

Process-Specific Interference Effects During Recognition of Spatial Patterns and Words

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The authors examined recognition memory for words or visuospatial patterns under full (FA) or divided attention (DA) conditions with a distracting task requiring either phonological (rhyme) or visuospatial (curved-line) processing of letters, in 72 young adults. The authors found an interaction such that the curved-line distracting task had a more detrimental effect on corrected recognition, and discriminability measured by d' , for spatial patterns than did the rhyme distracting task, whereas the reverse was true for memory of words. There was also a general effect of DA on response bias such that C increased under DA relative to FA conditions, regardless of the distracting task, and type of information being remembered. Results suggest memory interference from DA at retrieval is process-specific, and that DA at retrieval leads to a more conservative response strategy.

Keywords: memory, spatial, verbal, divided attention, retrieval

Understanding how memory retrieval is affected by situations in which attention is divided between two ongoing tasks is important for a number of reasons. First, it can provide insight into the limitations of human cognitive processing. Second, knowing the degree to which memory is disrupted can also provide insight into the code used to represent, or reactivate, stored memory traces. Whether different materials, such as verbal and visuospatial information, are stored in distinct long-term memory sites is a key question in memory research. At the level of neuroanatomy the question has been posed as to whether distinct brain areas are specialised for representing, and accessing, different stimulus types (Golby et al., 2001), and brain imaging studies have been used recently to address this question (see Cabeza & Nyberg, 2000). These studies suggest that stored information is reactivated in multiple, anatomically distinct brain areas. For example, clearly distinct activation patterns have been observed by contrasting spatial versus verbal working memory tasks (e.g., Jonides et al., 2003). In the current study, we used the dual-task paradigm to examine whether such a distinction between verbal and spatial memory representations is evident behaviourally, in an episodic memory task.

The logic in dual-task studies is that by comparing conditions in which attention is divided between a target and distracting task, one can infer by the disruption in performance relative to a

nondistracting condition whether the concurrent tasks require the same processing resources or representational system. Decrements in performance, termed interference effects, manifest because a common system, or brain area, is being overly taxed (Friedman, Polson, Dafoe, & Gaskill, 1982; Kinsbourne & Hicks, 1978; Klinberg, 1998; Klinberg & Roland, 1997). The effects of divided attention (DA) during either the encoding or retrieval stage, on memory performance, have been examined in previous work, and have provided clues as to the critical components needed for optimal performance.

The general finding is that dividing attention at encoding produces substantial decrements in memory performance (Anderson, Craik, & Naveh-Benjamin, 1998; Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Fernandes & Moscovitch, 2000; Naveh-Benjamin, Craik, Guez, & Dori, 1998), regardless of the type of distracting task used to divide attention. This has led researchers to conclude DA leads to a reduction in general processing resources needed for conscious awareness, elaboration, and organisation of information, all factors that promote memory at encoding. As a result, memory suffers when attention is divided. Dividing attention at retrieval, on the other hand, yields more variable results.

The critical component for successful retrieval appears to be different. Memory interference in studies of free and cued recall of unrelated lists of words is usually minimal (Anderson et al., 1998; Baddeley et al., 1984; Craik et al., 1996; Fernandes & Moscovitch, 2000; Naveh-Benjamin et al., 1998). Here the distracting task used to divide attention-involved materials dissimilar from the memory task; that is the distracting tasks consisted of monitoring lists of digits, sorting cards with geometric shapes, or visuospatial tracking of symbols, whilst the memory task was for word lists. Other work, however, has shown that substantial memory interference effects for lists of unrelated words are found when there is overlap between the materials used in the concurrent tasks. Under such circumstances, DA effects are said to be *material-specific* (Fernandes & Moscovitch, 2000, 2002, 2003). For example, Fernandes

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and Moscovitch (2000) found that dividing attention during word recall, with a word-monitoring distracting task (deciding if a word represents a living or nonliving thing), produced a decrement in memory of 30% from full attention; an equally demanding digit-monitoring task (deciding if digits were odd or even) led to a decrement of only 13%.

Thus, unlike the *general effect* of DA observed at encoding, this *material-specific* interference effect of DA was interpreted as resulting from competition between the word-based distracting task and the verbal memory test for a common representational system during recovery of the memory trace, and to a negligible extent on competition for general resources. Of note, relative differences in level of difficulty of the distracting tasks could not account for their differential effect of memory performance (Fernandes & Moscovitch, 2000, 2003; Fernandes, Davidson, Glisky, & Moscovitch, 2004). Based on these data Fernandes and Moscovitch (2000) suggested that successful memory retrieval required accessing or reactivating the content of memory traces, and that this was hampered under conditions in which there is competition from the distracting task for the same representational system. Evidence in support of this claim, however, comes only from studies of memory for words.

