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Transfer Appropriate Processing for Prospective Memory Tests

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SUMMARY

Transfer appropriate processing (TAP) is the assumption that retrospective memory test performance reflects the overlap between study and test phase processing. In a task analysis, we identify a similar sequential-type of processing overlap in prospective memory (ProM) situations. In addition, ProM test performance can also involve a concurrent overlap between processes engaged for an ongoing task and those required for recognizing relevant cues. A review of the ProM literature shows consistent TAP effects due to sequential processing overlap manipulations, but inconclusive findings for concurrent processing overlap manipulations. We examined the latter in a new experiment with young adult participants. The ongoing task required either semantic or perceptual processing of words, and the ProM task required either semantic or perceptual processing of words. Consistent with TAP, performance was higher when the ongoing task and the ProM task required the same kind of processing (i.e. semantic–semantic, perceptual–perceptual) rather than different kinds of processing (i.e. semantic–perceptual, perceptual–semantic). Copyright © 2000 John Wiley & Sons, Ltd.

Memory test performance is determined by the degree of overlap between processing of to-be-remembered (TBR) materials at study and test. This assumption about memory is known as Transfer Appropriate Processing (TAP; Morris *et al.*, 1977). In their seminal work, Morris *et al.*, required participants to learn words under two conditions, one focused on semantic properties of words and the other on phonemic properties, and memory was assessed by recognition tests that required processing words either semantically or phonemically. Consistent with TAP, the results showed higher performance levels in those conditions where study and test processing matched (i.e. in the semantic-study semantic-testing condition and in the phonemic-study phonemic-testing condition) rather than mismatched (i.e. in the semantic-study phonemic-testing condition and in the phonemic-study semantic-testing condition). This finding has been replicated and extended, and TAP has motivated theoretical accounts for a variety of phenomena, recently for performance dissociations between explicit and implicit memory tests (Graf and Mandler, 1984; Graf and Ryan, 1990; Roediger and Blaxton, 1987; Weldon *et al.*, 1989). Our goal in this article is to explore the implications of TAP for the domain of prospective memory (cf. Maylor, 1996a; Maylor *et al.*, in press; Mäntylä, 1993).

Prospective memory (ProM) has been characterized in many ways, including as intention memory (Goschke and Kuhl, 1996; Kvavilashvili and Ellis, 1996; Loftus, 1971), memory for future actions (Einstein and McDaniel, 1996; Mäntylä, 1996), and remembering that something has to be done (Dobbs and Rule, 1987; Maylor, 1996b).

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ProM is needed for such tasks as getting groceries *en route* home from work. The critical, defining difference between pro- and retrospective memory tasks occurs at the time of testing. For all retrospective memory (RetM) tests, participants are aware of retrieval cues, and at the time of testing, they are given specific instructions on how to work with them.[1] By contrast, for ProM tests, participants may or may not be aware of the cues; more importantly, they are not instructed–at the time of testing–to work with the cues in a ProM-task relevant manner. When driving by the supermarket, nothing alerts us to pay attention to this cue; no one instructs us that this cue is relevant to a previously formed plan. 'What is unique to ProM tasks is that they require identifying or recognizing cues as telltale signs of previously formed intentions when they [the cues] occur as part of ongoing thoughts or actions' (see Graf and Uttl, in press).

Previous research has highlighted differences among prospective tasks, for example, between time- and event-based tasks (Einstein *et al.*, 1995; Park *et al.*, 1997), episodic versus habitual tasks (Meacham and Leiman, 1982; Einstein *et al.*, 1998), and laboratory versus everyday tasks (Maylor, 1990; Kvavilashvili, 1992). Each of these tasks, and thus the difference between any pair of tasks, can be defined by the cues and instructions that are given to subjects and by the responses that are required of them (Graf and Birt, 1996). However, such attributes of tasks are not the focus of this article. Instead, we wish to draw attention to the subjective, conscious or intentional stance that seems to characterize different kinds of prospective activities.

ProM permits divisions analogous to those made in RetM, for example short-versus long-term memory (cf. Baddeley and Wilkins, 1984). In ProM, the short-term memory equivalent is required for activities such as monitoring and vigilance. What defines these activities is that the plan or intention to-be-performed is maintained in consciousness until it is performed. By contrast, our concern in this article is with the long-term memory equivalent, that aspect of ProM that corresponds to James' (1890) *memory proper*, today known more widely as explicit episodic memory. By analogy with James, we consider *ProM proper* to be that part of prospective memory that requires that 'we are aware of a plan [or intention], *of which meanwhile we have not been thinking* (emphasis added), with the additional consciousness that we had made the plan earlier' (Graf and Uttl, in press; see also Brandimonte and Passolunghi, 1994; Kvavilashvili, 1998; Maylor, 1996a; Park *et al.*, 1997).

The first part of this article begins with a brief task analysis of ProM and RetM situations. We highlight the fact that ProM and RetM situations present different opportunities for the occurrence of processing overlaps, and we review empirical research of TAP effects in ProM proper. The second part of the article reports a new experiment that examined one kind of TAP influence in ProM proper.

PART 1 A TASK ANALYSIS OF RetM AND ProM

The extension of TAP to the domain of ProM proper is complicated because of differences between ProM and RetM test situations. These differences are underscored by the task analysis summarized in Figure 1 and Table 1.

[1]This characterization of retrospective memory tests applies also to implicit memory tests. On implicit memory tests, subjects are given specific instructions–at the time of testing–on how to work with the cues (e.g. complete each stem with the first word to come to mind). The critical difference between explicit and implicit tests is that the instructions for implicit tests do not mention the prior study phase of the experiment (see Graf and Schacter, 1985).

