British Journal of Psychology (1999), **90**, 9–23 *Printed in Great Britain*

Experimental tests of prospective remembering: The influence of cue-event frequency on performance

Judi Ellis*
Department of Psychology, University of Reading

Lia Kvavilashvili
Department of Psychology, University of Hertfordshire

Alan Milne
Department of Psychology, University of Aberdeen

During recent years there has been an upsurge of interest in the processes underlying success or failure of intentions to perform an action in the future e.g. carry out an errand for a friend. Much of this research focuses on simulating these delayed-intention or prospective-memory tasks in the laboratory. A currently popular variant of these tasks is a repeated-instance event-based one in which the same action should be performed whenever a particular (repeated) event-cue occurs during an ongoing activity (e.g. a word in a running memory test of word recall). We report two experiments that investigated important dimensions of this task design, along which recent experimental tasks differ considerably, and explored their influence on prospective remembering. The results revealed that the variations in the event-cue frequencies explored here did not influence overall performance: relatively high event-cue frequency did not improve prospective remembering. However, performance was lower when event-cues were embedded in a general knowledge test than when a prose-reading task was used. Moreover, when remembering was compared for the first and final set of event-cues there was evidence for improvement over presentations during the general knowledge task and a contrasting decline using the prose task, under high event-cue frequency conditions only. The results have important repercussions for current experimental design and the development of tests of prospective remembering skills in particular population subgroups.

The ability to retain, recall and realize intentions is an important aspect of purposeful behaviour in our everyday lives although, importantly, errors here provide a common source of reported everyday memory failures (Crovitz & Daniel, 1984; Eldridge, Sellen, & Bekerian, 1991; Terry, 1988; West, 1984). The type of error that

All authors contributed equally to the research reported here.

* Requests for reprints should be addressed to Judi Ellis, Department of Psychology, University of Reading, Earley Gate, Whiteknights, Reading RG6, UK (e-mail: j.a.ellis @reading.ac.uk).

occurs may depend in part on the characteristics of a particular intention. For example, while some intentions can be realized immediately after their formation, others must be retained and recalled at a timely moment in the future: immediate and delayed intentions, respectively (Kvavilashvili & Ellis, 1996). Clearly, both types of intentions are vulnerable to errors that can arise during the performance of their respective actions ('action slips'; see, for example, Norman, 1981; Reason, 1984). A delayed intention, however, is exposed to additional sources of error: failure to correctly retain the intention over a period of delay and/or failure to recall it at an appropriate moment. In the studies reported here retention demands were simplified in order to examine some of the situational factors underlying the successful recall of delayed intentions simulated in the laboratory.

Methodologically, research on delayed intentions, or prospective memory (Meacham & Leiman, 1975), has undergone a gradual shift in focus from field to laboratory experiments. This change in experimental context has been accompanied by a move away from prescribing only a single opportunity for realizing an intention (single-instance intention, e.g. Kvavilashvili, 1987) towards the presentation of repeated opportunities for realizing that intention (repeated-instance intention, e.g. Einstein & McDaniel, 1990). Both of these trends present enhanced opportunities for the careful control, accurate measurement and experimental manipulation of performance on a prospective-memory task. In addition, they raise some interesting and important questions concerning the influence of basic experimental design characteristics on this performance. For example, does a repeated-instance design induce changes in performance over time, leading to a 'practice effect'? And, is performance generally enhanced by a relatively high number of opportunities for recall?

These questions may be particularly pertinent for current laboratory simulations of prospective-memory tasks. Such paradigms tend to specify repeated-instance event-based prospective-memory tasks[1]; that is, intentions that should be recalled whenever a particular event-cue (e.g. a word, object, or person) occurs in an ongoing activity. In a young adult population, in particular, these designs can induce very high levels of performance, often close to ceiling (e.g. Einstein & McDaniel, 1990) whereas there is some indication also of potential practice effects in a repeated-instance design (e.g. Maylor, 1993). The occurrence of either one of these effects may be influenced by the nature of the ongoing (concurrent) activity within which a designated event-cue occurs. Clearly this activity can and does take any one of a number of different forms (e.g. short-term memory or general knowledge tests). It is necessary, therefore, to consider whether any variations in performance that accompany changes in the frequency of repeated-instance events are consistent across different ongoing tasks.

The experiments reported here were designed to address these important methodological questions on repeated-instance event-based intentions and thereby examine some basic characteristics of current experimental tasks. The particular questions under investigation are: (i) what are the effects, on the overall level of

[1] These are often contrasted with activity-based intentions (Harris & Wilkins, 1982; Kvavilashvili & Ellis, 1996) and/or time-based intentions (Einstein & McDaniel, 1990, 1996); for example, recalling an intention before leaving a room or at 10 pm, respectively.

performance, of varying the number of occasions on which an event-cue occurs in a repeated-instance (event-cue) design? (ii) are repeated-instance designs vulnerable to either ceiling and/or practice effects? (iii) are the above effects consistent across different ongoing tasks?

