase, or was one that they believed was new. They responded by pressing the “1” button if the word they saw was one they recollected (R response), the “2” button if the word they saw was one they knew (K response), and the “3” button if the word they saw was one they believed was new (N response). They were told to use only their dominant hand and to respond as quickly and accurately as possible. The participants were given sufficient definitions and examples of remember, know, and new responses and were reminded several times that these judgements were to be made on only the studied words. The words presented in this phase consisted of the 40 studied words (phase 1), the 40 words that appeared only in the lexical decision phase (phase 3), and 40 new words.

The appearance of a word as a studied word, lexical decision new word, or test phase new word was randomised across participants. The presentation of words within each phase was randomised for each participant. Each participant completed two cycles of the above experiment with a simple problem-solving distractor phase in between cycles to minimise carry-over from one experimental cycle to the other. The order of lists for the two experimental cycles was counterbalanced across participants.

TABLE 1A

Means estimates of hits, misses, false alarms, correct rejections, and d prime for all experiments

	Hits	*Misses*	*False alarms*	*Correct rejections*	*d′*
Experiment 1a					
Overall	0.80 (0.02)	0.20 (0.02)	0.42 (0.04)	0.58 (0.04)	1.04
R responses	0.46 (0.04)		0.11 (0.02)		1.13
K responses	0.35 (0.03)		0.31 (0.02)		0.11
Experiment 1b					
Overall	0.80 (0.02)	0.20 (0.03)	0.46 (0.04)	0.54(0.04)	1.02
R responses	0.51 (0.03)		0.17 (0.03)		0.98
K responses	0.29 (0.03)		0.29 (0.03)		0.0
Experiment 2					
Overall	0.84 (0.02)	0.16 (0.02)	0.12 (0.03)	0.88 (0.03)	2.17
R responses	0.46 (0.03)		0.02 (0.01)		1.95
K responses	0.39 (0.03)		0.10 (0.01)		1.00

Means estimates of hits, misses, false alarms, correct rejections, and d prime for Experiment 1a, Experiment 1b, and Experiment 2 (standard errors are shown in parentheses next to the corresponding means).

Results

Recognition accuracy. As Table 1a shows, the proportion of responses that were correctly identified as either old (hits) or new (correct rejections) via the R/K procedure was significantly different from chance, $t(17) = 17.97$, $p < .001$. Further, the difference between R responses to old items (hits) and to new items (false alarms) was greater than this difference for K response items. This impression was confirmed by a repeated-measures ANOVA that examined the proportions of responses for old and new words in each of the test response categories (R, K, N). There was no difference in the proportion of responses between old and new words, $F(1,17) = 0.46, p > .05$, but there was a main effect of response, $F(2,34) = 4.89$, $p < .05$, and an interaction between the word type and response given, $F(2,34) = 61.40, p < .001$. Specifically, there were more R responses given to old words than to new words, $t(17) = 8.20$, $p < .001$ (Cohen's $d =$ 6.34) and more N responses given to new words compared to old words, $t(17) = 9.43$, $p < .001$ (Cohen's $d = 6.98$), but there was no difference in the proportion of K responses between old and new words, $t(17) = 1.37$, $p > 0.05$ (Cohen's $d =$ 0.75).

Because new words were of two types, those that appeared in the lexical decision phase for the first time and those that appeared only in the test phase, we divided them into these two categories and entered these values in a subsequent analysis (see Table 1b). There was a significant difference across the response types, $F(2, 34) = 47.81$, $p < .001$, and a significant interaction between the type of new word and the response given, F(2, 34) = 82.86, $p < .001$. Simpler comparisons revealed that there were more R responses (R false alarms) and K responses (K false alarms) for the new words that appeared in the lexical decision phase than the test phase new words, $t(17) = 5.67$, $p < .001$, Cohen's $d = 3.58$; $t(17) = 6.57$, $p < .001$, Cohen's $d = 3.91$, respectively, but more N responses (correct rejections) for the test phase new words than the lexical decision phase new words, $t(17) = 14.20$, $p < .001$ (Cohen's $d = 5.59$).

Comparing the proportion of responses across R, K, and N response types and the three word types (old, lexical decision new, test new), we found that there was a significant interaction, $F(4, 68) = 64.12$, $p < .001$. Both the lexical decision new words and test new words had significantly fewer R responses compared to old words; $t(17) = 5.68$, $p < .001$, Cohen's $d =$ 4.01; $t(17) = 9.59$, $p < .001$, Cohen's $d = 8.01$,

TABLE 1B

Proportion of R, K, and N responses for new words: Experiments 1a and 1b

	R response	*K response*	*N response*
Experiment 1a			
Lexical Decision New	0.18 (0.03)	0.41(0.02)	0.40 (0.04)
Test New	0.04 (0.01)	0.21 (0.03)	0.76 (0.04)
Experiment 1b			
Lexical Decision New	0.28 (0.03)	0.31 (0.03)	0.40 (0.03)
Test New	0.10 (0.02)	0.23 (0.04)	0.68 (0.05)

The proportion of R, K, and N responses for the two types of new words (lexical decision new words and test new words) for Experiment 1a and Experiment 1b (standard errors are shown in parentheses next to the corresponding means).

respectively. There were fewer K responses, $t(17) = 3.18$, $p < .005$, Cohen's $d = 3.58$, for test phase new words than old words (but not for the lexical decision new words). Also, old words were given significantly fewer N responses (misses) than both lexical decision new words and test new words: $t(17) = 4.71$, $p < .00$, Cohen's $d = 3.73$; $t(17) = 12.27$, $p < .001$, Cohen's $d = 9.11$, respectively.