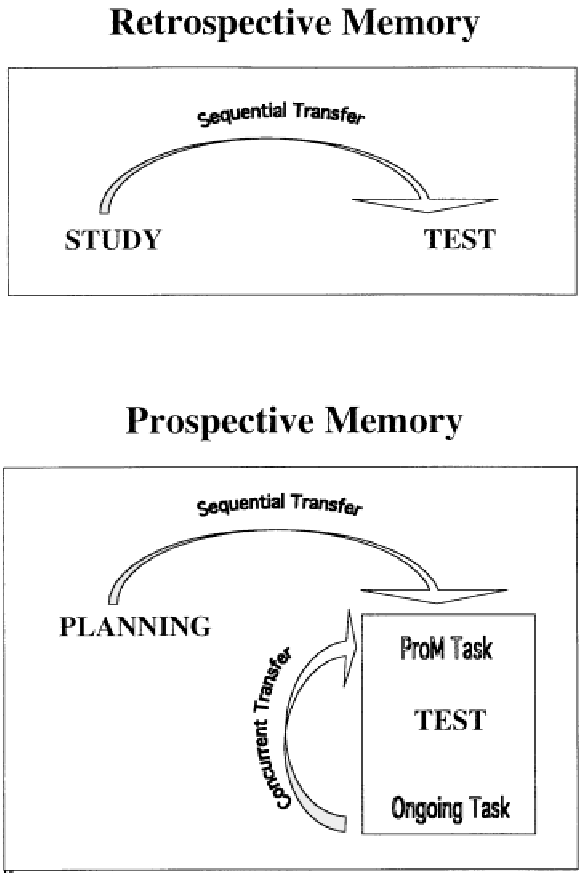

Figure 1. Processing overlaps in retrospective and prospective memory

On the surface, ProM and RetM situations are similar; both have three distinct phases and the middle phase–retention–is the same. However, the first and third phases differ markedly. For RetM tasks, Phase 1 is called the Study or Learning phase because the task for participants is to learn materials (items or events) for a later memory test. The third–Test or Retrieval–phase also gets its name from the task that is assigned to participants, in this case, retrieving previously learned materials from memory. If we keep to the convention of naming experimental phases according to the tasks assigned to participants, Phase 1 of a typical ProM proper task might be called the Planning phase because the focal task is to plan an activity (e.g. buy groceries *en route* home from work, press the *F1* key when you see a word with three *e*'s) that is to be carried out at a later time (i.e. when the appropriate circumstances or cues arise). In the third or Test phase, participants perform a cover or ongoing task[2] (e.g. drive home from work, make semantic decisions about words) and the ProM task relevant cues (e.g. the supermarket, a word with three *e*'s) occur in the course of this activity. Of interest is whether participants recognize the cues as being

[2]To facilitate communication among researchers, participants at the First International Conference on Prospective Memory (held in July 2000 in Hatfield, UK) resolved to use the label 'ongoing' to characterize the task used to engage subjects when the ProM cues are encountered.

Table 1. An analysis of retro- and prospective memory situations

		Retrospective memory	Prospective memory
Phase 1			
	Task	Learn TBR materials according to instructions	Plan an activity to be carried out later or commit to carrying out an assigned activity to be done later
	Materials	Words, names, stories, pictures, etc.	An intention or promise, each defined by a cue, an objective and its content
	Task orientation	Can be intentional or incidental	Is always intentional
Phase 2		Retention interval	Retention interval
Phase 3			
	Task(s)	Process or recollect TBR materials according to instructions	This phase typically involves two tasks or activities that must be carried out concurrently. One is called the ongoing task and the other is the ProM task. The ongoing task requires processing presented materials (e.g. learning words for a later memory test). The ProM task relevant cues occur in the course of the ongoing task. The ProM task is to carry out a previously planned activity when the cues appear
	Task orientation	Can be explicit or intentional versus implicit or incidental	Ongoing task processing is intentional; processing of ProM task relevant cues is unintentional, incidental to the ongoing activity

relevant for the ProM task and whether they perform the intended/planned action when the relevant cues appear.

Figure 1 emphasizes that RetM and ProM situations present different types of opportunities for the occurrence of overlaps in processing. For RetM tasks, processing overlaps can occur between Study and Test, between Time 1 (Study phase) and Time 2 (Test phase) processing. This type of processing overlap–a sequential overlap–can also occur in ProM situations, when there is a matching of processing between the Planning and Test Phase. In addition, ProM tasks permit another kind of overlap between the processing required for the ongoing task and the processing required for recognizing cues as being relevant to a prior plan or intention. This type of overlap–a concurrent overlap–has been called ‘task appropriate processing’ by Maylor (Maylor, 1996a; Darby and Maylor, 1998).

The precise format of the *sequential processing overlap* differs between RetM and ProM tasks, in part, because of differences in the TBR materials (see Table 1). For RetM, the TBR materials typically are words, pictures or stories, and TAP influences on test performance are interpreted in terms of how these materials were processed (e.g. perceptually, semantically) at study and test. For ProM proper, the TBR materials are intentions or promises to be executed at a later time. An intended activity, such as 'later today I will buy groceries *en route* home from work', implicates distinct elements (cf. Einstein and McDaniel, 1990; Ellis, 1996; Kvavilashvili, 1987; Maylor, 1996b; Winograd, 1988; Brandimonte and Passolunghi, 1994). We distinguish between the *cue* (e.g. the supermarket) that signals when the planned activity is to be executed, the *objective* that defines that something is to be done, and the *content* (e.g. the groceries to be purchased) that specifies what is to be done.[3] Therefore, it seems theoretically possible in ProM situations for TAP influences to occur as a consequence of overlaps between Planning and Test phase processing of cues, objectives or contents.

Prior research has systematically investigated only one of these types of overlaps, the manner in which cues were processed during the Planning and Test phase. Most relevant is work by McDaniel *et al.* (1998). Their Experiment 1 used homophonic words as cues (e.g. bat), with each cue appearing in a sentence that biased either one or another interpretation. In the Test phase, the cues were presented in a sentence that biased either the same meaning as in the Planning phase or a different meaning. The ongoing task was to verify whether or not each sentence was true. The ProM task was to press a key when each cue appeared in the Test phase. McDaniel *et al.*, found higher ProM test performance with cues in the same meaning condition (81%) than with cues in the different meaning condition (48%). In their Experiment 2, McDaniel *et al.* (1998) used either written words (as in Experiment 1) or pictures (i.e. line drawings) as cues; they were embedded in sentences that were presented for truth verification. The results showed higher ProM test performance when the same cues were used (i.e. in the picture–picture and word–word conditions) in the Planning and Test phase (83.5%) than when there was a cue change (i.e. in the picture–word and word–picture conditions) between the Planning and Test phase (64.5%).

McGann *et al.* (2000, Presentation at the First International Conference on Prospective Memory, Hatfield, UK) have extended these findings. They also used homophones as ProM cues that were embedded in sentences. The results showed that Planning to Test phase changes in the meaning of homophones reduced ProM performance when the ongoing task required semantic processing. By contrast, Planning to Test phase changes in the visual appearance of homophones reduced ProM performance when the ongoing task required perceptual processing.