In Experiment 1 two different ongoing tasks were employed: (i) a *text task* in which participants were asked to read aloud a continuous passage of prose (Kvavilashvili, in press) and (ii) a *sentence task* which required spoken semantic judgments (true or false) to a number of singly-presented general knowledge statements (Ellis & Milne, 1996). (The prose task only was employed in Expt 2.) A prospective-memory task was embedded in each of these two ongoing tasks; participants were requested to carry out a particular action instead of the one required by the ongoing task, whenever a particular word (event-cue) occurred. Thus they were asked either to *substitute* the event-cue word with an alternative word during the text task or to *substitute* a true or false response with the event-cue word during the sentence task.

EXPERIMENT 1

This experiment explored the effects on prospective-memory task performance of presenting the same event-cue on a relatively high and low number of occasions during one of two different ongoing tasks.

The number of event-cue presentations (opportunities for intention recall and performance) that can be included in a particular study is a question that has both practical and theoretical importance. At a practical level it is clearly preferable to maximize the number of data-points for a particular phenomena, without extending the total time spent on the task, and thus increase the reliability of a particular measure (cf. Maylor, 1993; Morris, 1992). However, a high number of event-cue presentations may alter the character of a prospective-memory task. For example, the processes underlying initial recall and performance of an intention may differ from those underlying recall on subsequent occasions (cf. Maylor, 1996). Moreover, as increasing the frequency of event-cues clearly reduces the interval (time period and number of intervening events) between individual event-cues, it may also increase the likelihood of following one successful recall occasion with another at the next opportunity for recall.

Intention recall depends on: (i) the successful encoding and retention of an action-intent-cue relation; and (ii) recall of this action and intent when the cue appears and is recognized as such (Brandimonte, 1991; Einstein & McDaniel, 1990; Ellis, 1991, 1996). In a repeated-instance design the former processes are greatly simplified (the same action is prescribed for each cue) and thus performance is likely to depend on the successful operation of the latter. Recent research, for example, has demonstrated that variables that benefit event-cue word recognition generally result in higher levels of performance on repeated-instance event-based prospective memory tasks (e.g. unfamiliar or locally distinctive event-cue words; Brandimonte & Passolunghi, 1994; McDaniel & Einstein, 1993). Event-cue frequency may have a similar effect on these recognition processes. For example, the presentation of an event-cue may raise the activation of a cue-word representation and thus influence the likelihood of

subsequent intention recall (cf. Ellis, 1996; Goschke & Kuhl, 1996; Mäntylä, 1996). When event-cue frequency is relatively high and the length of the ongoing task is kept constant, the interval between presentations is relatively short and thus an event-cue will be more highly activated with shorter periods for de-activation between presentations. Successful recall and performance on one occasion, moreover, is likely to increase the strength of the association between an event-cue and an intended action and thus reduce the likelihood of recall failure on subsequent event-cue presentations.

Under the preceding analysis we would expect to observe a relative improvement in aggregate (proportionalized) performance in high compared to low event-cue frequency conditions. High event-cue frequency, moreover, should be more likely to produce a 'practice' effect since the likelihood of recognizing an event-cue would be higher for later compared to earlier presentations (during the ongoing task). Each of these effects, however, may depend upon the characteristics and demands of the ongoing activity in which the event-cues are embedded and their influence on event-cue recognition processes.

The two ongoing activities employed in this study, a prose-reading and a semantic-judgment task, differ in a number of potentially influential ways. In the prose-reading task, for example, the event-cues are encountered while reading aloud a piece of continuous text. Individual statements do not require a specific judgment and the task tends to cause one to focus on the thematic links between separate statements and to induce a 'look ahead' strategy—from one sentence to the next. Connected and continuous sentences, moreover, may promote event-cue anticipation while reading aloud as this clearly provides an additional auditory record of events (compared with silent reading). By contrast, in the semantic-judgment task event-cues occur within a set of statements each of which is presented singly, read silently and requires a spoken judgment. The statements, moreover, are neither thematically nor semantically linked. Thus we might expect event-cue recognition (and thus prospective-memory task performance) to be generally higher when event-cues are embedded in the prose compared with the semantic-judgment task. Of particular interest here, however, is the consistency of any effects of variations in event-cue frequency across the two ongoing tasks.

Method

Subjects

Forty-one male and 39 female undergraduate students, undertaking a variety of degree courses, participated in the study and received either course credit or a small payment of £2.00 ($3.00) in return. Their ages ranged from 19 to 31 years.

Design

A 2×2 between-subjects design was employed to examine the effects of the following two factors on prospective memory task performance: type of ongoing task (prose, semantic processing); and event-cue frequency (high, low). Twenty people were assigned to each of the four experimental conditions. Each was tested individually in an experimental session that took 30–35 minutes to complete.