In subsequent work it was shown that the greatest memory interference was observed when the distracting task involved phonemic or orthographic (word-form) processing of information (Fernandes & Moscovitch, 2002), and related work has gone on to show that oral recall suffers substantially when the distracting task requires phonological processing, even if those decisions are made to pictures (e.g., syllable decisions to line drawings; Fernandes et al., in preparation). This suggests that memory interferences increase to the extent that the distracting and memory tasks require the same processing resources; oral recall likely required accessing phonological representations, and any distracting tasks that also required phonological processing interfered with memory, regardless of the form (material) of the distracting task.

In the current study, we tested whether competition for process-specific resources is a general feature characterising conditions under which memory is disrupted from DA. We tested whether process-specific effects of DA at retrieval applied to nonverbal, as well as verbal materials. Previous studies of DA focussed mainly on memory for verbal (word) information. Assuming that the component processes critical for memory success are the same for verbal as for nonverbal information, one should be able to show a process-specific interference effect from DA on memory for visuospatial patterns as well as for words.

Whilst there are studies examining the effects of DA on memory for visuospatial materials, they considered working rather than episodic memories. For example, a study by Logie, Zucco, & Baddeley (1990) showed that a concurrent arithmetic task (requiring subvocalizations) substantially disrupted performance of a letter span task, but had only a marginal effect on a visual span task. The converse was true on a visual span task—it was substantially impaired by a number matrix task, designed to require visuospatial processing. In a similar study, Robbins and colleagues (1996) examined the effects of distracting tasks that were intended to disrupt either the phonological loop, the visuospatial sketchpad, or the central executive, on memory for arrangement of chess pieces, an activity that likely uses a visuospatial more so than verbal code to represent information. They found that short-term

memory performance was not impaired when retrieval was performed simultaneously with an articulatory suppression task, meant to tax the phonological loop, but that performance was disrupted by a concurrent visuospatial task, and even more by one that taxed central executive resources (generating random digits). These results are thus in line with the proposed processing-specific account of memory interference during episodic memory for words.

In this investigation, we measured episodic recognition memory for words or spatial patterns, performed under full attention and divided attention conditions with two different distracting tasks that made use of the same stimuli (letters) but required different types of processing, phonological versus visuospatial. If retrieval of information from episodic memory requires a process-specific representational system, then we should see a double dissociation in which the distracting task requiring visuospatial processing produces greater interference on memory retrieval of spatial than verbal information, whereas the distracting task requiring phonological (verbal) processing produces relatively greater interference on memory retrieval of verbal than spatial information. We measured recognition memory performance, for either words or spatial patterns, within each participant in the two DA and in a full attention (FA) condition. The distracting tasks were designed so that they could be presented in a different modality (auditory) than the memory task (visual), thereby reducing the amount of structural interference between concurrent tasks.

Method

Participants

Seventy-two undergraduate students (32 male) studying at the University of Waterloo received course credit, or token monetary remuneration, for participating in the study. All participants were native English speakers, and had normal or corrected to normal vision and hearing. Ages ranged from 17 to 27 years ($M = 20.17$, $SD = 1.91$), with a mean of 14.59 ($SD = 1.35$) years of education. Participants were informed that the study had received full clearance from the local Office of Research Ethics.

Materials

Visuospatial memory task. Spatial patterns were created with a computer programme that, for each stimulus, produced a 5×5 square grid (measuring 15.2 cm in length by 14.5 cm in width; see Figure 1 for sample) with eight randomly selected squares coloured in black, and the rest in white. This technique generated random patterns within the 5×5 grid. One-hundred-five such unique stimuli were created. Fifteen of these were used in the practise phase: five were randomly chosen to be in the study phase and 10 were used as lures in the recognition test. Ninety stimuli were used in the experimental phase: three 10-item lists were created for the study phases and the remaining 60 were used as lures in the three recognition tests.

Verbal memory task. Word stimuli consisted of 112 unrelated two-syllable common nouns, with a word frequency between 40 and 100 per million from the *Frequency Analysis of English Usage* (Francis & Kucera, 1982), and a mean word length of 5.84. Sixteen of these were chosen to be in the practise phase: eight were

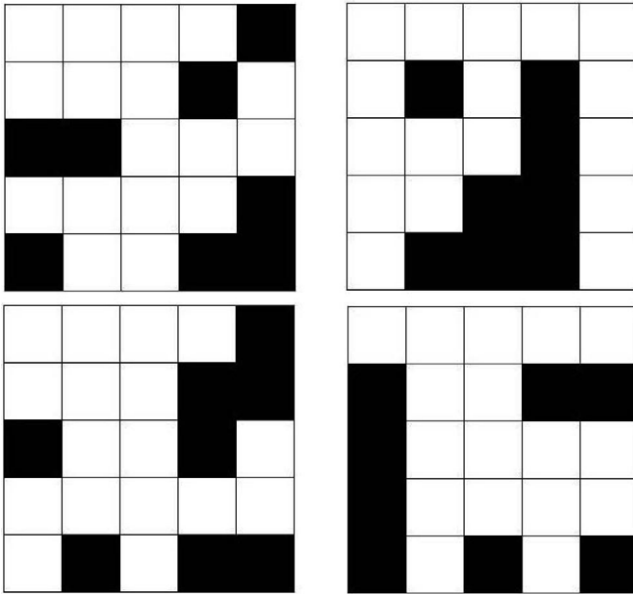


Figure 1. Sample of the spatial patterns used in the visuospatial memory task.

randomly chosen to be in the study phase and eight were used as lures in the recognition test. Ninety-six words were used in the experimental phase: three 16-word lists were created for the study phases and the remaining 48 were used as lures in the three recognition tests.