In a related investigation by Einstein *et al.* (1995) words were displayed on a computer monitor and the ongoing task was for participants to recollect upon request the last 10 presented words. The ProM task was to press a designated key, either 'whenever the words leopard, lion or tiger' appeared on the screen or 'whenever any animal word' occurred. The animal words *leopard*, *lion* or *tiger* were used as cues in the latter condition. The results showed higher ProM performance with instructions that identified specific words as cues (i.e. that enable Planning phase pre-processing of cues) rather than the category membership of the cues.

The foregoing experiments illustrate consistent TAP effects in ProM across a variety of different methods for manipulating Planning to Test phase processing overlaps. However, only cue processing overlaps have been examined to date, most likely because only cues are presented in both the Planning and Test phase. Neither the objective nor the content of

[3]Although the proposal that intentions and promises can be decomposed into three separable parts–cues, objectives and contents–is speculative, it is based on the observation that each may be forgotten independently of the others.

planned activities are re-presented in the Test phase, and we are not aware of any methods that have been developed for varying Planning to Test phase overlaps in processing objectives and contents.

The sequential processing overlaps explored in the preceding paragraphs can occur with both ProM and RetM situations. By contrast, *concurrent processing overlaps* are unique to ProM situations. As highlighted by Figure 1, ProM test situations involve a combination of processing activities, those required for the ongoing task (e.g. make semantic decisions about words) and those required for recognizing cues as being relevant to the ProM task. The degree of concurrent processing overlap is variable; it would be large, for example, between an ongoing task that requires making semantic decisions about words (e.g. name the category membership of each word) and a ProM task that requires responding to semantically defined stimuli (e.g. press the *F1* key on the keyboard when you see an animal word). The concurrent processing overlap would be smaller if the same ongoing activity were used together with a ProM task that required responding to perceptually defined stimuli (e.g. press the *F1* key when you see a word with three *e*'s).

To our knowledge, only a few experiments have directly examined the effects of concurrent processing overlaps on ProM test performance. In an experiment by Darby and Maylor (1998, poster presented at the Seventh Cognitive Aging Conference, Atlanta, Georgia), the ongoing task was either semantic – to find among six words the one closest in meaning to a target word, or structural – to find among six words the one following the target in alphabetical order. The ProM task was similarly either semantic – to respond if the name of a colour appears in the word sets, or structural – to respond if a word with a double letter appears in the word sets. Darby and Maylor were interested primarily in whether age-differences in ProM would vary across the four experimental conditions defined by the combination of ongoing tasks and ProM tasks (i.e. semantic–semantic, semantic–structural, structural–semantic and structural–structural). Here, we focus on the overall effects due to concurrent processing overlaps between the ongoing tasks and the ProM tasks. Contrary to the expectation that performance would be higher with a greater concurrent processing overlap, the results showed slightly lower performance in the high-overlap conditions (i.e. semantic–semantic, structural–structural) than in the low-overlap conditions (i.e. semantic–structural, structural–semantic), 24% versus 28.25%, respectively.

A study by West and Craik (1999) yielded more encouraging results. In their experiment, the ongoing task required making decisions either about the semantic category of words or about the display color of words, and the ProM task was to respond to cue words belonging either to specific semantic categories (e.g. a part of a building) or to specific perceptual categories (e.g. printed in upper-case letters). Unfortunately, West and Craik's short report does not include the results most relevant to concurrent TAP effects. However, according to Craik (2000, presentation at the First International Conference on Prospective Memory, Hatfield, UK) and West (R. West, personal communication, 18 August 2000) performance for categorically defined cues was higher when the ongoing task required semantic rather than perceptual processing. On the other hand, performance for the perceptually defined cues did not differ across the ongoing tasks.[4]

In a recent study, Brunfaut *et al.* (2000) examined concurrent TAP effects in Korsakoff patients and alcoholic control subjects, and they found a pattern of results similar to that

[4]West (R. West, personal communication, 18 August 2000) and his colleagues recently have extended their work and found TAP effects with both semantic and perceptual ongoing tasks.

reported by West and Craik (1999). However, the method used by Brunfaut *et al.*, involved displaying a ProM cue about every 8 seconds, that is, at a rate where subjects with intact memory functions would be likely to maintain the ProM task in conscious awareness. For this reason, the findings reported by Brunfaut *et al.*, may be relevant to concurrent TAP effects in monitoring tasks, but may not generalize to tasks that require ProM proper.

The combined findings from the foregoing experiments on concurrent TAP effects in ProM proper are difficult to interpret. They may reflect methodological differences between the experiments. However, with the exception of the study by Brunfaut *et al.*, we are unable to identify relevant methodological differences because neither of the earlier experiments has been reported in detail.

The investigation of how TAP affects ProM proper has only just begun. Our main purpose in reviewing the existing research on the topic was to underscore the distinction between sequential and concurrent processing overlaps, and to illustrate the methods that have been used to investigate them. We believe that the results from the existing research must be interpreted very cautiously, for a number of reasons. One is that most of the findings remain to be replicated. Another reason is that processing overlaps have been examined to date under only a narrow range of conditions and thus very little is known about the generality of the findings.

PART 2 CONCURRENT TAP EFFECTS IN ProM PROPER

The present study was designed to examine the hypothesis that ProM proper would vary as a function of the degree of concurrent processing overlap between the ongoing task and the ProM test task. We focused on concurrent rather than sequential processing overlaps because (a) the former is unique to ProM, (b) less research has been done on this topic, and (c) the existing findings are inconsistent.

The experiment had several parts, with the final and most critical focusing on assessing ProM proper. Participants were presented with several lists of common words, and each list was followed by a short-term recall test. In addition to learning the lists for the recall test, the ongoing task required either making a semantic decision about each presented word (i.e. decide whether or not the word represents something natural) or making a perceptual decision about each word (i.e. decide whether or not the word has two or fewer enclosed spaces). The ProM task required pressing a designated key either in response to seeing a word that represented an animal or in response to seeing a word with three *e*'s. By combining the two ongoing tasks with the two ProM tasks, we created four critical conditions: semantic–semantic, perceptual–semantic, semantic–perceptual and perceptual–perceptual. We expected higher test performance in the conditions with greater concurrent processing overlaps, that is, where the ongoing and ProM task required the same kind of processing (e.g. semantic–semantic, perceptual–perceptual) rather than different kinds of processing (e.g. perceptual–semantic, semantic–perceptual).