Materials

The prose passage was a short story, 'The Purloined Letter', by Edgar Allan Poe (1908). An abbreviated version was prepared and typed onto 10 single-sided sheets of paper. The prospective memory event-cue word 'prefect', one of the main characters in the story[2], was selected and the text amended slightly so that this word occurred on either one or two occasions on each page in the low and high event-cue frequency condition, respectively. Its occurrence was evenly spaced across the 10 typed pages: either once every 150 words (high frequency) or once very 300 words (low frequency)[3]. Thus there were 20 intention recall opportunities in the high event-cue frequency condition and 10 in the low frequency one. Pilot studies established that people took, on average, 2 minutes to read aloud each page of both versions of the text.

The semantic-processing task was a modified and extended version of a task devised by Baddeley (1981) and developed by Logie & Baddeley (1985). Five hundred statements, designed to tap basic general knowledge, were constructed to be of a similar form; for example, 'Doctors undergo a long training' and 'Shoes undergo a long training'. The event-cue word 'ship' was selected and close associates were excluded from the statements. This cue word appeared in either 20 (high frequency condition) or 10 (low frequency condition) of the 500 statements and the occurrence of these 'target statements' was distributed evenly within the statements: either once every 20–25 or once every 40–45 non-target statements, respectively. The cue-word 'ship' appeared as the second noun in a target statement and half these statements were designed to elicit a true response and the remaining a false one. In addition, a practice list of 10 (non-target) statements was constructed. The presentation of target and non-target statements in both conditions was controlled by a program designed to run on an Apple Macintosh computer. Previous studies using the task indicated that participants take a mean of 2.4 seconds to respond to each statement and thus approximately 2 minutes to complete 50 statements (e.g. Ellis & Milne, 1996). In both the prose and semantic-processing tasks, therefore, either one (low frequency) or two (high frequency) event-cue words were designed to be encountered every 2 minutes, on average.

Procedure

Equal numbers of participants were recruited to take part in the prose-reading and semantic-processing tasks. In each of these two groups half of the participants were presented with the high and half with the low event-cue frequency versions of these ongoing tasks. A repeated-instance prospective-memory task was embedded in both the prose and semantic-processing tasks and introduced, after instructions for the relevant ongoing task had been administered, as an additional task to be completed while carrying out the ongoing activity. A short filled period of delay was interposed between instructions for both the ongoing and prospective-memory task and the start of the ongoing activity.

Participants in the prose-reading task were informed that they were taking part in an investigation of text comprehension in 15–16-year-old children. The aim of these studies was to examine children's understanding of ambiguous texts read aloud either by themselves or by someone else and on variations in comprehension that arise from different speakers' voices. Each participant was asked to assist in this endeavour by acting as a narrator for the Edgar Allan Poe story. He or she was asked to read it at average speed and as accurately as possible but without worrying about the odd mistake that occurs naturally when one reads aloud. In addition, he/she was told that a colleague of the experimenter had recently used this story and found that a particular word in the text—'prefect'—seemed to cause some confusion. Since the prefect of the Parisian police was a main character in the story it would be better

[2] In this story Monsieur G, the Prefect of the Parisian Police, fails to retrieve a letter stolen from the Royal apartments by the scheming Minister D. He therefore requests the assistance of two friends (M. Dupin and the narrator) who clearly resemble Sherlock Holmes and Dr Watson. Thanks to Dupin's ingenuity and boldness the letter is eventually retrieved. The Prefect, therefore, is clearly a central character in this story—his friends' actions are carried out to protect him from failure.

[3] Changes to the text that were required to increase event-cue frequency were largely effected by replacing references to Monsieur G, via the personal pronoun, his name or an oblique referent, with 'prefect'. These minor changes made no substantial differences to either the meaning, sense, or format of the story in this and the following experiment.

if the participant could change the word prefect to 'detective' whenever he/she encountered it. Thus the prospective-memory task was to substitute 'detective' for 'prefect' whenever it was encountered in the prose-reading task. Participants were not informed of the number of occasions on which they might expect to encounter this word (for a more detailed description of this task, see Kvavilashvili, in press).

After the above instructions had been administered and understood a short delay was introduced on the pretext of setting up the tape recording equipment and participants were asked to use this time to assist in a separate study collecting ratings of face typicality for a colleague's face-recognition experiment. This delaying task took approximately 5 minutes to complete and following this the prose-reading task commenced. There was no direct reminder of the prospective-memory task at this time. On completion of the prose-reading task, participants who failed to substitute prefect with detective on any of the 10 out of 20 occasions were asked if there was any other task that they had been requested to carry out (indirect probing for the delayed intention task) and to subsequently describe this task (direct probing of delayed intention instructions).