Reaction time. To examine the effect of word type (old versus new) on response time (RT) during the lexical decision phase, we calculated each participant's mean RT to make a lexical decision. To ensure that lexical decision RT was accurately reflected by the mean RT, we set a response criterion of at least 10 correct responses in each of the critical experimental categories. This involved testing 26 participants to get 18 who met this criterion (only the data for the 18 participants who met the response criterion were included in the above recognition accuracy analyses). Furthermore, RTs that were too fast (less than 350 ms) or too slow (greater than 3500 ms) were eliminated, as were RTs associated with incorrect lexical decision responses. This eliminated less than 8% of the total responses across all participants.

The mean RT to old words was 680 ms ($SD = 110$ ms), which was faster than the mean RT to new words (730 ms, $SD = 119$). A paired sample *t*-test confirmed that this difference was significant, $t(17) = 4.31, p < .001$ (Cohen's $d = 0.97$) indicating that there was a priming effect in this experiment.

Given that participants completed two study–test cycles, a repeated measures ANOVA was run on the mean lexical decisions RTs for old and new words with list order as the within-participants factor. Not surprisingly, there was a main effect of word type, $F(1, 17) = 18.97, p < .001$; however, the effect of list order was not significant, $F(1, 17) = 1.49$, $p > .05$, nor was the interaction between word type and list order, $F(1, 17) = 0.09$, $p > .05$. This confirms that list order did not affect the pattern of results for this study.

Mean RTs to words presented in the lexical decision phase were then categorised according to their associated response in the test phase. Therefore we had a total of six experimental categories: old words given a remember (R), know (K), or new (N) response, and new words given a remember (R), know (K), or new (N) response. The corresponding means are reported in Table 2.

TABLE 2
Mean lexical decision response times: Experiments 1a and 1b

Word type	*R response*	*K response*	*N response*
Experiment 1a			
Old	656 (21.8)	692 (26.9)	703 (32.9)
New	721 (36.2)	713 (25.3)	751 (35.4)
Experiment 1b			
Old	696 (26.7)	681 (34.5)	657 (27.4)
New	670 (30.7)	699 (35.0)	697 (34.3)

Mean lexical decision response times (in ms) as a function of study status and recognition response (standard errors are shown in parentheses next to the corresponding means) in Experiment 1a (experimental condition) and Experiment 1b (control condition).

Since there were few participants who reached the appropriate response criterion (10 responses) for new words given R responses (recollection false alarms) and old words given N responses (misses), we first will focus on the three conditions in which the associated test response was correct (old words with a R response, old words with a K response, new words with a N response).

From Table 2 it is evident that RTs to old words with a R response and to old words with a K response were significantly faster than to new words with a N response. Furthermore, RTs to old words with a R response were significantly faster than to old words with a K response. A repeated-measures ANOVA confirmed this pattern. RTs were significantly different across the three types of words, $F(1.57, 26.83) = 11.69$, $p < .001$; degrees of freedom corrected using the Huynh-Feldt estimates of sphericity. Simple planned comparisons revealed that RTs to old words with a R response were faster than RTs both to old words with a K response, $t(17) = 3.41$, $p < .005$ (Cohen's $d = 0.74$) and to new words with a N response, $t(17) = 4.68$, $p < .001$ (Cohen's $d = 1.67$). RTs to old words with a K response were also faster than to new words with a N response, $t(17) = 2.98$, $p < .01$ (Cohen's $d = 0.95$).

RTs to words with the appropriate R, K, and N responses were also compared to the overall mean RT for all old words and all new words. A repeated-measures ANOVA revealed significant differences between these responses, $F(4, 68) = 11.21, p < .001$. RTs to new words with a N response were not significantly different from RTs to all new words, regardless of their subsequent memory response, $t(17) = 1.51$, $p > .05$ (Cohen's $d = 0.35$). Furthermore, RTs to old words with a R response were significantly faster than the RTs to all new words, $t(17) = 5.91, p < .001$ (Cohen's $d = 1.58$), as were RTs of old words with a K response, $t(17) = 3.26$, $p < .01$ (Cohen's $d = 0.74$). RTs to old words with a R response were also significantly faster than the mean RTs of all old words, $t(17) = 2.73$, $p = .014$ (Cohen's $d = 0.56$), but that was not the case for RTs to old words with a K response, $t(17) = 1.54$, $p > .05$ (Cohen's $d = 0.22$).

One question that was important to address is whether RTs to items that were studied but not recognised (misses) were faster than the RTs to items that were not studied, and whether misses differed from old words given correct R and K responses. To examine this, we performed a repeated-measures ANOVA on RTs to all old words categorised by their subsequent memory response (R, K, N) and to new words correctly recognised as N. A note of caution is that, in this analysis, some participants did not contribute an adequate number of responses (i.e., 10 or greater) to the old words given an N response condition (misses). Nevertheless, these analyses found a significant difference across the four responses, $F(3, 51) = 9.49$, $p < .001$. Simple planned comparisons revealed a significant difference between RTs to old words given a R response and to those given a N response, $t(17) = 2.42$, $p < .05$ (Cohen's $d = 0.86$), no significant difference between RTs to old words given a K response and those given a N response, $t(17) = 0.62$, $p > .05$ (Cohen's $d = 0.18$), and a significant difference between RTs to old words given a N response and new words given a N response, $t(17) = 2.62$, $p < .05$ (Cohen's $d = 0.70$).