Method

Participants and design

The participants were 80 undergraduate volunteers (17 men and 63 women) from the University of British Columbia, between 18 and 33 years of age ($M = 19.9$ years). They participated in return for course credit. The core part of the experiment consisted of four between-subjects conditions that were defined by crossing two ongoing tasks (semantic and perceptual) with two ProM tasks (semantic and perceptual). Twenty participants were randomly allocated to each between-subjects condition.

Material

A total of 126 concrete six-letter words were selected from the MRC Psycholinguistic database (Coltheart, 1981; MRC, 2000). Half of them belonged to the category of natural things (e.g. tomato); the other half referred to fabricated things (e.g. pencil). In addition, approximately half of the words in each subset were selected so as to contain two or fewer enclosed spaces (e.g. pencil), while the other half had three or more enclosed spaces (e.g. tomato). (The letters a, b, d, e, g, o, p and q each have one enclosed space). These words were used repeatedly for the series of activities listed in Table 2.

An additional 12 words were required as ProM test cues. Six of these were animal words – *turtle, rabbit, spider, monkey, beaver* and *lizard*, and six were words with three *e*'s – *sleeve, keeper, fleece, needle, breeze* and *beetle*.

For short-term memory practice, we used three sets of 4-, 5-, 6-, 7-, 8- and 9-word lists, for a total of 18 lists. To create each list, we sampled randomly from the pool of 126 words. Sampling was without replacement within lists, but with replacement across lists.

For practising the semantic and perceptual decision-making tasks, we randomly drew a new set of 80 words from the initial pool. Sampling was without replacement.

A new set of 6 lists, one of each length (i.e. with 4, 5, 6, 7, 8 or 9 words), was used for practising the short-term memory task in combination with either semantic or perceptual decision making. The words for these lists were drawn in the same manner as for short-term memory practice.

A final group of 42 lists were used for testing ProM proper. This group was arranged to form 6 sets, and each set had one 4-, 5-, 6-, 8- and 9-word list plus two 7-word lists. Each list was constructed in the same manner as for short-term memory practice, with one notable exception. In each set, one of the 7-word lists was modified, by replacing its fifth word with one of the ProM task cues. The ProM task cues were used without replacement.

A unique set of lists was constructed for each participant. However, for all participants assigned to the ProM task conditions that required responding to animal words, one of

Table 2. Ordering of activities and use of materials in the experiment

Activity type	Trials and materials
(1) Short-term-memory (STM) task practice	18 trials were given, using 3 sets of 6 lists. Each set included one 4-, 5-, 6-, 7-, 8- and 9-word list
(2) Decision task (semantic or perceptual) practice	A single trial was given; it required an 80-word list
(3) Planning: ProM instructions	
(4) Ongoing task (STM and decision task) practice	6 trials were given, using one 4-, 5-, 6-, 7-, 8- and 9-word list
(5) Retention interval	Filled by completing an unrelated questionnaire
(6) Test: ProM task and ongoing task	42 trials were given, requiring 6 sets of lists. Each set included one 4-, 5-, 6-, 8- and 9-word list, and two 7-word lists. In each set, one of the 7-word lists contained the ProM cue

these cue words appeared in the modified lists. By contrast, for all participants assigned to the ProM task conditions that required responding to words with three *e*'s, one of these words appeared in the modified lists.

Procedure

Participants were tested individually. They were seated in front of a computer and informed that the experiment involved a variety of tasks, with some focusing on prospective and others on retrospective memory. After giving consent, each participant completed the sequence of activities in Table 2. The short-term memory and decision tasks were used to familiarize participants with the experimental procedure, so that they could practise these activities alone prior to having to do them concurrently. Experimental materials were presented in black against a white background in the centre of a VGA-monitor.

The short-term memory task had 18 trials. On each trial, a different list was presented, one word at a time, at a rate of 1 word per second. The end of each list was signaled by the instruction to recall the list. Participants had 10 seconds to recall each list aloud before the instruction to 'press the spacebar for the next list' appeared on the monitor. Pressing the spacebar initiated the next trial. The lists with 4 words were used for the first three trials; the 5-word lists were used for the next three trials, etc., in this way exposing participants to increasingly longer lists across trials.

The next task, decision making, was given immediately after short-term memory practice. The instructions for the decision task were different, depending on experimental conditions. For the semantic task, the instructions were to decide for each word whether it referred to a natural or fabricated object. For the perceptual task, the instructions were to decide for each word whether it had two or fewer enclosed spaces versus three or more enclosed spaces. The participants were encouraged to make their decisions as rapidly and accurately as possible. The 80-word list constructed for this task was shown once, and participants made their responses by pressing designated keys. Each key-press initiated the display of the next word.

Immediately after practising decision making, the ProM task instructions were given, with different instructions depending on experimental conditions. Participants were informed that they would now do both of the previous tasks–short-term memory and making decisions–in combination. In the semantic task, they had to decide for each word whether it represented a natural or fabricated thing, and they had to recall the just presented words when instructions to do so appeared on the computer screen. In the perceptual task, they had to decide for each word whether it had two or fewer versus three or more enclosed spaces, and they had to recall the just presented words when the recall instructions appeared on the computer monitor. Participants were also given instructions for the ProM tasks. A random half of the participants were assigned to the semantic proM cue condition (i.e. responding to animal words) and the other participants were assigned to the perceptual proM cue condition (i.e. responding to words with three *e*'s). In each condition they were instructed to press the A-key at the end of the list in which they saw a target word[5]. To exclude the possibility that the STM-task would interfere with

[5]We required subjects to respond at the end of the list rather than when the ProM cue was presented following considerable pilot work. When instructed to respond to cues immediately many subjects pressed the key for the ongoing task, before they realized that they just processed a ProM-cue (typically accompanied by exclamations like 'oh'). Therefore we changed the procedure so that the key-press for the ongoing activity did not interfere with the response to the ProM cue.

remembering to press the A-key, participants were not required to recall any list that contained a ProM cue (even though the recall instructions appeared at the end of every list). Upon pressing the A-key, the instruction to 'press the spacebar for the next trial' appeared on the screen.

The instructions were explained until participants understood and were able to repeat them. Then a total of 48 trials were presented, arranged into 7 blocks, the first with 6 trials and the remaining with 7 trials. For each trial, a list of words was presented one at a time. Participants made either semantic or perceptual decisions as practised previously, and they recalled each list when prompted to do so. The order of presenting the lists in each block (i.e. the lists in each set) was determined randomly, except as indicated next. The most critical difference between the first block and the remaining blocks was that the lists with the embedded ProM cues appeared only in the latter blocks, and in these blocks, those lists were always presented last.