For the semantic-processing task, participants were informed that they were taking part in an investigation of basic general knowledge of everyday objects, people etc. in both brain-damaged and non-brain-damaged populations. The experimenter had prepared a large number (500) of general knowledge questions and was interested in identifying ambiguous or difficult questions. Each participant was asked to assist in this study by reading each statement and saying whether it was true or false as quickly and accurately as possible but without worrying about the small number of mistakes that inevitably occur. The practice set of statements was presented on an Apple Macintosh computer and each participant was asked to respond 'true' or 'false' to each (singly presented) statement using a small microphone connected to the computer. (A distinctive 'tone' indicated the onset of a recorded response.) In addition, the participant was also told that some of the patients under investigation appeared to have difficulties understanding certain words. To explore this finding further he/she was asked to note whenever he/she came across one of these words in a sentence by saying it aloud instead of saying true or false to that statement. The participant was told that the word we were interested in on this occasion was 'ship'. After the instructions had been administered and understood a short delay was introduced on the pretext of setting up the computer program and participants were asked, as in the prose task, to use this time to assist in a separate study (ratings of face typicality). Following this the semantic-processing task commenced. As before, there was no direct reminder of the prospective-memory task at this time and on completion participants were prompted (indirectly and directly) to recall the existence of and instructions for this task.

Results and discussion

The questioning that followed both the prose-reading and the semantic-processing (ongoing) tasks confirmed that all participants correctly recalled both the existence of and instructions for the prospective-memory task. Performance on this task was initially coded into one of three different response categories: correct, late or omissions. A correct response is an error-free substitution of the event-cue word at the moment it was encountered in the text or while it appeared on the screen. A late response is a delay or error in substitution e.g. starting to say 'true' (or 'prefect') and then changing it to 'ship' (or 'detective') or saying 'true/prefect' and then immediately adding 'ship/detective'. Omissions are failures to make the substitution prior to the next appearance of the target word. Correct and late responses, therefore, provide potentially different measures of success on the delayed intention task: accurate and inaccurate success, respectively (see Kvavilashvili, in press). Theoretically, however, both types of response indicate recall of the task while omissions provide a measure of failure to recall at or soon after the appropriate moment. Thus the accurate–inaccurate distinction was collapsed to provide a single

class of successful responses. To examine changes in performance across the duration of both the prose-reading and the semantic-processing tasks, participants' scores were divided into those relating to the event-cue presentations that occurred in the first half of the ongoing task (a possible total of 5 or 10, as appropriate) and those relating to the second half. Raw scores were then expressed as a proportion of the total number of event-cue presentations in each half of the task. Mean proportional successful responses, for each half of the prose-reading and semantic-processing tasks, are given in Table 1.

Table 1. Proportion of mean successful responses in Expt 1 (SD) as a function of ongoing task, event-cue frequency, and first and second half of event-cue presentations

	Prose-reading task		Semantic-processing task	
	High event-cue frequency	Low event-cue frequency	High event-cue frequency	Low event-cue frequency
First half of task	0.88 (0.17)	0.83 (0.31)	0.65 (0.30)	0.65 (0.39)
Second half of task	0.82 (0.16)	0.82 (0.25)	0.82 (0.26)	0.69 (0.37)

We conducted a $2 \times 2 \times 2$ mixed analysis of variance (ANOVA) on participants' mean proportional successful prospective-memory task responses. There were two between-subjects variables (type of ongoing task and frequency of event-cue presentation) and one within-subject variable (first or second half of ongoing task). The ANOVA revealed a mean effect of task such that a higher proportion of correct responses were produced in the prose task ($M = 0.84$) than in the semantic task ($M = 0.70$); $F(1,76) = 4.82$, $MSe = 0.14$, $p < .05$. While proportionally more responses were observed in the high ($M = 0.79$) than in the low ($M = 0.75$) event-cue frequency conditions this difference was not reliable, $F < 1$, and the interaction between these variables also failed to reach significance, $F < 1$. Although the analysis revealed a non-reliable improvement in performance from the first ($M = 0.75$) to the second ($M = 0.78$) half of event-cue presentations ($F\,1,76 = 2.50$, $MSe = 0.02$, $P > .1$), as the data in Table 1 indicate there was a reliable interaction between task-half and type of ongoing task, $F(1,76) = 9.67$, $P < .01$). *Post hoc* analyses revealed no reliable change in performance over time in the prose task ($Ms = 0.85$ and 0.81, for first and second half, respectively); in contrast, performance in the semantic task clearly improved over time ($Ms = 0.65$ and 0.76, respectively; $P < .05$). The latter effect was modified by a three-way interaction, $F(1,76) = 4.08$, $P < .05$. Further analyses revealed that the primary effect of event-cue frequency is to produce a marked 'practice effect' in prospective-memory performance, in the semantic-processing task under the high-frequency condition only ($P < .01$). Interestingly, the

reverse, a slight decline in performance across target presentations, occurs in the prose task under these high-frequency conditions ($P < .05$). The data in Table 1 also illustrate the superior performance in the prose task as compared with the semantic task. The only exception to this occurs in the second half of the semantic task under high-frequency conditions when performance is within the range of that observed in all conditions in the prose task. (The remaining interaction between frequency and task-half failed to reach significance; $F < 1$.)