Discussion

In Experiment 1a we found that studied words later recognised via R responses were associated with faster lexical decision RTs (more priming) than both studied words later given a K response and new words. Furthermore, studied words that were given a R response were significantly faster than those given a N response (misses). This was not the case for old words given a K response as compared to misses, although both had faster RTs compared to new words correctly labelled as new (N response). This suggests that processes underlying explicit memory per se do not confer a benefit to priming because priming associated with K responses (presumably based on familiarity) is no greater than that for studied items that were missed (but see below). It is only the processes underlying R responses (presumably recollection) that contribute to priming beyond what typically is reported on implicit memory tasks.

These priming results need to be interpreted in light of the accuracy performance on the recognition test. Accuracy was greater for old words given R responses than for K responses. Hits given R responses were significantly greater than R response false alarms (FA), but hits and FA were equivalent for K responses. As well, the proportion of FA was greater for new words that appeared in the lexical decision phase as compared to words that appeared for the first time at test. Overall, these findings suggest that when assigning a K response, participants could not distinguish old from new items, although they could do so on the basis of recollection. These results may reflect K responses relying primarily on item memory. Participants had seen the targets and many of the lures during the priming phase, thus making item memory a poor basis for distinguishing between them.

In light of the poor accuracy performance of K responses, the equivalent RTs to K responses to words recognised (hits) and words not recognised (misses), both of which were significantly faster than to new words, suggest that priming for K responses is independent of explicit memory, and vice versa. Had fluency of processing influenced recognition memory for K responses, then it would have paralleled the priming results, and better memory would have been observed for old items than for new ones, which was not the case.

There remains the possibility that the particular words presented in the experiment have attributes that led to both greater priming and recollection. That is, some underlying item characteristic may have influenced both RTs during the lexical decision phase and performance on the recognition test. Similarly, it is possible that studied words with a fast RT induced a R response on the subsequent test, or led to greater fluency of processing on the subsequent test which influenced both R and K responses, although as we noted the likelihood of this affecting K is low. Thus, before accepting the above conclusion that recollection benefits priming disproportionately, it is necessary to examine these alternative hypotheses. To do so, we conducted Experiment 1b.

EXPERIMENT 1B

The purpose of Experiment 1b was to rule out the possibility that the relation observed in Experiment

1a was determined by item characteristics that influence both lexical decision RTs and item memorability (Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004) or the possibility that the items associated with the fastest RTs on the lexical decision task provoked R responses at recognition. To test this we replicated Experiment 1a, but with the experimental phases presented in a different order. Participants first made lexical decisions, then studied a list of words that included those presented in the lexical decision phase, and then were tested for their recognition of the studied words. If lexical decision speed or other item characteristics are a factor in determining the subsequent memory of a later studied word, then items with the fastest lexical decision RTs should be the ones given R responses rather than those given K responses at recognition. On the other hand, if lexical decision speed or other item characteristics are not a determining factor, then there should be no relation between the lexical decision RTs and studied words given a R or a K response.

Method

Participants. A total of 18 people selected from the same participant pool as in Experiment 1a completed this experiment. This involved testing 25 participants to get 18 participants who appropriately met the criterion stated in Experiment 1a. The participants mean age was 21.0 years and 13 were female.

Stimuli and procedure. The stimulus set was the same as that used in Experiment 1a. The experimental task differed only in terms of order of tasks (phases). In this experiment, participants completed (1) the lexical decision phase, (2) the study phase, (3) the distractor phase, and then (4) the test phase.

Results and discussion

Recognition accuracy. Shown in Table 1a, the proportion of responses that were correctly identified as either old (hits) or new (correct rejections; CR) was significantly different from chance, $t(17) = 19.60$, $p < .001$. A repeated measures ANOVA examining the proportions of responses given to old and new words in each of the response categories (R, K, N) showed that there was no difference in proportion between old and new words, $F(1,17) = 1.00$, $p > .05$, no difference in the proportion of responses, $F(2, 34) = 1.57$, $p > .05$, but an interaction between word type and response given, $F(2, 34) = 66.45$, $p < .001$. Simpler comparisons showed that there were more R responses given to old words than new words, $t(17) = 8.15$, $p < .001$ (Cohen's $d = 5.24$), more N responses given to new words compared to old words, $t(17) = 9.63$, $p < .001$ (Cohen's $d = 6.08$), but no difference in the proportion of K responses between old and new words, $t(17) = 0.12$, $p > .05$ (Cohen's $d = 0.05$).

As in Experiment 1a, we investigated the influence exerted by the two types of new words on the proportion of responses (Table 1b). There was a significant difference across the response types, $F(2, 34) = 48.17$, $p < .001$, and a significant interaction between the type of new word and the response given, $F(2, 34) = 8.26$, $p = .001$. There were more R responses (FA) for the new words that appeared in the lexical decision phase than for the test phase new words, $t(17) = 4.02$, $p < .001$ (Cohen's $d = 3.54$), a similar number of K responses across the type of new words, $t(17) = 0.69$, $p > .05$ (Cohen's $d = 0.66$) and more N responses (CR) for the test phase new words than the lexical decision phase new words, $t(17) = 3.20$, $p = .005$ (Cohen's $d = 2.77$).