Between the first and second block of trials, participants were given a paper and pencil questionnaire that required about 10 min to complete. The main purpose of this intervention was to create a filled retention interval or delay before assessing ProM test performance (cf. Einstein and McDaniel, 1990). After completing the questionnaire, participants were reminded about the combined tasks, and reminded to keep responding quickly and accurately. The ProM task was not mentioned again. The entire experiment lasted about 1 hour.

Results

ProM test performance was scored as successful if the participant remembered to press the designated response key any time between the occurrence of the ProM cue and the end of the trial in which it appeared. For each participant, the prospective memory score was the proportion of successful responses out of a possible six. Figure 2 shows ProM test performance in the main experimental conditions. With the semantic ongoing task, the mean proportions were 0.58 for semantic ProM cues and 0.37 for perceptual ProM cues, and with the perceptual ongoing task, performance averaged 0.39 and 0.77 with semantic and perceptual ProM cues, respectively. These results underscore the higher levels of performance in the conditions with higher processing overlaps (between the ongoing task and ProM task) – semantic–semantic and perceptual–perceptual – than in the

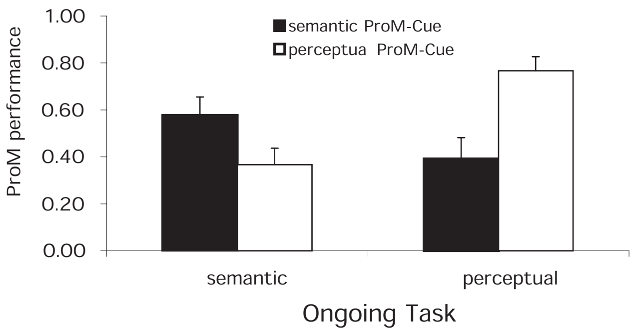

Figure 2. Mean ProM task performance (vertical bars indicate standard errors) as a function of type of ongoing task (i.e. semantic versus perceptual decision making) and ProM cue type (semantic versus perceptual)

conditions with a smaller degree of processing overlap – semantic–perceptual and perceptual–semantic.

For all statistical analysis an alpha level of 0.05 was used. A 2×2 between-subjects analysis of variance (ANOVA) with the factors ProM-cue type (semantic versus perceptual) and ongoing task type (semantic versus perceptual) revealed a significant interaction between these factors, $F(1, 76) = 15.24$, $MSe = 0.11$, $p < 0.01$. No other effects achieved significance. Follow-up tests showed a significant difference due to the ProM-cue type for the semantic ongoing task, $t(38) = 2.04$, $p < 0.05$, as well as for the perceptual ongoing task, $t(38) = 3.43$, $p < 0.01$. For perceptual ProM cues, there was a significant difference due to the ongoing task type, $t(38) = 4.27$, $p < 0.01$; for semantic ProM cues, the effect due to ongoing task type was marginal, $t(38) = 1.57$, $p = 0.12$.

We also examined the distribution of performance across participants. The number of participants with perfect ProM task scores (i.e. who were successful on all six trials) was 3 and 4 for the high processing overlap conditions (i.e. semantic–semantic and perceptual–perceptual, respectively), versus 3 and 1 for the lower overlap conditions (i.e. semantic–perceptual and perceptual–semantic, respectively). The number of participants who failed to remember the ProM task on all six occasions was 2 and 1 for the high processing overlap conditions (i.e. semantic–semantic and perceptual–perceptual, respectively), versus 7 and 5 for the lower overlap conditions (i.e. semantic–perceptual and perceptual–semantic, respectively). These results indicate that in each condition, between 50% and 75% of the participants remembered the ProM task at least once or missed it at least once.

Table 3 summarizes performance on the ongoing tasks. The means show that participants recalled just over 3 words per short-term memory trial. ANOVAs of the recall scores showed no significant main effects due to ProM cue type (semantic versus perceptual) or ongoing task type (semantic versus perceptual). As expected, the number of words recalled per list increased with longer lists, $F(5, 380) = 14.66$, $MSe = 0.15$, $p < 0.01$, while the proportion of words recalled per list decreased, $F(5, 380) = 345.8$, $MSe = 0.005$, $p < 0.01$.

The overall low level of recall may seem surprising. However, the experiment involved a large number of trials, and similar materials were presented across trials, thereby creating optimal conditions for the build-up of proactive interference (Underwood, 1957;

Table 3. Means (standard errors in parentheses) for performance on the ongoing tasks (i.e. remembering words and making semantic or perceptual decisions about words) as a function of word-list length

	List length					
	4 words	5 words	6 words	7 words	8 words	9 words
STM RECALL						
Words	3.02 (.07)	3.15 (.07)	3.11 (.08)	3.34 (.09)	3.39 (.09)	3.42 (.09)
Proportion	0.76 (.02)	0.63 (.01)	0.52 (.01)	0.48 (.01)	0.42 (.01)	0.38 (.01)
Decision Task						
Accuracy	0.88 (.01)	0.89 (.01)	0.89 (.01)	0.89 (.01)	0.88 (.01)	0.88 (.01)
Speed (seconds)	1.64 (.05)	1.67 (.05)	1.64 (.05)	1.63 (.05)	1.65 (.05)	1.62 (.05)

Wickens *et al.*, 1981; Wixted and Rohrer, 1993). Our findings are consistent with previous investigations of short-term memory performance under conditions of high proactive interference (Turvey *et al.*, 1971).

Table 3 also shows performance accuracy on the ongoing semantic and perceptual decision tasks, as well as the speed of making correct semantic and perceptual decisions. Each set of data was examined in an ANOVA, with ProM cue type (semantic versus perceptual) and ongoing task type (semantic versus perceptual) as between-subjects factors and list length as a within-subjects factor. In each case, the main effect due to ongoing task type was significant, with $F(1, 76) = 5.31$, $MSe = 0.023$, $p = 0.05$, for the accuracy scores and $F(1, 76) = 38.19$, $MSe = 0.846$, $p < 0.01$, for decision speeds. These results reflect the higher performance accuracy with the ongoing task that required making semantic (0.90) rather than perceptual (0.87) decisions, and the fact that semantic decisions were made faster (1.38 seconds) than perceptual (1.90 seconds) decisions. No other effects were significant.[6]

Discussion

The present experiment examined the hypothesis that test performance would be higher under conditions with greater concurrent processing overlaps, that is, when the ongoing and ProM task involve the same kind of processing (e.g. semantic–semantic, perceptual–perceptual) rather than different kinds of processing (e.g. perceptual–semantic, semantic–perceptual). The results are consistent with this hypothesis.