Overall, the above results suggest that when successful prospective-memory task performance is averaged across all event-cue presentations, event-cue frequency has no reliable effect when embedded in either of the two ongoing tasks under consideration. The influence of variations in event-cue frequency on performance emerges only when one examines changes in performance from earlier to later event-cue presentations. To understand these variations we may need to consider the relative differences in levels of performance observed in the two ongoing tasks. We suggested earlier that a prose-reading task has particular characteristics that might be expected to result in a relatively high level of prospective-memory task performance. The requirement to read a passage of continuous and thematically linked prose is likely to lead to expectations of how the story will develop which in turn may 'prime' one for the appearance of one of the main characters in that story, i.e. the event-cue word 'prefect'. Reading the story aloud moreover results in an additional 'auditory' record which may act as a further prompt for event-cue recognition. Both factors are likely to increase the likelihood of cue recognition and thus facilitate recall of the delayed intention. In addition, we note that the word 'prefect' not only denotes a main character in the prose passage (i.e. it is relatively distinctive in its local thematic context) but is also a less familiar one to native English speakers than 'ship'—the event-cue word employed in the semantic-processing task. Previous research has demonstrated that both unfamiliarity and local distinctiveness raise prospective-memory task performance (Brandimonte & Passolunghi, 1994; McDaniel & Einstein, 1993). It is perhaps unsurprising then to observe a relatively high level of performance in this task. (Indeed, we note that performance on the prose task is similar to that reported for highly distinctive or relatively unfamiliar event-cue words.) These and other differences between the two ongoing tasks may contribute to the improvement in prospective remembering observed in the semantic-processing task under high event frequency.

In conclusion, it would appear that when prospective-memory performance is expressed as an aggregate measure (mean performance over all event-cue presentations) then variations in event-cue frequency, between one and two every 2 minutes, have no direct effect. The influence of more extreme variations in event-cue frequency, using the prose-reading task only, are explored further in Expt 2.

EXPERIMENT 2

Experiment 1 revealed a high level of prospective-memory performance when event-cues for this task are embedded in a prose-reading test. In this second experiment we attempted to lower performance by decreasing event-cue frequency to only five appearances in the text. By examining also the potential effects on performance of

increasing this frequency to 30 appearances we were able to extend the generality of the findings reported in Expt 1 when a prospective-memory task is embedded in a prose passage.

Method

Subjects

Twenty male and 20 female undergraduate students, undertaking a variety of courses, participated in the study and received either course credit or a small payment of £2.00 (approximately $3.00) in return. Their ages ranged from 18 to 32 years.

Design

In a between-subjects design, 20 persons were assigned to one of two event-cue frequency conditions: very low and very high (5 and 30 event-cue occasions, respectively). Each person was tested individually in an experimental session that took 30–35 minutes to complete.

Materials

The prose passage employed in Expt 1 was modified as follows. In the very high-frequency condition the event-cue word 'prefect' appeared either three times per page (once every 100 words, approximately) while in the very low-frequency condition it appeared once on pages 1, 3, 5, 7 and 9 (once every 600 words, approximately).

Procedure

The procedure was identical in all relevant respects to that described in Expt 1 for the prose-reading task, apart from the modifications to materials outlined above.

Results and discussion

Questions following completion of the prose-reading task revealed, as before, that all participants correctly recalled both the existence of and instructions for the prospective-memory task. Performance on this task was coded into the response categories described in Expt 1: successful responses and omissions. In the very high-frequency condition participants' scores in each response category were divided into five sections corresponding to cue presentations on pages 1–2, 3–4, 5–6, 7–8, 9–10; thus a total score of six successes was potentially attainable for each section. These divisions were chosen to match as closely as possible the presentations of the event-cue word in the very low-frequency conditions. (A total possible score of one success was attainable in each section.) Raw scores for each category were expressed in proportional form and the means are given in Table 2.

A mixed design 2×5 ANOVA was conducted on participants' mean proportional correct responses. There was one-between subjects factor (very low-, very high-frequency) and a single within-subjects factor (1st, 2nd, 3rd, 4th, 5th section of task). The ANOVA revealed a main effect of task section; $F(4,152) = 2.91$, $MSe = 0.04$, $p < .05$. Whereas performance in the first section ($M = 0.92$) was higher than that

Table 2. Proportion of successful responses in Expt 2 (SD) as a function of event-cue frequency and event-cue appearance (1st–5th section of task)

Very low frequency (5 targets)		Very high frequency (30 targets)	
Targets		Targets	
1	0.95 (0.22)	1–6	0.95 (0.10)
2	0.80 (0.40)	7–12	0.83 (0.19)
3	0.75 (0.44)	13–18	0.90 (0.13)
4	0.75 (0.44)	19–24	0.82 (0.26)
5	0.85 (0.37)	25–30	0.81 (0.20)

observed in all subsequent sections ($Ms = 0.81, 0.82, 0.79$ and 0.83 for sections 2, 3, 4 and 5, respectively), *post hoc* analyses revealed that this difference was reliable only between sections 1 and 4. There was no main effect of event-cue frequency ($F < 1$) and no interaction, $F(4,152) = 1.31$, $p < .1$. These results support the conclusions drawn from Expt 1 that event-cue frequency does not have a reliable effect upon aggregate prospective-memory performance when variations from one event-cue presentation every 4 minutes to one per 40 seconds are examined. They also provide broad support for the observation, in Expt 1, that performance declines slightly over the course of the prose-reading task. Moreover, as the data in Table 2 indicate, performance in both the very low- and very high-frequency conditions is at a comparable level to that observed using the prose task in Expt 1. Thus it would seem that a high level of performance is maintained even under conditions of comparatively low event-cue frequency (one every 4 minutes) in this prose task. Particular characteristics of this task, some of which were considered earlier, appear to facilitate prospective remembering.