Importantly, comparing the proportion of responses across R, K and N response types and the three word types (old, lexical decision new, test new), we found a significant interaction, $F(4, 68) = 23.13$, $p < .001$. Both the lexical decision new words and test new words had significantly fewer R responses than old words, $t(17) = 3.41$, $p < .005$ (Cohen's $d = 3.32$; $t(17) = 10.89$, $p < .001$ (Cohen's $d = 6.63$), but there was no difference in the proportion of K responses compared to old words, $t(17) = 0.17$, $p > .05$ (Cohen's $d = 0.05$); $t(17) = 1.28$, $p > .05$ (Cohen's $d = 0.64$). Also, old words were given significantly fewer N responses than both lexical decision new words and test new words, $t(17) = 4.68$, $p < .001$, (Cohen's $d = 4.20$); $t(17) = 10.05$, $p < .001$ (Cohen's $d = 6.50$), respectively.

Reaction time. As in Experiment 1a, the mean RTs to all old words and new words were first compared. It is important to note that since the lexical decision phase preceded the study phase, old words were not actually "old" when the participants made the lexical decision; however, to make appropriate comparisons to Experiment 1a, we will use this terminology. The mean RT to old words (682 ms, $SD = 105$ ms) was not significantly different from the mean RT to new words (mean = 686 ms, $SD = 124$); $t(17) = 0.31$, $p > .05$ (Cohen's $d = 0.08$). This was expected since participants were seeing both old and new words for the first time in this experiment.

Following Experiment 1a, mean RTs to words presented in the lexical decision phase were then categorised according to their associated responses in the test phase (R, K, N). These mean RTs are reported in Table 2. A repeated-measures ANOVA indicated that RTs were not significantly different across the three types of correct responses, $F(2, 34) = 0.14$, $p > .05$. Again, none of the simple comparisons that were significant in Experiment 1a was significant in this experiment—Old-R responses: Old-K responses, $t(17) = 0.48$, $p > .05$, Cohen's $d = 0.25$; Old-R responses: New-N responses, $t(17) = 0.09$, $p > .05$, Cohen's $d = 0.05$; Old-K responses: New-N responses, $t(17) = 0.36$, $p > 0.05$, Cohen's $d = 0.18$.

RTs to old words with R and K responses and to new words with N responses were also compared to the overall mean RTs for all old words and all new words. A repeated-measures ANOVA did not reveal significant differences between these responses, $F(4, 68) = 0.17$, $p > .05$. Again, none of the simple planned comparisons that were significant in Experiment 1a was significant in this experiment.

We also performed a repeated-measures ANOVA on the RTs to all old words categorised by their subsequent memory response (R, K, N) and to new words correctly recognised as N (see note of caution from Experiment 1a), and did not obtain a significant difference across the four responses, $F(3, 51) = 0.92$, $p > .05$. Not surprisingly, there was no significant difference between RTs to old words given a R response and to those given a N response, $t(17) = 1.9$, $p > .05$ (Cohen's $d = 0.77$), between RTs to old words given a K response and to those given a N response, $t(17) = 0.85$, $p > .05$ (Cohen's $d = 0.43$), nor between RTs to old words given a N response and to new words given a N response, $t(17) = 2.08$, $p > .05$ (Cohen's $d = 0.63$).

To assess further the possibility that some features of specific items led to fast lexical decision RTs as well as an increased likelihood that the item would be recollected, we used the average RTs for each word in Experiment 1b as a baseline measure to adjust the RTs from Experiment 1a in an item-specific manner. That is, for each participant in Experiment 1a, we subtracted the baseline calculated from the RTs collected Experiment 1b for each item. Then we did the same analysis as stated previously wherein we compared the average mean RTs to items given R, K and N responses. If there were an item-specific contribution to the recollection superiority effect, this procedure would nullify it. Importantly, we found the same pattern as in Experiment 1a. That is, there was a significant difference between RTs to old words given a R response, old words given a K response, missed old words and new words given a N response, $F(3, 51) = 6.99$, $p = .001$. Simple comparisons revealed that RTs to old items given a R response, a K response, and a N response (missed items) items were faster than RTs to correctly labelled new items, $t(17) = 4.65$, $p < .05$ (Cohen's $d = 1.03$); $t(17) = 2.46$, $p < .05$ (Cohen's $d = 1.04$); $t(17) = 2.32$, $p < .05$ (Cohen's $d = 0.80$), respectively.

Importantly, RTs to old items given a R response were faster than to old items given a K response, $t(17) = 2.15$, $p < .05$ (Cohen's $d = 0.62$) and to missed old items $t(17) = 2.21$, $p < .05$ (Cohen's $d = 0.80$), but RTs to old items given a K response were not different from RTs to missed old items, $t(17) = 0.53$, $p < .05$ (Cohen's $d = 0.19$). This demonstrates that there is not some item characteristic that is leading to fast lexical decision RT and better recognition memory.

EXPERIMENTS 1A AND 1B: DISCUSSION

Experiment 1a suggests that processes associated with R responses can benefit performance on implicit memory tasks. Experiment 1b rules out the possibility that lexical decision speed or other item characteristics were the cause of the effect found in Experiment 1a because there was no relation between RT and item memorability when the lexical decision RTs were measured *before* the study phase.