Distracting tasks. The same stimuli were used for both the rhyme and curved-line distracting tasks, and consisted of letters of the alphabet (omitting A, M, and W) that were recorded by author EG as separate audio files (.wav) via a microphone using Sound-Designer II software (Palo Alto, CA). Audio files were created such that each .wav file was approximately 1500 ms in duration.

Procedure

Stimulus presentation and response recording were controlled by an IBM PC, using E-prime v.1.1 software (Psychology Software Tools Inc., Pittsburgh, PA). Participants were tested individually, in three conditions (FA, DA with rhyme task, and DA with curved-line task), were randomly placed in either the spatial or verbal memory group (between-subjects manipulation), and completed the experiment in approximately 1 hour.

Practise session. Participants in the spatial memory group were asked to study five of the visuospatial pattern stimuli for a later memory test. Stimuli were presented one at a time on a computer screen for 3,500 milliseconds, followed by a fixation cross for 500 milliseconds (1 item every 4 seconds). Immediately after study, a recognition test was given in which the five studied items were presented randomly amongst 10 new patterns, at a rate of one pattern every 2 seconds (1,500 milliseconds stimulus presentation followed by a fixation cross for 500 milliseconds). Participants were asked to press a key ('m' on a standard keyboard) to identify patterns from the study list, and were told to make their response whilst the stimulus was on the screen.

For participants in the verbal memory task group, participants were asked to study eight words for a later memory test. Words were presented in black on a white background, in 18-point Arial font for 2,000 milliseconds, followed by a fixation cross for 500 milliseconds (approximately one word every 2 seconds). At test, participants were asked to press a key ('m' on the keyboard) to identify words from the study list; the eight items from study were presented intermixed randomly with eight lure words. Each word was presented on the screen for 1,500 milliseconds followed by a fixation cross for 500 milliseconds, and participants were told to make their response whilst the stimulus was on the screen.

Both groups also completed a practise session for the "rhyme" and "curved line" distracting tasks. For both tasks, participants heard a female voice speaking a list of 15 letters aloud. Each audio file was played for 1,500 milliseconds in duration followed by 500 milliseconds of silence. Participants were asked to make a "yes" or "no" response immediately after presentation of each letter, and the experimenter recorded their responses. For the rhyme task participants had to respond "yes" if the letter presented rhymed with the long "e" vowel. For example, letters requiring a "yes" response are B, C, D, E, G, P, T, and V. If the letter did not rhyme with the long "e" vowel, the participant responded "no." Thus, the task required the participant to make phonological decisions about the letters. Five letters requiring a "yes" response were randomly selected, and presented randomly amongst 10 randomly selected letters requiring a "no" response. In the practise phase of the curved line decision task, participants had to imagine the letter in their "mind's eye," and respond "yes" if the letter contained a curved line, when in its capitalized form. Participants were instructed to think of the capitalized alphabet as they learned in primary school. For example, correct "yes" responses would be to the letters B, C, D, G, P, J, O, P, Q, R, S, and U). If the letter, when capitalized, did not contain a curved line, the participant responded "no." To clarify the task, the experimenter referred to the letters on the computer keyboard as illustrating how participants should visualise the alphabet they based their decisions on. As in the rhyming distracting task, the list consisted of five letters requiring a "yes" response that were randomly selected, and presented randomly amongst 10 randomly selected letters requiring a "no" response. Participants were encouraged to ask for clarification on any of the tasks if needed.

Experimental session. After practise, single-task performance for one of the distracting tasks was measured, with single-task performance on the other task measured (in counterbalanced order) at the end of the final memory condition. Following the first single-task measure, the three memory conditions (FA plus two DA conditions) were administered, counterbalanced across participants. For those in the visuospatial memory group, letter lists for the rhyme and curved-line distracting tasks (used in the two single-task and two DA conditions) consisted of 30 randomly selected letters, presented at a rate of 1 letter every 2,000 milliseconds; 11 letters requiring "yes" responses were distributed randomly amongst 19 requiring "no" responses. For those in the verbal memory group, the letter lists consisted of 32 randomly selected letters (also presented at a rate of one letter every 2,000 milliseconds), 12 of which required a "yes" response and 20 a "no" response. This adjustment, in number of letters presented across memory groups, was made so that the length of the distracting tasks matched that of the memory tasks; the visuospatial recogni-

tion tasks consisted of fewer items than on the verbal recognition tasks, as pilot testing indicated that performance was at floor using the same list length (and distribution of old to new items, and stimulus encoding duration) as on the verbal memory task.