The conclusion that can be drawn from Expts 1 and 2, that overall prospective-memory performance is insensitive to the variations in event-cue frequency explored here, has important implications for experimental design in this area. As a further and more stringent test of this claim, we addressed the potential problem of insufficient power to detect subtle changes in performance by entering the data from Expts 1 and 2, for prospective remembering during the prose-reading task, into a further 2×4 ANOVA. There was one within-subjects factor of task phase (first or second) together with a second between-subjects factor of event-cue frequency [very low (5 event-cues), low (10), high (20), very high (30)]. For convenience, mean performance on the very high- and very low-frequency conditions from the current experiment are re-presented in Table 3, alongside the re-calculated means for the low- and high-

frequency conditions from Expt 1 (a total possible score of 2 or 4 on each of the five sections of the task). As Table 3 illustrates, once again we failed to observe a reliable main effect of event-cue frequency and the interaction between this and task section also failed to reach significance; $F < 1.30$, $p > .05$. However, there was a reliable main effect of task section in which event-cues appeared; $F(4,304) = 3.63$, $MSe = 0.04$, $p < .01$. Although performance was higher in the first section ($M = 0.89$) than in the remaining four sections ($Ms = 0.84, 0.81, 0.78$, and 0.86, respectively), *post hoc* tests revealed that only the difference between performance in sections 1 and 4 reached significance ($p < .01$).

Table 3. Proportion of successful responses (SD) to event-cues in the prose-reading task only, Expts 1 and 2

	1st–5th section of prose-reading task				
	1	2	3	4	5
Very low frequency (5 targets, Expt 2)	0.95 (0.22)	0.80 (0.40)	0.75 (0.44)	0.75 (0.44)	0.85 (0.37)
Low frequency (10 targets, Expt 1)	0.80 (0.38)	0.85 (0.33)	0.83 (0.76)	0.75 (0.38)	0.90 (0.26)
High frequency (20 targets, Expt 1)	0.91 (0.12)	0.88 (0.24)	0.76 (0.31)	0.80 (0.24)	0.88 (0.13)
Very high frequency (30 targets, Expt 2)	0.95 (0.10)	0.83 (0.19)	0.90 (0.13)	0.82 (0.26)	0.81 (0.20)

GENERAL DISCUSSION

The results of two experiments investigating the effects of event-cue frequency on prospective memory task performance demonstrate that the variations in frequency investigated in these experiments has no appreciable effect on mean (proportional) performance. While it would be inappropriate to argue that more extreme variations in event-cue frequency would never affect prospective remembering performance, the manipulations employed here are within the range that most researchers are likely to consider. High frequency, however, appears to induce changes in performance over event-cue presentations, resulting in a marked practice effect when cues are embedded in a semantic-processing task while the opposite trend (a decline in performance) was observed for high frequency with the prose-reading task (Expt 1). The latter trend was qualified by the results from Expt 2 since in this instance it occurred in both the very high- and very low-frequency conditions.

It is encouraging to note some consistency in the effects of certain variables on prospective-memory task performance when the intention is embedded in one of two very different ongoing tasks. When mean performance over event-cue presentations is measured neither event-cue frequency nor delay in presentation of the first event-cue appear to exert a reliable influence. Mean performance, however, does appear to

be influenced by the ongoing task and is consistently higher when event-cues are embedded in the prose-reading task than when the semantic-processing task is employed. Performance using the semantic-processing task, by contrast, is within the range reported when other memory or general knowledge computer-based tasks are utilized (e.g. Einstein & McDaniel, 1990; Ellis & Milne, 1996).

Further differences in the effects of ongoing task on prospective-memory performance emerge when changes in performance over event-cue presentations are investigated. While high frequency appeared to impair performance on later presentations in the prose task (Expt 1) the results reported in Expt 2 suggest that this may be a general feature of this task, relatively independent of changes in event-cue frequency. In contrast, high event-cue frequency appears to facilitate prospective memory performance on later presentations in the semantic-processing task. These differences, we suggest, argue in favour of more widespread usage of similar, detailed assessments of prospective-memory task performance across event-cue presentations (cf. Maylor, 1993; 1996).

Logically, the observed variations in performance must be attributable to either the characteristics of the ongoing tasks, features of the individual event-cue word and/or the interrelationship between the ongoing task and an event-cue word. The exact role of these factors could be investigated most profitably, we suggest, through a systematic exploration of their effects where the many differences between the two ongoing tasks are more effectively controlled. For the present we consider briefly the theoretical and practical implications of the results reported here.