Overall, the results of these experiments are consistent with the hypothesis that recollective processes underlying R responses that are presumed to be involved exclusively in explicit memory also influence performance on tests of implicit memory. We believe that this finding is unlikely to be related to contamination of implicit memory performance by voluntary retrieval of information from episodic memory (see MacLeod, 2008). First, the R advantage was found on a test of lexical decision, which has been shown to be insensitive to deliberate contamination (Goshen-Gottstein, & Moscovitch, 1995). Second, the mean lexical decision RT, which was on the order of 760 ms, was much faster than the mean RT to make a recognition response, which was on the order of 1200 ms, a decision that requires conscious retrieval. Third and more importantly, the traditional priming advantage for unrecognised studied items (misses) over unstudied items, which constitutes the basis of uncontaminated priming, was no different than the priming advantage for familiar words (K responses). These familiar words are also considered part of explicit memory (because they are recognised on the memory test) and are therefore as open to "contaminated" priming as recollected words. However, the priming augmentation pertained only to R responses.

It is important to note that although the proportion of R response hits was greater than R response FA, this was not the case for the difference between K response hits and FA. This indicates that participants could distinguish between targets and lures on the basis of recollection, which capitalises on context or source information, but not on the basis of familiarity, which depends only on item information. Thus, whereas priming seems to benefit from explicit memory for words associated with R responses, equivalent priming was obtained for K hits and misses. This suggests that priming for the latter cases (K responses), but not the former case, is similar to that obtained by patients with amnesia whose explicit memory is severely impaired. The significance of this finding for strength theories of memory will be considered in the General Discussion.

Because of the implications these findings have for theories of explicit and implicit memory, it is important to determine whether the R advantage seen here generalises to other implicit memory tasks. We conducted a second study using word stem completion; one of the most commonly used implicit tests of memory.

EXPERIMENT 2

To examine the effects of processes underlying recollection and familiarity on word-stem completion we chose the Horton et al. (2001) procedure for administering this task because it has been shown to be minimally affected by explicit, conscious retrieval. Thus we can assess whether automatic processes associated with R responses affect performance on implicit tasks without a voluntary, conscious retrieval component and thereby establish the generality of the R advantage on implicit tasks.

In the Horton et al. (2001) procedure participants study a list of words, and then receive a practice stem completion test in which none of the stems corresponds to the studied words, and during which participants respond as quickly as possible. The inclusion of this task minimises any bias participants may have to adopt the strategy of using explicit memory of studied words to complete the task. After the practice test, participants are given the stem completion phase in which half of the stems can be completed with the studied words. Again, they are encouraged to complete the stems as quickly as possible. Horton et al. (2001) found that participants under this procedure completed critical stems more quickly than participants who performed this task but were asked to switch to a conscious retrieval strategy. The faster RTs during the speeded variation of the task compared to the conscious retrieval strategy variation are thought to represent the exclusion of conscious, deliberate retrieval from the speeded version.

Following the results of Experiment 1a and 1b, we hypothesised that even in the case where explicit retrieval is not emphasised, automatic processes associated with R responses will benefit performance on the word stem completion task. To test this we modified the above-described speeded variation of the stem completion task so that we could assess subsequent memory using the R/K procedure, as described in Experiment 1a. We expected that stem completion RTs would be faster for words associated with a R response than for words associated with a K response.

Method

Participants. A total of 28 people selected from the same participant pool as in Experiment 1a completed this experiment. Of these, 16 met the set response criterion as described in Experiment 1a, and were included in this experiment. The mean age was 18.9 years and nine of the participants were female.

Stimuli. The stimulus set used in this experiment consisted of 180 words and their respective stems chosen from a normative set of word stem responses (Horton, 1989). The words were chosen so that their stems had a 0.10 to 0.30 probability of being completed with the critical word.

Furthermore, all stems were unique within the stimulus set list.

Procedure. Participants completed five phases: study phase, practice stem completion phase, distractor phase, critical stem completion phase, and test phase. Words were randomly assigned to a phase for every participant. For the study phase, participants were asked to rate the pleasantness of 60 words on a scale of 1 to 5, indicating their responses by key presses. The practice phase consisted of 60 stems in which the participants were instructed to complete the stem as quickly as possible with the first word that came to mind. None of these stems could be completed with the studied words. Their response times were recorded via a microphone. As well, the experimenter recorded the responses. In the distractor phase, participants completed a 3-minute distractor task in which they had to decide which of two mathematical equations would result in a larger value. Participants completed as many of these problem sets as possible within the time limit. The critical implicit phase consisted of the same stem completion task as the practice phase; however, the stimulus set for this task consisted of the 60 words from the study phase (critical words) and 60 new stems. The R/K recognition test phase was the same as that described in Experiment 1a. The words presented in this phase consisted of the 60 studied words (phase 1) and 60 words that could be used to complete the new stems seen in the critical stem completion phase.

Results

Recognition accuracy. As shown at the bottom of Table 1a, the proportion of responses that were correctly identified as either old or new was significantly different from chance, $t(15) = 34.68$, $p < .001$. A repeated-measures ANOVA that examined the proportions of responses given to old and new words in each of the response categories showed that there was no significance in proportions between old and new words, $F(1,15) = 0.00$, $p > .05$, but a significant difference in the proportions across responses, $F(2, 30) = 61.74$, $p < .001$, and a significant interaction between the word type and response given, $F(2, 30) = 266.31$, $p < .001$. There were more R responses given to old words than given to new words, $t(15) = 13.35$, $p < .001$ (Cohen's $d = 13.48$), more K responses given to old compared to new words, $t(15) = 8.96$, $p < .001$ (Cohen's $d = 6.46$), and more N responses given to new words compared to old words, $t(15) = 23.50$, $p < .001$ (Cohen's $d = 18.94$). Unlike Experiment 1a and 1b, there was only one type of "new" word.