Our study augments the work by West and Craik (1999). They found a performance benefit under conditions with greater concurrent processing overlap, but only when the ProM cue was semantically rather than perceptually defined. The present study also replicates and extends the recent study by Marsh, Hicks and Hancock (this issue). Marsh and his colleagues crossed two types of ongoing tasks, make pleasantness ratings about words or find words with repeated letters, with two types of ProM tasks, respond to animal words or to words that are palindromes. Performance was higher in the conditions with greater concurrent processing overlap; the pattern of performance was the same as in our Figure 2. By contrast to these investigations, however, an earlier study by Darby and Maylor (1998) found no evidence for a concurrent TAP effect on ProM test performance.

We cannot offer a definitive interpretation for these different findings across investigations, but suspect the influence of two major factors: differences in the degrees of overlap in concurrent processing and differences in the resource demands of different tasks. Consistent with the notion of TAP, we expect performance benefits to reflect the precise degree of overlap in concurrent processing in all experimental conditions, but we know of no metric for measuring this overlap. Our choice of ongoing tasks and ProM tasks was based on intuition and pilot testing and we suspect that other investigators proceeded on the same basis. It is possible therefore, that we were just more fortunate than others (e.g. Darby and Maylor, 1998) in selecting task-pairs with a high degree of processing overlap.

We believe that concurrent TAP effects may occur only when comparing performance between two experimental conditions that do versus do not necessitate the processing of

[6]In a follow-up analysis, we explored whether the speed difference between the perceptual and semantic ongoing tasks influenced ProM test performance. From each condition, we selected a subset of 5 subjects that had closely matching times in the ongoing tasks (with means between 1450 and 1491 ms in each condition). Although this data subset was too small for a meaningful statistical analysis, performance on the ProM test showed the same pattern as in Figure 2.

cues in a ProM-task relevant manner. This condition was met by our experiment. In one of our high-overlap conditions, for example, the processing required in order to identify cues as being ProM-task relevant (e.g. it is a word with 3 e's) was closely similar to that required for the ongoing task (e.g. counting the number of enclosed spaces), and in this sense, the processing of ProM cues was obligatory. By contrast, in one of the low-overlap conditions, the ongoing task (e.g. counting the number of enclosed spaces) did not necessitate processing cues in a ProM-task relevant manner (e.g. as an animal word). A detailed examination of West and Craik's (1999) work and of the work by Marsh *et al.* (this issue) shows that they also found concurrent TAP effects only between conditions where ProM-cue processing was versus was not obligatory.

The absence of a concurrent TAP effect may be interpreted as evidence that two experimental conditions did not differentially involve the processing of ProM-cues. Clearly, we would not expect a concurrent TAP effect between two conditions if, for example, ProM-cue processing was not required by either of them. Similarly, we would not expect a concurrent TAP effect if ProM-cue processing were equally obligatory in both of them. We believe that the first of these situations applied in the case of Darby and Maylor (1998). One of their ongoing tasks (i.e. the structural task) required finding a word (among a set of words) that follows another in the alphabet, and in the high-overlap condition, the ProM cue was defined as a word with double letters (e.g. maroon). By our intuition, this task-pairing did not ensure that cues were processed in a ProM-task relevant manner, because depending on the alternatives in the word set, subjects were able to perform the ongoing alphabet task without processing the double letters that defined the ProM cues.

The second situation, where ProM cue processing is equally likely in two conditions that are being compared, seems to apply to part of West and Craik's study, to Experiment 3 of Marsh *et al.*, as well as to part of Darby and Maylor's study. In that part of West and Craik's study that produced no concurrent TAP effect, the ProM cue was a word written in upper-case letters. In the high-overlap condition, the ongoing task was to judge the display color of the words whereas in the low-overlap condition, subjects had to make decisions about the category membership of the words. However, it would seem that case information about words has to be processed in order to make category membership decisions. If so, West and Craik may have failed to find a concurrent TAP effect with perceptually defined ProM cues because they were obligatorily processed irrespective of whether participants had to make category or colour decisions about words. Similarly, Marsh *et al.* (this issue) may have failed to find evidence for a concurrent TAP effect in their Experiment 3 because all ProM cues were surrounded by angle brackets, that is, by distinct visual marks that were likely to be processed under all experimental conditions. A similar interpretation may fit the semantic ongoing task conditions of Darby and Maylor. This task required finding among a set of words one that was closest in meaning to a specified target. In the high-overlap condition, the ProM cue was defined as a color word (e.g. maroon), and in the low-overlap condition the cue was defined as a word with double letters (e.g. maroon). Because letter information has to be processed in order to determine the meaning of a word, it would seem that the ongoing task entailed the processing required for identifying both semantically and structurally defined ProM cues.

The foregoing speculations about obligatory processing focus on the circumstances that do versus do not yield concurrent TAP effects. Still missing, however, is the specification of a function for obligatory processing. By definition, ProM tasks require identifying or recognizing cues as telltale signs of previously formed plans and intentions when they occur as part of ongoing thoughts, actions or situations. We assume that interrupting ongoing activities, and switching over to previously formed intentions is highly demanding of attention resources (Anderson and Craik, 2000; Craik, 1986; Einstein *et al.*, 1997). For this reason, switching to a ProM task is less likely when all or most available resources are required for the ongoing task, and it is also less likely when the resource pool has been reduced, for example, by age (Maylor, 1996b). We assume that when cue processing is obligatory, this works like a resource-efficient external trigger for switching to the ProM task, thereby facilitating test performance.

The proposal that obligatory processing facilitates ProM test performance by serving as a trigger for switching is consistent with Craik's (1986) account of age effects in memory. Craik distinguished between subject-initiated and environmentally-driven processing, postulating that age-related performance declines are larger on those tests that make greater demands on attention-demanding subject-initiated processing. Further, Craik hypothesized the largest age-related declines for ProM tests because they make the greatest demands on subject-initiated processing. We speculate that conditions where ProM cue processing is obligatory reduce the need for subject-initiated processing, that such conditions facilitate ProM test performance by enabling a more environmentally driven switching from an ongoing activity to the ProM task.