A widely proposed view of the processes underlying prospective remembering has been described recently by McDaniel (1995) as an 'activation' account (e.g. Einstein & McDaniel, 1996; Ellis, 1996; Goschke & Kuhl, 1996; Mäntylä, 1996). According to this type of theory, the representation of a delayed intention includes a record of the action to be performed, the retrieval criterion for when the action should be carried out, the intent or decision to act in a certain way when the retrieval criterion is satisfied, together with their inter-associational links. This representation is thought to have a certain level and threshold of activation at encoding, the values of which may depend primarily on motivational factors (Ellis, 1996; Goschke & Kuhl, 1996). For successful retrieval to occur, the retrieval criterion (a cue word in an verbal event-based task) must be recognized not only in terms of identification *per se* but also with regard to its specific significance as a cue for a particular intended action. Identification may lead to a sense of familiarity and promote a directed search for its significance in the current context (cf. Einstein & McDaniel's 'notice & search' model) but need not necessarily lead to the recovery of the intention.

When the cue word appears, activation of the representation of this word spreads to related concepts and associations. One of these is the cue word's episodic representation as a retrieval cue and the association between this and an intent and action. In a repeated-instance design, successful recall of the delayed intention on one occasion should increase the activation level of the intention thus increasing the likelihood of successful recall on subsequent re-presentations of the cue word. Previous studies have presented findings that are compatible with this theory and have identified factors that may either strengthen the association between a cue word and a delayed intention and/or raise the activation level of that intention

representation; for example, cue-distinctiveness, -specificity and -familiarity (Brandimonte & Passolunghi, 1994; Einstein & McDaniel, 1990; Ellis & Milne, 1996; McDaniel & Einstein, 1993; Mäntylä, 1993). The results reported here suggest that event-cue frequency (at least with respect to variations between 1 and 4 presentations per minute) does not influence overall (aggregate) prospective remembering. Thus it would appear that increases in event-cue activation (from repeated presentations, together with shorter intervals between presentations for the dissipation of this activation) that were predicted to occur under high-frequency conditions, are not sufficient to improve the likelihood of successful prospective remembering, on the task as a whole. These event-cue related factors do not necessarily promote activation and/or retrieval of the intention or prospective-memory task. It would appear, however, that this claim may have to be modified to explain the change in performance (from the first to the second set of event-cues) in the high-frequency condition of the semantic-processing task (Expt 1). Unfortunately, differences between the two ongoing tasks (e.g. thematic/non-thematic connections, silent reading/reading aloud) and the event-cue words (e.g. familiarity, number of syllables) preclude, at present, identification of the factors producing this effect.

Our results have implications for the practical issues of design in experimental tests of delayed intentions and their potential development in clinical tests. First, they indicate the benefits of examining changes in performance across event-cue presentations. Second, they suggest that several presentations of a single event-cue can be included within an ongoing task, at a rate of approximately one per minute, thus increasing the sensitivity of a measure of performance without incurring a risk of ceiling effects as the ongoing task progresses. Even in the commonly used computer-based tasks, of which the semantic-processing task is an example, a high frequency of event-cue presentations has no appreciable effect on prospective remembering during the early phase of the task. Together, these results suggest that short computer-based ongoing tasks are possible, even desirable, as long as a delay of approximately 20–24 events (lasting approximately 1 minute) occurs between event-cue presentations. These features are encouraging for the future development of tests of prospective remembering skills for a clinical population. The reported high test–retest reliability (after a delay of 4 days) of performance on the prose task is also encouraging in this respect (Ellis, Kvavilashvili, & Milne, 1996). Finally, the different levels of performance observed using the two ongoing tasks reported here could also be usefully employed in both experimental and clinical settings. Thus, whereas the prose task could be used to examine the effects of variables expected to depress performance (e.g. divided attention), the semantic-processing task lends itself to tests of variables expected to improve performance (e.g. cue-distinctiveness). Similarly, the two tasks could have complementary uses in a clinical setting. The high prospective-memory performance observed when the prose task is employed could enable detection of persons with major dysfunctions in prospective memory skills without incurring the risk of a floor effect for such individuals. However, as performance using this ongoing task may be insufficiently sensitive to minor dysfunctions such deficits could be examined by embedding event-cues within the semantic-processing task.

Acknowledgements

This research was supported, in part, by a postdoctoral fellowship awarded by the Royal Society to Judi Ellis and Lia Kvavilashvili and by the School of Psychology at the University of Wales, Cardiff. Part of the work reported here was presented at the Annual Conference of the British Psychological Society in March 1994.

References

Baddeley, A. D. (1981). The cognitive psychology of everyday life. *British Journal of Psychology*, **72**, 257–269.

Brandimonte, M. A. & Passolunghi, M. C. (1994). The effect of cue-familiarity, cue-distinctiveness and retention interval on prospective remembering. *Quarterly Journal of Experimental Psychology*, **47**, 565–588.

Crovitz, H. F. & Daniel, W. F. (1984). Measurements of everyday memory: Toward the prevention of forgetting. *Bulletin of the Psychonomic Society*, **22**, 413–414.