For old words, there was a significant difference in the proportion of responses given in each of the three response types, $F(2, 30) = 24.38$, $p < .001$. There were significantly more R responses and K responses than N responses, $t(17) = 6.74$, $p < .001$ (Cohen's $d = 6.88$; $t(17) = 6.97$, $p < .001$ (Cohen's $d = 5.69$), respectively, but no difference between the proportion of K responses and R responses, $t(17) = 1.41$, $p > .05$ (Cohen's $d = 1.92$). For new words, the proportion of responses in each response type also showed a significant difference, $F(2, 30) = 358.53$, $p < .001$. Significantly more N responses were given than R or K responses, $t(15) = 28.56$, $p < .001$ (Cohen's $d = 33.34$), $t(15) = 15.83$, $p < .001$ (Cohen's $d = 19.20$), respectively, and more K responses than R responses, $t(15) = 4.17$, $p = .001$ (Cohen's $d = 3.47$).

Reaction time. To compare our results to those of Horton and colleagues (2001), we first compared the average mean response times (RT) to the stems associated with studied words (regardless of whether the studied word was used to complete the stem) and the RTs to the stems associated with the new words presented in the critical stem completion phase. To be consistent with the statistics used in Experiment 1a and 1b, the average mean RT was used in this experiment rather than the average median RT that was used by Horton and colleagues, although the same pattern of results is obtained if the median RTs are used. Replicating Horton et al. (2001), studied words had significantly faster stem completion times (1053 ms, $SD = 270$ ms) compared to new words (1128 ms, $SD = 263$ ms), $t(15) = 3.37$, $p < .01$ (Cohen's $d = 0.63$) (removing stems that were incorrectly completed or took over 3500 ms to complete). Both had significantly faster stem completion times compared to the practice stem completion phase (1356 ms, $SD = 407$ ms); $t(15) = 3.53$, $p < .01$ (Cohen's $d = 2.00$); $t(15) = 2.78$, $p < .05$ (Cohen's $d = 1.52$); old and new words, respectively. Therefore we are confident that our methods are similar to those of Horton and colleagues: Participants were not using conscious explicit retrieval to complete the stems in our study, just as they were not in the Horton et al. (2001) study.

Similar to Experiment 1a and 1b, the stems were then classified according to their recognition response (R or K for old words). We could not include the RTs for misses (old words given a N response) in this experiment because many participants did not have any miss responses. A repeated-measures ANOVA revealed a significant difference between the stems completed with studied words given a R (923.6 ms, $SD = 160$ ms) or K response (973.9 ms, $SD = 172$ ms) and the mean RT to new stems (1128 ms, $SD = 263$ ms), $F(2, 30) = 22.80$, $p < .001$. Planned comparisons revealed that RTs to stems completed with studied words given a R response were significantly faster than to those given a K response, $t(15) = 3.31$, $p = .005$ (Cohen's $d = 0.67$), and to new words, $t(15) = 5.08$, $p < .001$ (Cohen's $d = 2.93$). Stems completed with studied words given a K response were also significantly faster than to new words, $t(15) = 4.50$, $p < .001$ (Cohen's $d = 2.52$).

Discussion

In Experiment 2 we found that studied words that received a R response were associated with faster word stem completion times than were words that received a K response or new words. Also, studied words given a K response were faster than new words. Because there were such few misses, we could not determine whether completion to words that were missed differed significantly from those that were recognised correctly. Also, unlike Experiment 1a and 1b, the proportion of both R and K hits significantly exceeded that of FA of each type. Here, memory based on K responses is well above chance, yet priming for R responses, as measured by time to complete the stems, still exceeds that for K responses. Overall, these findings are consistent with those from Experiment 1a and support the hypothesis that some processes underlying R responses benefit performance on implicit memory tasks.

We think that our results are not due to the contamination of consciously retrieved memories. As noted earlier, we chose Horton and colleagues' (2001) speeded word stem completion task because it has been shown to be free from contamination by conscious retrieval. In fact, previous studies suggest that when conscious retrieval is used in a word stem completion task, RT suffers (see Richardson-Klavehn & Gardiner, 1995, 1996, 1998; Toth, 1996). Our pattern of results was opposite to this in that RTs were faster to words given R responses than to words given K responses, reinforcing our conjecture that participants were not using conscious retrieval of the studied words to complete the stems. Moreover, the R advantage was weakened when accuracy rather than RT was used as a measure. In contrast to speed, accuracy provides a measure of all influences on performance, both conscious and unconscious, without distinguishing between them. Words receiving K responses were also completed more accurately than misses, suggesting that the contribution of consciously retrieved information to accuracy is not insignificant.

Overall, our finding that words given a R response were associated with faster stem completion performance supports the two-stage account of recollection. Information associated with recollection can be retrieved from episodic memory during an initial phase rapidly, relatively automatically, and without conscious awareness (Moscovitch, 2008).