In all three of the memory task conditions for each group, encoding was always performed under full attention. In the FA condition, participants completed the recognition task without any distracting task. In the DA conditions (DA rhyme and DA curved-line), participants had to make their recognition memory decisions, to either spatial patterns or words, whilst simultaneously making decisions to letters in a distracting task. In each memory condition, participants in the spatial memory group were presented with 10 visual patterns, as in the practise phase, and were asked to memorize these for a later memory test. Immediately following this, a recognition test was given in which participants were presented with 30 patterns: 10 patterns from study, presented randomly amongst 20 new “lure” patterns, and participants pressed the ‘*m*’ key to identify “old” studied patterns. For participants in the verbal memory group, the study list consisted of 16 words presented as in the practise phase, followed by a recognition test in which the 16 words from study were presented randomly amongst 16 lure words, and participants made a keypress to old words. For all of the experimental phase recognition tests, items (spatial patterns or words) were presented for 1,500 milliseconds followed by a fixation cross for 500 milliseconds, as in the practise recognition test. A short break of 1 to 2 minutes was given after each recognition memory test condition (FA, DA curved-line, DA rhyme).

In the DA conditions (DA rhyme and DA curved-line) for each group, participants had to make their recognition memory decisions, to either spatial patterns or words, whilst simultaneously making decisions to letters in the distracting task. The onset of the first item in the visually presented recognition task and the auditorily presented distracting task was simultaneous. Participants were told to place equal effort on performing the memory and distracting task. During recognition in the DA curved-line condition, participants simultaneously made keypress responses to old items whilst making “yes/no” responses aloud if the spoken letter contained a curved line. During recognition in the DA, rhyme condition participants simultaneously made keypress responses to old items whilst making “yes/no” responses aloud if the spoken letter rhymed with the long vowel ‘e.’

Results

Recognition Memory Performance

Corrected recognition accuracy. Data were analysed in a mixed analysis of variance (ANOVA), with Condition (FA, DA curved-line, DA rhyme) as a within-subjects variable, and Memory list type (words, visuospatial patterns) and order of conditions (six orders) as between-subjects variables. The dependent variable was corrected recognition score (hereafter referred to as accuracy), calculated as hit rate minus false alarm rate (Egan, 1958; Woodworth, 1938) that is used frequently in recognition memory studies (Gillund & Shiffrin, 1984; Tulving & Thomson, 1971). The number of items in the recognition list was different depending on Memory list type; accuracy for word lists was calculated as the number of hits divided by 16, minus the number of false alarms divided by 16, whereas accuracy for spatial pattern lists was calculated as the number of hits divided by 10, minus the number of false alarms divided by 20 (see Table 1 for means).

Preliminary analyses indicated that there were no significant main effects or interactions with the order factor on recognition accuracy. There was a main effect of Condition, $F(2, 140) = 40.84$, $MSE = 0.03$, $p < .001$, with better performance under FA than under either of the DA conditions, and a significant effect of memory list type, $F(1, 70) = 70.18$, $MSE = 0.07$, $p < .001$, with higher accuracy for words than visuospatial patterns. The effects were qualified by a significant Condition X Memory list interaction $F(2, 140) = 3.71$, $MSE = 0.03$, $p < .05$. To further understand this interaction we considered the effect of Condition separately for each Memory list.

There was a main effect of Condition on recognition accuracy for visuospatial patterns, $F(2, 70) = 14.45$, $MSE = 0.03$, $p < .001$. Simple effects contrasts showed accuracy in the FA condition was better than in the DA rhyme, $F(1, 35) = 14.70$, $MSE = 0.07$, $p < .01$, $\eta^2 = 0.30$, and DA curved-line conditions, $F(1, 35) = 24.26$, $MSE = 0.08$, $p < .001$, $\eta^2 = 0.41$. Whilst performance in the DA curved-line was worse than in the DA rhyme condition, this difference did not reach significance, $F(1, 35) = 2.00$, $p = .15$, $\eta^2 = 0.05$. There was also a main effect of Condition on recognition accuracy for words, $F(2, 70) = 31.46$, $MSE = 0.03$, $p < .001$. Simple effects contrasts showed higher accuracy in the FA than DA rhyme, $F(1, 35) = 54.24$, $MSE = 0.06$, $p < .001$, $\eta^2 = 0.61$, and DA curved-line conditions, $F(1, 35) = 51.45$, $MSE =$

Table 1
Recognition Memory Measures in Each Condition, for Each Memory List Group

Memory list and condition	Accuracy (hit rate – FA rate)	Hit rate	FA rate	d'	criterion (C)
Visuo-spatial patterns					
Full attention	0.50 (0.20)	.71 (.14)	.21 (.14)	1.54 (.72)	.16 (.35)
DA curved-line	0.28 (0.22)	.54 (.21)	.27 (.16)	0.85 (.66)	.29 (.46)
DA rhyme	0.34 (0.22)	.58 (.20)	.24 (.15)	1.01 (.65)	.29 (.46)
Words					
Full attention	0.85 (0.15)	.87 (.14)	.02 (.03)	3.04 (.60)	.27 (.29)
DA curved-line	0.63 (0.22)	.73 (.17)	.10 (.11)	2.06 (.83)	.32 (.32)
DA rhyme	0.55 (0.25)	.67 (.19)	.12 (.10)	1.74 (.88)	.39 (.33)

DA = divided attention.