Future research will need to examine these speculations about the function of obligatory processing, and about the experimental circumstances that give rise to concurrent TAP effects. Future research also will need to investigate the generality of our findings, for example, whether they hold for both event- and time-based tasks (Einstein and McDaniel, 1990). Event- and time-based tasks are defined, respectively, by whether the cue for executing an intention is a designated event (e.g. the occurrence of the word TIGER or of a word with three e's) or a designated time (e.g. 3 pm tomorrow, 10 minutes from now). All existing studies of concurrent TAP effects have used event-based tasks for assessing ProM performance, most likely because with such tests it is easier to manipulate the overlap between the processing required for an ongoing task and for processing cues in a ProM task relevant manner. However, this method difficulty seems surmountable. For a time-based task (e.g. press the A-key in 10 minutes), a high-overlap condition might be created, for example, by the use of an ongoing task that requires processing time information (e.g. estimate how much time is required for performing each of a series of briefly described tasks, such as 'making coffee'). In a low-overlap condition, the ongoing task might be to estimate the difficulty of each task. With this type of manipulation, we see no reason in principle why concurrent TAP effects could not be demonstrated on time-based tasks.

Investigations of concurrent TAP effects on time-based ProM tasks could serve to link the present findings with monitoring–the short-term memory equivalent of ProM. So far, we have focused on concurrent TAP effects in the domain of ProM proper. Research with time-based tasks would be interesting, in part, because they are hybrids that combine aspects of ProM proper and monitoring. It is unclear whether concurrent TAP effects would occur under conditions where participants tend to track the 'distance' to the execution of an intention (i.e. by monitoring time on a clock) while engaged in an ongoing task.

To our knowledge, only one prior study has investigated concurrent TAP effects on a monitoring task (Brunfaut *et al.*, 2000). In an event-based task, words were shown on a computer and the ongoing task was either to count the number of letters in each word or to briefly explain the meaning of each word. The prospective tasks were either to respond to animal words or to words with 5 letters. The pairing of ongoing and prospective tasks produced four experimental conditions: semantic–semantic, semantic–perceptual, perceptual–semantic and perceptual–perceptual. The results showed a concurrent TAP effect with the perceptual ongoing task, but not with the semantic ongoing task. However, these results must be interpreted cautiously for several reasons, most importantly, because they come from a sample of Korsakoff patients and alcoholic control subjects. The results may not generalize to subjects with intact memory functions. The finding that monitoring task performance is preserved in Korsakoff patients parallels the results from research on retrospective memory showing that amnesic patients can have normal short-term memory test performance together with severely impaired explicit episodic memory performance (Baddeley, 1999; Mayes, 2000).

Brunfaut *et al.* (2000) did not describe their investigation as focusing on monitoring. However, in order to focus on this prospective aspect of memory (rather than ProM proper), their ongoing task made use of a short list of 22 nouns that included 8 ProM cue words. Although word presentation was subject paced, a new prospective cue was displayed about every 8 to 10 seconds,[7] that is, well within the limits of the working memory span. Future research will need to examine the relationship between concurrent TAP effects on ProM proper and monitoring tasks.

CONCLUSION

In this article we investigated how TAP notions from RetM might be applied in the domain of ProM proper. We emphasized that ProM situations permit two kinds of processing overlaps, one operating sequentially and the other concurrently. Distinguishing between these kinds of processing overlaps helps to organize existing research. It underscores the fact that previous research has provided fairly strong evidence for positive TAP effect due to sequential processing overlaps, but mixed results for TAP effects due to concurrent processing overlaps. The new research reported in this article clarifies the latter evidence. The distinction between sequential and concurrent overlaps in processing is likely to inspire new research to explore, for example, how degrees of processing overlaps of one kind interact with overlaps in the other. In addition, the distinction between sequential and concurrent processing overlaps also highlights a key difference between ProM proper and explicit episodic memory.

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[7]The critical difference between monitoring and ProM proper is not defined by the time interval between cues. Monitoring tasks are those where an intention is maintained in consciousness until it needs to be executed. By contrast, for ProM proper, intentions are not maintained in consciousness through the retention interval, while performing an ongoing task. A clear operational distinction between monitoring and ProM proper may be difficult to achieve in each case. However, ProM researchers might go forward as did RetM researchers in the 1960s (when they struggled to find clear operational distinctions between short- and long-term memory), by avoiding boundary cases and instead focus research on clear examples of monitoring and ProM proper.

REFERENCES

Anderson ND, Craik FIM. 2000. Memory in the aging brain. In *The Oxford Handbook of Memory*, Tulving E, Craik FIM (eds). Oxford University Press: New York; 411–425.

Baddeley AD. 1999. *Essentials of Human Memory.* Psychology Press: Hove.

Baddeley AD, Wilkins AJ. 1984. Taking memory out of the laboratory. In *Everyday Memory, Actions and Absent-mindedness*, Harris JE, Morris PE. (eds). Academic Press: New York.

Brandimonte MA, Passolunghi MC. 1994. The effect of cue-familiarity, cue-distinctiveness, and retention interval on prospective remembering. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology* **47A**: 565–587.

Brunfaut E, Vanoverberghe V, d'Ydewalle G. 2000. Prospective remembering of Korsakoffs and alcoholics as a function of the prospective-memory and on-going tasks. *Neuropsychologia* **38**: 975–984.

Coltheart M. 1981. The MRC psycholinguistic database. *Quarterly Journal of Experimental Psychology*: *Human Experimental Psychology* **33A**: 497–505.

Craik FIM. 1986. A functional account of age difference in memory. In *Human Memory Capabilities: Mechanisms and Performances*, Klix F, Hagendorf H (eds). Elsevier Science: Amsterdam; 409–422.

Dobbs AR, Rule BG. 1987. Prospective memory and self-reports of memory abilities in older adults. *Canadian Journal of Psychology* **41**: 209–222.

Einstein GO, McDaniel MA. 1990. Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory and Cognition* **16**: 717–726.

Einstein GO, McDaniel MA. 1996. Retrieval processes in prospective memory: Theoretical approaches and some new empirical findings. In *Prospective Memory: Theory and Application*, Brandimonte M, Einstein GO, McDaniel MA (eds). Erlbaum: Mahwah, NJ; 115–141.