GENERAL DISCUSSION

The goal of the current study was to explore the relation between processes underlying recollection and performance on two implicit memory tasks: lexical decision and speeded word stem completion. We hypothesised that processes associated with recollection would contribute to performance on these non-conscious, implicit memory tasks. Our primary finding was in line with this hypothesis. Studied words that were later given a R response were associated with greater priming than studied words that were later given a K response. No difference was found between recognised words given a K response and missed words, although both showed priming effects. Our results establish the basic phenomenon that some non-voluntary processes associated with explicit memory can contribute to performance on tests of implicit memory.

Alternative explanations of the R advantage

Before describing possible interpretations of our findings, we consider a number of alternative explanations for our results in light of our own data and previous findings.

Contamination of implicit memory tasks by voluntary or involuntary retrieval of explicit memory. As we noted earlier, we chose implicit memory tests that are likely to be resistant to contamination (Goshen-Gottstein & Moscovitch, 1995: Horton et al., 2001; see discussion in MacLeod, 2008). For both tasks, latencies for completing the implicit memory task (lexical decision = 760 ms; word stem completion = 1014 ms) were significantly faster than the recognition judgement response times, a task that does require the retrieval of specific conscious explicit memories (1224 ms and 1575 ms for the lexical decision task and word stem task, respectively). In addition, numerous studies have found that when conscious retrieval contaminates implicit memory tasks, the process is slowed (Horton et al., 2001; Toth, 1996), but here we found the opposite effect. Items given R responses were associated with more rapid priming than those that were presented but not recognised at all. Even the items associated with K responses were not slowed with respect to misses, although both were faster than the RTs to new items.

It is possible that awareness of an item from the study phase arose spontaneously during the implicit memory task, accounting for enhanced priming effects. The idea that involuntary conscious memory affects priming is a contentious issue with some researchers endorsing it (e.g., Kinoshita, 2001) and others not (e.g., Richardson-Klavehn & Gardiner 1996; Roediger & McDermott, 1993). Although we are not opposed to this idea in principle, we think it cannot account fully for our results, as it would also predict a benefit for all memorable words of which the participants were aware, including those judged as familiar, in comparison to words that were presented but not recognised (misses). Contrary to this prediction, we found no difference in priming between words receiving a K response and missed words in Experiment 1a. This interpretation, however, is mitigated by the fact that there was no significant difference between the proportion of K hits and FA.

Using the PDP, Jacoby and colleagues (Jacoby, 1991; Toth, Reingold, & Jacoby, 1994) argued that performance on indirect tests of memory may be contaminated by explicit memory. They note that applying the PDP can remove the source of contamination, leaving a measure of implicit memory that is not influenced by variables that benefit explicit memory, such as depth of processing or generation. While this may be true, applying such reasoning (or the PDP) to our study effectively would remove most of the items associated with recollection, given that recollection is most influenced by those variables. By removing all the recollected items, the PDP does not allow one to answer the question we have posed—do processes associated with recollection influence performance on implicit tests *before or without* the participant's awareness of the explicit memory for the item? Our tests suggest that a crucial part of the interaction between explicit and implicit memory occurs before participants become aware of their explicit memory.

Greater priming leads to greater recollection. As a first step, Experiment 1b ruled out the possibility that it was lexical decision times (or item characteristics associated with lexical decision times) that influenced subsequent memory for words. When lexical decision times were measured prior to learning, there was no relation between RTs and subsequent memory.

One might still argue that implicit memory itself may be causally contributing to recollection, as it does on some tests in which explicit memory for the studied item is weak and benefits, by inference, from priming or processing fluency (see Kinoshita, 2001; Masson & MacLeod, 1997). If true, this finding itself would be novel and noteworthy, but we believe that this interpretation is unlikely for the following reasons. First, there is evidence from Wagner, Maril, and Schacter (2000) to indicate that priming leads to worse recognition memory for primed as compared to unprimed items (see also Stark, Gordon, & Stark, 2008). This pattern is the opposite of the one that we obtained making the hypothesis that priming contributes to recollection suspect.

Further to this point, in the present study the amount of time spent processing highly primed words (those with the fastest RTs) during the implicit memory phase was significantly less than the amount of time spent processing the words that were not primed as much, or not primed at all. Since explicit memory is known to vary with study time for the same item (items typically have better memory when they are studied longer), one would expect that memory would be better for an item when it is more poorly primed than when that item is more highly primed because of the additional processing the poorly primed item would receive during the implicit memory task. On an item-level basis, we did not see a relation between amount of processing time and explicit memory. That is, explicit memory was no better for a particular item that was allotted more processing time (i.e., more poorly primed) for a particular participant than when it was a highly primed word for another participant.

Last, in Experiment 1a we found significant priming for old words regardless of whether they were recognised correctly or missed. This is particularly telling for proportion of K response hits, which were equivalent to that of K response FA. If priming had influenced recognition via fluency, one would have expected that K response hits would have exceeded K response FA since the former were primed but the latter were not.