0.04, $p < .001$, $\eta^2 = 0.60$. Contrary to the pattern for visuospatial memory, performance in the DA curved-line was *better* than in the DA rhyme condition, and this effect approached significance, $F(1, 35) = 3.13$, $MSE = 0.08$, $p = .09$, $\eta^2 = 0.08$.

These contrasts suggest that the interaction observed in the overall analysis was because of the differential effect of the two distracting tasks on the two memory list types. That is, the curved-line distracting task had a more detrimental effect on memory for visuospatial patterns than did the rhyme-distracting task, whereas the rhyme distracting task had a more detrimental effect on memory for words than did the curved-line distracting task.

d' and response bias. For each participant in the study we also calculated discriminability (d'), which provides a bias-free estimate of recognition performance, and response bias (C ; Snodgrass & Corwin, 1988), which provides an estimate of the participant's tendency to respond "old" and "new" in each condition (where larger values indicate a more conservative response bias-tendency to respond "new" more often than "old, and smaller values indicate a liberal bias-tendency to respond "old" more often than "new"). We conducted ANOVAs using these measures as the dependent variable¹ (see Table 1 for means). The pattern of results using d' as the dependent measure was identical to that for corrected recognition. There was a main effect of Condition, $F(2, 140) = 52.45$, $MSE = 0.35$, $p < .001$, with better performance under FA than under either of the DA conditions, and a significant effect of Memory list type, $F(1, 70) = 79.24$, $MSE = .30$, $p < .001$. These effects were qualified by a significant Condition X Memory list interaction $F(2, 140) = 7.71$, $MSE = 0.35$, $p < .001$.

The simple effects contrasts showed the same pattern as for the accuracy measure: the curved-line distracting task had a more detrimental effect on memory for visuospatial patterns than did the rhyme-distracting task ($p = .18$), whereas the rhyme-distracting task had a more detrimental effect on memory for words than did the curved-line distracting task ($p = .06$). As in the accuracy results, d' for visuospatial patterns was significantly lower in both the curved-line and rhyme DA conditions relative to FA (both $ps < .01$), though the effect size was larger in former ($\eta^2 = .41$) than in the latter DA condition ($\eta^2 = .30$). Similarly, the d' for word recognition was significantly lower in both the curved-line and rhyme DA conditions relative to FA ($ps < .001$). For word recognition, however, the effect size was larger in the rhyme ($\eta^2 = .68$) than curved-line DA condition ($\eta^2 = .66$). Thus, as with the accuracy measure of recognition, the interaction observed in d' scores was because of the differential effect of the two distracting tasks on the two memory list types.

Interestingly, when we conducted an ANOVA using C as the dependent measure, we found a main effect of Condition, $F(2, 140) = 3.69$, $MSE = 0.08$, $p < .05$, with higher C values (conservative response bias) in both DA conditions relative to FA. Of note, there was no effect of Memory list type ($F < 1.0$), nor a Condition X Memory list interaction, $F(1, 70) = 1.30$, $p > .05$.

Controlling for full attention levels of performance. Because memory performance across memory list types differed significantly we wanted to reexamine the data, equating for FA levels of recall. To this end we conducted an analysis on yoked data such that we compared performance in the 15 participants from the spatial memory group with the highest FA levels of memory with 15 participants from the verbal memory group with comparable levels of FA recognition accuracy (within .10 of each other). In

this way FA performance was matched across groups ($M = .67$, $SD = .15$ for spatial patterns and $M = .73$, $SD = .14$ for words; $t(28) = -1.14$, $p > .05$).

We then conducted a mixed MANOVA (sphericity assumption for ANOVA was violated), with Condition (FA, DA curved-line, DA rhyme) as a within-subjects variable, and Memory list type (words, visuospatial patterns) as a between-subjects variable. The pattern of results was similar to the overall analysis: There was a main effect of Condition, $F(2, 27) = 39.54$, $p < .001$, with better performance under FA than under either of the DA conditions and the main effect of Memory list type remained, $F(1, 28) = 8.22$, $p < .01$, $MSE = 0.02$, with higher accuracy for words than visuospatial patterns. As in the overall analysis, these effects were qualified by a significant Condition X Memory list interaction $F(2, 27) = 7.12$, $p < .01$. Thus, differences in FA levels of recall do not account for the significant Condition X Memory list interaction. When we examined the effect of Condition, separately for each Memory list, the pattern of results was also similar to the overall analysis in that the curved-line distracting task was more detrimental to memory for visuospatial patterns than was the rhyme distracting task, whereas the rhyme distracting task had a more detrimental effect on memory for words than did the curved-line distracting task (see Figure 2).