Einstein, G. O. & McDaniel, M. A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory & Cognition*, **16**, 717–726.

Einstein, G. O. & McDaniel, M. A. (1996). Retrieval processes in prospective memory: Theoretical approaches and some new empirical findings. In M. Brandimonte, G. O. Einstein & M. A. McDaniel (Eds), *Prospective memory: Theory and applications*, pp. 115–141. Hillsdale, NJ: Lawrence Erlbaum.

Eldridge, M., Sellen, A. & Bekerian, D. A. (1991). *Memory problems at work: Their range, frequency and severity*. Technical Report EPC-92-129, Rank Xerox EuroPARC, Cambridge, UK.

Ellis, J. A. (1991). *An eclectic approach to the study of prospective memory tasks*. Paper presented at the International Conference on Memory, July, Lancaster, UK.

Ellis, J. A. (1996). Prospective memory or the realisation of delayed intentions: A conceptual framework for research. In M. Brandimonte, G. O. Einstein & M. A. McDaniel (Eds), *Prospective memory: Theory and applications*, pp. 1–22. Mahwah, NJ: Lawrence Erlbaum.

Ellis, J. A., Kvavilashvili, L. & Milne, A. B. (1996). *Individual differences in prospective remembering*. Paper presented at the Second International Conference on Memory (ICOM-96), Padova, Italy.

Ellis, J. A. & Milne, A. B. (1996). Retrieval cue specificity and the realisation of delayed intentions. *Quarterly Journal of Experimental Psychology*, **49A**, 862–887.

Goschke, T. & Kuhl, J. (1996). Remembering what to do: Explicit and implicit memory for intentions. In M. Brandimonte, G. O. Einstein & M. A. McDaniel (Eds), *Prospective memory: Theory and applications*, pp. 53–114. Mahwah, NJ: Lawrence Erlbaum.

Harris, J. A. & Wilkins, A. J. (1982). Remembering to do things: A theoretical framework and an illustrative experiment. *Human Learning*, **1**, 123–136.

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

Kvavilashvili, L. (in press). Remembering intentions: Testing a new method of investigation. *Applied Cognitive Psychology*.

Kvavilashvili, L. & Ellis, J. A. (1996). Varieties of intention: Some distinctions and classifications. In M. Brandimonte, G. O. Einstein & M. A. McDaniel (Eds), *Prospective memory: Theory and applications*, pp. 23–52. Mahwah, NJ: Lawrence Erlbaum.

Logie, R. H. & Baddeley, A. D. (1985). Cognitive performance during simulated deep-sea diving. *Ergonomics*, **28**, 731–746.

Mäntylä, T. (1993). Priming effects in prospective memory. *Memory*, **1**, 203–218.

Mäntylä, T. (1996). Activating and interrupting intentions: Mechanisms of retrieval sensitivation in prospective memory. In M. Brandimonte, G. O. Einstein & M. A. McDaniel (Eds), *Prospective memory: Theory and applications*, pp. 23–52. Mahwah, NJ: Lawrence Erlbaum.

Maylor, E. A. (1993). Aging and forgetting in prospective and retrospective memory tasks. *Psychology and Aging*, **3**, 420–428.

Maylor, E. A. (1996). Does prospective memory decline with age? In M. Brandimonte, G. O. Einstein & M. A. McDaniel (Eds), *Prospective memory: Theory and applications*, pp. 23–52. Mahwah, NJ: Lawrence Erlbaum.

McDaniel, M. A. (1995). Prospective memory: Progress and processes. In D. L. Medin (Ed.), *The psychology of learning and motivation*, vol. 33, pp. 191–221. San Diego: Academic Press.
McDaniel, M. A. & Einstein, G. O. (1993). The importance of cue familiarity and cue distinctiveness in prospective memory. *Memory*, **1**, 22–42.
Meacham, J. A. & Leiman, B. (1975). Remembering to perform future action. In U. Neisser (Ed.), *Memory observed*, pp. 327–336. San Francisco: Freeman.
Morris, P. E. (1992). Prospective memory: Remembering to do things. In M. M. Gruneberg & P. E. Morris (Eds), *Aspects of memory*, vol. 1, pp. 196–222. Cambridge: Cambridge University Press.
Norman, D. A. (1981). Categorisation of action slips. *Psychological Review*, **88**, 1–15.
Poe, E. A. (1908). The purloined letter. In P. Colum (Ed.), *Poe's tales of mystery and imagination*. London: Dent.
Reason, J. T. (1984). Lapses of attention. In W. Parasuraman, R. Davies, & J. Beatty (Eds), *Varieties of attention*, pp. 515–549. New York: Academic Press.
Terry, W. S. (1988). Everyday forgetting: Data from a diary study. *Psychological Reports*, **62**, 299–303.
West, R. L. (1984, August). *An analysis of prospective everyday memory*. Paper presented at the meeting of the American Psychological Association. Toronto.

Received 18 August 1997; revised version received 15 May 1998