Implications and interpretations

As stated previously, our results broadly support the notion that explicit and implicit memory share underlying processes, consistent with findings from other researchers (e.g., MacLeod & Masson, 2000; Masson & MacLeod, 1997). We have theoretically framed our study with a dual-process model of recognition memory to investigate the specific benefit of recollection to implicit memory. Early dual-process views described familiarity as a continuous, strength variable and recollection as a categorical, high-confidence (threshold) variable (Yonelinas, 2002). An alternative interpretation, however, is that R responses and K responses do not reflect recollection and familiarity, but reflect different degrees of memory strength. Items that receive R responses have a stronger memory trace than items that receive K responses (Dunn, 2008; Wixted & Stretch, 2004). In fact, single-system, signal detection strength models have been proposed to account for the relation between explicit and implicit memory in a number of tasks (see Berry, Shanks, & Henson, 2008). The pattern we obtained in Experiment 1a resembles the pattern of RTs that Berry and colleagues observed in their own study and in others that they reviewed for priming of items associated with hits, misses, FA and CRs.

However, behavioural (Diana, Reder, Arndt, & Park, 2006; Yonelinas, 2002) and neuropsychological evidence (Diana, Yonelinas, & Ranganath, 2007; Eichenbaum et al., 2007; Rugg et al., 1998; Wagner, Gabrieli, & Verfaellie, 1997) regarding explicit memory, have led many investigators to favour a dual-process model of recognition. In light of such evidence, some investigators, combining both viewpoints, have proposed dual-process, aggregate strength models to account for recognition performance. In contrast to dual-process threshold models, the aggregate strength models posit that both recollection and familiarity vary continuously in strength (Mickes, Wais, & Wixted, 2009; Rotello & Macmillan, 2006; Rotello, Macmillan & Reeder, 2004; Wixted, 2007). To our knowledge, such dual-process, strength models have not been applied to deal with the relation between explicit recognition and priming, although it is conceivable that they can do so. With respect to our own findings, such models may predict that priming, like recognition, would be determined by the aggregate strength drawn from recollection and familiarity. Because recollection is typically associated with greater strength than familiarity, one would expect that priming should be better for items associated with R than with K responses, as was the case.

However, the equivalent RTs for K response hits and misses in Experiment 1a, and the greater RTs for misses compared to CR, are problematic for strength models. This problem is easily resolved if we assume that strength for K response hits is very weak, which it seems is the case in our study as they are indistinguishable from K response FAs, and that misses are based on stronger traces than are CR. To test these theories against each other and against our own model (see below), future investigations should collect data on confidence levels associated with each of these responses.

The two-stage model of recollection

Related to the hypothesis we set out to test, and taking into account the other alternatives we have considered, we believe our findings are consistent with the two-stage model of recollection (Moscovitch, 2008). The first stage is automatic, dependent on the MTL, and can be implemented without conscious awareness. The second stage is slower, dependent on the interaction of prefrontal and parietal cortex with the MTL and, as a result, is associated with conscious awareness.

Evidence for the first stage of recollection comes from the present study in which there was a priming advantage for items that were also recollected as well as from other studies that have found a recollective advantage on tasks thought not to rely on explicit/episodic memory (Westmacott & Moscovitch, 2002, 2003; Westmacott et al., 2004). In these cases the retrieval required is not specifically linked to recovering details from the past at the moment of retrieval. That is, the demands at retrieval are fairly minimal, such as those during lexical decision or word stem completion. In other situations when task demands are minimal, such as in particular old/new recognition tasks, RTs are faster for those items that are recollected than for those that are recognised on the basis of familiarity (Dewhurst & Conway, 1994; Dewhurst, Holmes, Brandt, and Dean, 2006; Diana et al., 2007; Gardiner, Gregg, & Kariyianni, 2006), paralleling the priming results that we found.

The second stage of recollection is involved when retrieval of specific details from past episodes is accompanied by conscious awareness of the episode and decisions must be made on this basis. That is, if the task demands are great, a slower process comes into play in which more information is recovered and evaluated. This was the case for the explicit memory task used in our experiments wherein participants had to reflect on the retrieved information to determine whether it was adequate to support a recollection decision. In these cases, decisions based on recollection are slower than those based on familiarity, the reverse of what occurs when merely deciding whether an item is old or new or when task demands are fairly minimal (e.g., dual-process model; Boldini, Russo, & Avons, 2004; Toth, 1996; Yonelinas & Jacoby, 1994).

Earlier studies, typically those that employ the PDP model (Jacoby, 1991; Toth et al., 1994), describe recollection as a slow and effortful process much like the second stage of the two-stage model. Thus our model is not inconsistent with such theories of recollection. While earlier models help disentangle the contributions of the recollection and familiarity when one is engaged in high-demand decisions (e.g., stage two), our model helps to disentangle processes involved when the additional strategic and monitoring processes associated with such tasks either are not implicated or come into play before such processes take effect (see also discussions in MacLeod, 2008, and in studies by Gardiner & Richardson-Klavehn and their colleagues).

On a final note, like the strength models our proposal does not explain adequately the pattern of results associated with K responses in Experiment 1a. It would seem that priming associated with K responses is based on a different system that is not influenced by the same memory strength that determines explicit memory performance. In short, the classic systems dissociation between explicit and implicit memory, at least as assessed by priming, may apply only when comparing priming with familiarity. Such a proposal would be consistent with Schacter et al.'s (2004, 2007) distinction between two types of priming—one that is mediated by the MTL and can be influenced by processes that also underlie explicit memory (Ostergaard & Jerningan, 1993), and one that is mediated by structures outside the MTL that may be unique to implicit memory (Jacoby, 1991; Moscovitch et al., 1993; Toth et al., 1994).

Manuscript received 30 June 2009
Manuscript accepted 28 May 2010

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