The identical pattern of results was found using d' as the dependent measure: main effect of Condition $F(2, 27) = 50.92$, $p < .001$, and Memory list type $F(1, 28) = 10.01$, $MSE = .24$, $p < .01$, qualified by a significant Condition X Memory list interaction $F(2, 27) = 4.84$, $p < .05$. We also conducted a mixed ANOVA (sphericity assumption maintained) using C as the dependent measure. Unlike the ANOVA with the full sample, the effect of Condition was not significant, $F < 1.0$, but as in the full ANOVA, the effect of Memory list was nonsignificant $F(1, 28) = 1.51$, $p > .05$. In this reduced sample, the Condition X Memory list interaction was, however, significant, $F(2, 56) = 3.51$, $MSE = 0.07$, $p < .05$; for those in the visuospatial memory list group, C was higher in the DA curved-line than FA condition, though C did not differ in the DA rhyme compared to FA condition. For those in the word memory list Group C did not differ across conditions.

Distracting Task Performance

Accuracy on the distracting task was calculated as hit rate minus false alarm rate (see Table 2 for means). Data were analysed in a 2 (Attention: single and dual-task) $\times$ 2 (Distracting task: rhyme, curved-line) $\times$ 2 (Memory list type: words, visuospatial patterns) ANOVA, with the first two factors being within-subject and the last a between-subjects manipulation. There was a main effect of Attention $F(1, 70) = 86.17$, $MSE = 0.02$, $p < .01$, with better performance under single than dual-task conditions, and a main effect of Task $F(1, 70) = 7.56$, $MSE = 0.03$, $p < .01$, such that performance on the rhyme distracting task was better than performance on the curved-line distracting task, but no significant Task $\times$ Memory list interaction. This suggests that although there

¹ When calculating estimates of d' and C for each participant in each condition, hit rates of 1 were replaced by $1-1/(2N)$, and false alarm rates of 0 were replaced by $(1/2N)$, where N is the maximum number of hits and false alarms that the participant could make in that condition (Macmillan & Creelman, 1991).

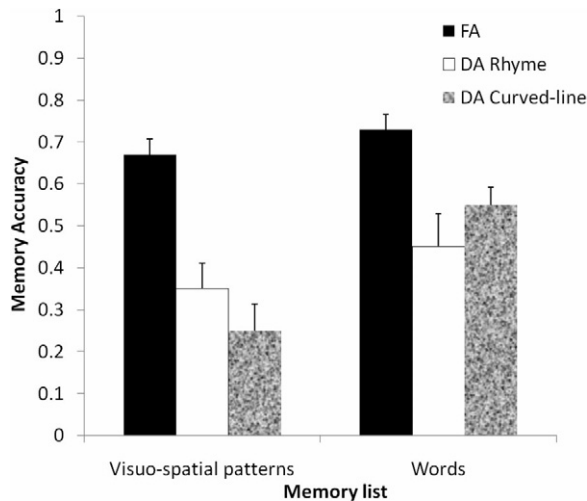


Figure 2. Accuracy (hit rate minus false alarm rate) for memory of visuospatial patterns and words in the full attention (FA), divided attention (DA) rhyme, and DA curved-line conditions in the 15 participants from the spatial memory group with the highest FA levels of memory, and the 15 participants from the verbal memory group with comparable levels of FA recognition accuracy.

was an effect of task, performance on the distracting tasks was comparable regardless of whether participants were in the visuospatial or word memory list group. No other main effects or interactions were significant.

Correlational Analysis

We considered correlations between distracting and memory task performance (accuracy) under DA conditions, to determine whether there were any trade-offs between the two tasks. These were done separately for each Memory list group. None of the correlations were significant, arguing against the possibility of trade-offs in performance of concurrent tasks during DA conditions.

Discussion

This study tested whether episodic memory retrieval of words and spatial patterns was affected differently by concurrently performed distracting tasks, differing only in type of processing required for each: phonological or visuospatial. Whilst our earlier work showed material-specific effects of DA on recall (Fernandes & Moscovitch, 2000, 2002, 2003), these studies considered only memory for verbal information. The goals of the current study were to determine whether memory interference occurs similarly for visuospatial information, and whether competition for process-rather than material-specific resources better characterises conditions under which memory is disrupted from DA conditions at retrieval.