Einstein GO, McDaniel MA, Richardson SL, Guynn MJ, Cunfer AR. 1995. Aging and prospective memory: Examining the influences of self-initiated retrieval processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **21**: 996–1007.

Einstein GO, McDaniel MA, Smith RE, Shaw P. 1998. Habitual prospective memory and aging: Remembering intentions and forgetting actions. *Psychological Science* **9**: 284–288.

Einstein GO, Smith RE, McDaniel MA, Shaw P. 1997. Aging and prospective memory: The influence of increased task demands at encoding and retrieval. *Psychology and Aging* **12**: 479–488.

Ellis J. 1996. Prospective memory or the realization of delayed intentions: A conceptual framework for research. In *Prospective Memory: Theory and Application*, Brandimonte M, Einstein GO, McDaniel MA (eds). Erlbaum: Mahwah, NJ; 1–22.

Goschke T, Kuhl J. 1996. Remembering what to do: Explicit and implicit memory for intentions. In *Prospective Memory: Theory and Application*, Brandimonte M, Einstein GO, McDaniel MA (eds), Erlbaum: Mahwah, NJ; 53–91.

Graf P, Birt AR. 1996. Explicit and implicit memory retrieval: Intentions and strategies. In *Implicit Memory and Metacognition*, Reder LM (eds). Erlbaum: Mahwah, NJ; 25–44.

Graf P, Mandler G. 1984. Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior* **23**: 553–568.

Graf P, Ryan L. 1990. Transfer-appropriate processing for implicit and explicit memory. *Journal of Experimental Psychology*: *Learning, Memory and Cognition* **16**: 978–992.

Graf P, Schacter D. 1985. Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory and Cognition* **11**: 501–518.

Graf P, Uttl B. in press. Prospective memory: A new focus for research. *Consciousness and Cognition*.

James W. 1890. *Principles of Psychology.* Holt: New York.

Kvavilashvili L. 1987. Remembering intention as a distinct form of memory. *British Journal of Psychology* **78**: 507–518.

Kvavilashvili L. 1992. Remembering intentions: A critical review of existing experimental paradigms. *Applied Cognitive Psychology* **6**: 507–524.

Kvavilashvili L. 1998. Remembering intentions: Testing a new method of investigation. *Applied Cognitive Psychology* **12**: 533–554.

Kvavilashvili L, Ellis J. 1996. Varieties of intentions: Some distinctions and classifications. In *Prospective Memory: Theory and Application*, Brandimonte M, Einstein GO, McDaniel MA. (eds). Erlbaum: Mahwah, NJ; 23–51.

Loftus E. 1971. Memory for intentions: The effect of presence of cue and interpolated activity. *Psychonomic Science* **23**: 315–316.

Mäntylä T. 1993. Priming effects in prospective memory. *Memory* **1**: 203–218.

Mäntylä T. 1996. Activating actions and interrupting intentions: Mechanisms of retrieval sensitization in prospective memory. In *Prospective Memory: Theory and Application*, Brandimonte M, Einstein GO, McDaniel MA (eds). Erlbaum: Mahwah, NJ; 93–113.

Marsh RL, Hicks JL, Hancock (this issue). On the interaction of ongoing cognitive activity and the nature of an event-based intention. *Applied Cognitive Psychology.*

Mayes AR. 2000. Selective memory disorders. In *The Oxford Handbook of Memory*, Tulving E *et al.* (eds). Oxford University Press: New York; 427–440.

Maylor EA. 1990. Age and prospective memory. *Quarterly Journal of Experimental Psychology* **42A**: 471–493.

Maylor EA. 1996a. Age-related impairment in an event-based prospective-memory task. *Psychology and Aging* **11**: 74–78.

Maylor EA. 1996b. Does prospective memory change with age? In *Prospective Memory: Theory and Application*, Brandimonte M, Einstein GO, McDaniel MA (eds). Erlbaum: Mahwah, NJ; 173–197.

Maylor EA, Darby RJ, Logie RH, Della Sala S, Smith G. in press. Prospective memory across the lifespan. To appear in *Lifespan Memory Development*, Graf P, Ohta N. (eds). MIT press: Cambridge, MA.

McDaniel MA. 1995. Prospective memory: Progress and process. *The Psychology of Learning and Motivation* **33**: 191–221.

McDaniel MA, Robinson-Riegler B, Einstein GO. 1998. Prospective remembering: Perceptually driven or conceptually driven processes? *Memory and Cognition* **26**: 121–134.

Meacham JA, Leiman B. 1982. Remembering to perform future actions. In *Memory observed*: *Remembering in Natural Contexts*, Neisser U. (ed.). Freeman: San Francisco, CA.

Morris CD, Bransford JD, Franks JJ. 1977. Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior* **16**: 519–533.

MRC (2000, January). *MRC Psycholinguistic Database (Version 2).* http://www.psy.uwa.edu.au/MRCDataBase/uwa_mrc.htm

Park D, Hertzog C, Kidder DP, Morrell RW, Mayhorn CB. 1997. Effect of age on event-based and time-based prospective memory. *Psychology and Aging* **12**: 314–327.

Roediger HL, Blaxton TA. 1987. Effects of varying modality, surface, features, and retention interval on priming in word-fragment completion. *Memory and Cognition* **15**: 379–388.

Turvey MT, Mosher DL, Katz L. 1971. Subsequent recognition of items subjected to proactive interference in short-term memory. *Psychonomic Science* **25**: 365–367.

Underwood BJ. 1957. Interference and forgetting. *Psychological Review* **64**: 49–60.

Weldon MS, Roediger HL, Challis BH. 1989. The properties of retrieval cues constrain the picture superiority effect. *Memory and Cognition* **17**: 95–105.

West R, Craik FIM. 1999. Effects of aging, cover task demands, immediacy of response, and cue characteristics on event-based prospective-memory. *Brain and Cognition* **39**: 25–28.

Wickens DD, Moody MJ, Dow R. 1981. The nature and timing of the retrieval process and of interference effects. *Journal of Experimental Psychology: General* **110**: 1–20.

Winograd E. 1988. Some observations on prospective remembering. In *Practical Aspects of Memory*: *Current research and issues: Vol. 1 Memory in Everyday Life*, Gruneberg MM, Morris PE, Sykes RN (eds). John Wiley: Toronto.

Wixted JT, Rohrer D. 1993. Proactive interference and the dynamics of free recall. *Journal of Experimental Psychology: Learning, Memory and Cognition* **19**: 1024–1039.