The distracting tasks in the current study were created such that they made use of the same stimuli (letters) but required different types of processing, phonological for rhyme decisions, and visuospatial for curved-line decisions. We found an interaction such that the curved-line distracting task was more detrimental to memory

for visuospatial patterns than was the rhyme distracting task, and that the rhyme-distracting task had a more detrimental effect on memory for words than the curved-line distracting task. This pattern emerged in both corrected recognition accuracy and in d' measures of performance. Memory for spatial patterns and words likely call on more visuospatial and phonological processing resources, respectively. Our results suggest that similarity in processing requirements, between the memory and distracting task, modulates the magnitude of memory interference observed under DA conditions at retrieval, rather than similarity in materials, as this was held constant across DA conditions. Using a yoked control procedure, we also showed that the interaction remained even after the memory list groups were equated for FA levels of recognition performance.

Previous studies (Fernandes & Moscovitch, 2000, 2002, 2003) have suggested that memory retrieval is disrupted primarily by DA conditions in which the materials in the memory and distracting tasks are similar. By creating two distracting tasks that utilise the same stimuli (letters) whilst requiring different processing resources, we have demonstrated that the magnitude of memory disruption from DA at retrieval varies with the overlap in processing requirements between the memory and distracting tasks. That we observed an interaction suggests that the magnitude of memory interference does not depend solely on the relative level of difficulty of the distracting task. If it were, memory performance for words and visuospatial materials should have varied with task difficulty. Looking at performance on the distracting task we see that performance was lower overall on the curved-line task, which might suggest it is more difficult than the rhyme task. Yet, memory performance for words and visuospatial patterns interacted with condition, even when FA levels were matched across memory list groups. Recognition was affected differently by the rhyme and curved-line distracting tasks, suggesting memory interference depends on whether the tasks call on the same processing resources.

Our data also suggest that there is a general effect of DA on recognition memory performance that affects response bias, but not sensitivity or ability to discriminate old from new items. Specifically, C was shown to increase under DA relative to FA conditions, and this was true regardless of the distracting task used to divide attention, and type of information being remembered. Thus, a general effect of dividing attention is to make participants

Table 2

Accuracy Rates on the Curved-line and Rhyme Distracting Tasks Under Full and Divided Attention Conditions, for Each Memory List Group

Memory list group and condition	<i>M</i>	<i>SD</i>
Visuo-spatial patterns		
FA curved-line	0.96	0.08
DA curved-line	0.82	0.22
FA rhyme	0.91	0.14
DA rhyme	0.82	0.16
Words		
FA curved-line	0.98	0.04
DA curved-line	0.83	0.17
FA rhyme	0.91	0.11
DA rhyme	0.73	0.26

DA = divided attention, FA = full attention.

adopt a more conservative response strategy.² It may be that DA negatively affects the richness, or quality, of the memory that can be retrieved and this leads to participants adopting a more stringent response criteria for endorsing an item as old; that is, they may be less willing to endorse an item as "old" when they have only a gist-based feeling of familiarity with the item rather than a rich and robust memory of it. In line with this suggestion, our other work has shown that DA at retrieval has a general effect of decreasing accuracy of recollection (context-imbued) but not familiarity, or gist-based, memory responses for a studied word list, regardless of the material used in the distracting task (Skinner & Fernandes, 2008).

The dissociation in effects of visuospatial and phonological distracting tasks on memory for spatial patterns and words, observed in this study, aligns in many ways with the component-process model of memory (Moscovitch & Umiltà, 1990, 1991; see also Moscovitch, 1992, 1994; Fernandes & Moscovitch, 2000, 2002, 2003). According to that model, retrieval requires two main types of components. The first, mediated by the frontal cortex, is needed to maintain retrieval mode and implement strategic aspects of retrieval search and monitoring, and to coordinate competing task demands. The second component, believed to be mediated by the medial temporal lobe and hippocampal structures, involves the relatively automatic reactivation of memory traces that results from their interaction with memory cues; a process termed *ecphory* by Semon (1924; see also Schacter, Eich, & Tulving, 1978). This model suggests that the *ecphoric* process requires little if any resources, and would not be affected by DA unless the task material, or type of processing necessary for retrieval, is required in the distracting task as well. That is, DA is believed to exert its effect by disrupting the neocortical representations that constitute the memory trace for studied words and the processes necessary to maintain or activate those representations.

The dissociation observed in our study suggests that verbal and spatial episodic memories require reactivation of qualitatively different types of code. This coincides with previous studies showing a marked separation in episodic memory ability for verbal and visuospatial materials in patients (Temple & Richardson, 2006) and brain regions subserving performance during the encoding (Golby et al., 2001; Lee et al., 2002; Optiz et al., 2000; Wagner et al., 1998) and retrieval stages of memory (Lee et al., 2002; Optiz et al., 2000; Wagner et al., 1998). Whilst it is not always clear whether the resulting asymmetry is because of differences at the retrieval stage itself, or because of differences at the encoding or maintenance stage, it is clear that different materials rely on different underlying brain structures at some stage of the memory process. For example, Temple and Richardson (2006) describe two patients; one was a young girl with developmental dysmnesia (Casalini, Brizzolara, Cavallaro, & Cipriani, 1999) who had impaired episodic memory for words and stories but intact episodic memory for visual designs and features, the second (Temple, 1992) was a highly intelligent adult woman with degrees in medicine and psychology who had intact verbal but impaired visual episodic memory. There was no clear aetiology for either patients, though the functional specificity of their deficits suggest a double dissociation between verbal and visuospatial episodic memory processes (Temple & Richardson, 2006).

As well, it has long been known that there are asymmetrical deficits after unilateral medial temporal lobe (Milner, 1972) or, with variable consistency, after frontal lobe lesions (Milner & Petrides, 1984): Memory is poor for verbal material after left hemisphere lesions and poor for nonverbal material after right hemisphere lesions. Although lesion studies cannot distinguish whether these effects arise from differences at the encoding, storage, or retrieval stage of memory, they suggest that asymmetrical memory deficits arise according to material type, or to processes typically engaged by these materials.

These findings also contribute to the large literature, from studies of working memory, suggesting specialised subsystems for maintaining visuospatial and verbal information, which are also dissociable from a general purpose cognitive resource (Baddeley, 1986; Baddeley et al., 1975b; Farmer et al., 1986; Logie et al., 1990). In these studies, as in ours, a secondary task with a spatial or verbal component differentially disrupted working memory task performance for visual and verbal materials. As well, in those studies, there was a general decrease in performance under dual-task conditions, believed to be because of the change in processing load, or need to coordinate tasks (Logie et al., 1990). This is similar to the general effect of DA in our study. On our episodic memory task, we observed a general shift in response bias under DA, regardless of memory list or distracting task condition, toward more conservative responses. According to the component-process model, the prefrontal cortex mediates the general, resource-demanding, strategic processes associated with retrieval. Our data show that it is the response selection process that is affected by any DA condition at retrieval, but that this effect is independent of discriminability, or the *ecphoric* process. Thus, DA at retrieval can have both process-specific and general effects on memory.

Our current investigation thus highlights two novel effects of DA at retrieval. First, similarity in processing requirements between the memory and distracting task influences the magnitude of memory interference from DA at retrieval. This suggests different codes are used to represent different information: episodic retrieval of words requires phonological, more so than visuospatial, processing resources, whereas the reverse is true for retrieval of spatial patterns. Second, we showed a general effect of DA at retrieval on response criterion such that the pattern of responding becomes more conservative.

Résumé

Nous avons examiné la mémoire de reconnaissance pour les mots et les patrons visuo-spatiaux sous des conditions d'attention complète (AC) ou divisée (AD) avec une tâche distractive requérant le traitement phonologique (rimes) ou visuo-spatial (lignes courbes) de lettres, auprès de soixante-douze jeunes adultes. Nous avons trouvé une interaction traduisant que la tâche distractive de la ligne courbe a eu un effet plus nuisible sur la reconnaissance corrigée et sur la discriminabilité, telle que mesurée par d' , pour les patrons spatiaux que la tâche distractive de rime, alors que l'inverse a été

² This effect on C was noted in the overall analysis, though not in the reduced sample, suggesting considerable variability exists, and that future studies with larger sample size are needed to confirm this pattern.

observé pour la mémoire des mots. Un effet général de l'AD sur les biais de réponse a aussi été observé, C augmentant de façon plus importante dans la condition AD que AC peu importe la tâche distractive ou le type d'information à se rappeler. Les résultats suggèrent que l'interférence de l'AD au rappel est propre au processus et qu'elle mène à une stratégie de réponse plus prudente.

Mots-clés : mémoire, spatiale, verbale, attention divisée, rappel

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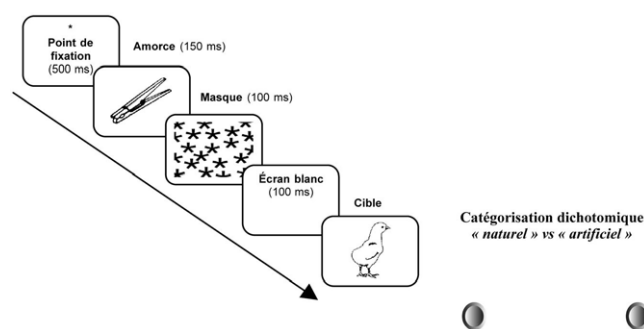
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Correction to Ferrier (2007)

Figure 1 in the article “L’influence de la taille typique des objets dans une tâche de catégorisation” (by Laurent Ferrier et al., *Canadian Journal of Experimental Psychology*, Vol. 61, No. 4, pp. 316–321) was printed incorrectly. The figure below presents the correct version of the experimental priming procedure of Figure 1.

Correction à l'article de Ferrier (2007)

La Figure 1 dans l'article “L’influence de la taille typique des objets dans une tâche de catégorisation” (par Laurent Ferrier et al., *Revue canadienne de psychologie expérimentale*, Vol. 61, No. 4, pp. 316–321) a été imprimée incorrectement. La figure ci-dessous présente la version correcte de la procédure expérimentale d'indication de la Figure 1.



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