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Prospective memory functioning in people with and without brain injury

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Abstract

Prospective remembering has been relatively underinvestigated in neurological patients. This paper describes a group study in which the prospective memory performance of 36 people with brain injury and 28 control participants is compared. We used a new instrument, the Cambridge Behaviour Prospective Memory Test (CBPMT) to assess prospective memory. This comprises 4 time-based and 4 event-based tasks. Participants were allowed to take notes to help them remember the tasks. The relationships between CBPMT scores, scores on formal tests and subjective reports on memory, attention and executive functioning were analyzed. The key findings were that (1) note-taking significantly benefited prospective memory performance, (2) significant relationships were found between scores on the prospective memory test and scores on tests of memory and executive functions, and (3) participants had more difficulty with the time-based than with the event-based prospective memory tasks. The results suggest that compensatory strategies improve prospective memory functioning; memory for content as well as attention and executive functioning processes are involved in prospective memory; and that time-based tasks are more difficult than event-based tasks because they place higher demands on inhibitory control mechanisms. Discussion focuses on the implications of these results for neuropsychological assessment and rehabilitation. (*JINS*, 2002, *8*, 645–654.)

Keywords: Prospective memory, Memory, Brain Injury, Assessment, Executive functions

INTRODUCTION

Prospective memory involves remembering to perform previously planned actions at the right time or within the right time interval or after a certain event takes place while being involved in other activities. Cohen (1996) gave the following description of prospective memory. Prospective memory is remembering a plan of action (i.e., what to do) as well as remembering to do it at a specified time or within certain time limits. Everyday life examples include putting a letter in the mailbox on your way home, remembering to turn off the oven, and calling your mother at 8:00 p.m. Memory problems are frequently associated with neurological conditions (Wilson, 1995). For people with brain injury, failures in prospective memory, such as forgetting to take medication, can have devastating effects on everyday life. Forgetting to do things could threaten independent living. Despite its clinical significance, prospective memory has been relatively underinvestigated in this group, possibly due to the absence of a standardized clinical prospective memory instrument.

Ellis (1996) said that the term *prospective memory* carries the implicit assumption that this is a distinct form of memory. She suggested that prospective memory is a misleading or inadequate description as it refers to the formation, retention, and retrieval of intended actions that cannot be realized at the time of initial encoding. Ellis finds the term “the realization of delayed intentions” more appropriate. Shimamura et al. (1991) claim that prospective memory not only involves memory, but also shares common features with skills of planning and decision-making, and with inhibitory control mechanisms, all of which are thought to be mediated by the frontal lobes. Cockburn’s (1995) view was that retrospective and prospective memory are similar in that memory for content is essential to both but the essential differences between the two are that (1) remember-

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ing prospectively also requires memory for intention, and (2) the cue for retrieval has to be self-initiated. According to Einstein and McDaniel (1990), prospective memory differs from retrospective memory in that prospective memory requires people to remember to remember in the first place, whereas in retrospective memory tasks, the experimenter initiates or requests remembering.

Most studies of prospective memory functioning compare prospective memory with retrospective memory. Very few studies look at the relationship between prospective memory functioning and executive functioning. To our knowledge this is the first group study in which prospective memory is investigated in people with brain injury, together with an analysis of the relationships between prospective memory and both episodic memory and executive functions. Two types of prospective memory tasks are used, and we record whether compensatory strategies such as writing notes are employed.

Prospective memory tasks can (1) be self-imposed or imposed by someone else, and (2) involve remembering routine or novel actions (Cohen, 1996). The degree of specificity and timing can also vary. Ellis (1988) distinguished between "pulses" and "steps." A pulse specifies the exact time for an action to be carried out, while a step is less specific. Ellis found that pulses are not only better recalled than steps, they are also judged to be more important, and people are more likely to use an external memory aid to remind them of pulses. Einstein and McDaniel (1990) distinguished between two kinds of prospective memory on the basis of the cues that trigger retrieval. They suggested that prospective memory tasks vary in the degree to which they rely on self-initiated cues relative to external cues. In other words, retrieval may be time-based or event-based. Time-based prospective memory requires performance of a task at a certain time or after a certain period of time has elapsed. An everyday example would be turning up at a meeting at 10:00 a.m. tomorrow. Event-based prospective memory requires an activity to be carried out in response to a certain external event or physical stimulus. An everyday example would be giving a message to your colleague when you next meet. Einstein et al. (1995) stated that time-based prospective memory tasks are generally harder to remember both because the passage of time has to be monitored and because remembering is self-initiated. In contrast, event-based tasks are triggered by an external stimulus.

Few studies describe prospective memory functioning in people with brain injury. Mateer et al. (1987) showed that both people with brain injury and control participants perceive themselves as having more trouble with prospective memory tasks than with other memory tasks. They used factor analysis to identify four factors (attention/prospective memory, anterograde memory, retrograde memory and historical/overlearned memory) involved in self reports of memory. The attention/prospective memory factor accounted for the highest frequency ratings.

Sohlberg and Mateer (1989) describe a Prospective Memory Screening (PROMS) tool looking at the ability to remember to carry out tasks after 60 s, 2 min, 10 min, 20 min, and 24 hr. We assume there was no control over the strategies used in the 24-hr period. A Prospective Memory Process Training (PROMPT) is also described with the overall goal of systematically extending the amount of time an individual is able to remember to carry out tasks.

Shallice and Burgess (1991) described three patients whose ability to organize their lives was grossly impaired yet performed in the normal range on traditional frontal lobe tests. Consequently, Shallice and Burgess developed tasks of executive functioning to capture these difficulties. One task involved going to a shopping mall to buy certain things and find out information (e.g., the rate of the British pound against the dollar in the newspaper). Certain rules had to be obeyed during the shopping trip. The second task involved carrying out six tasks within a given time period. Once again certain rules had to be followed. These tasks can be seen as analogous to prospective memory tasks. Cockburn (1995) described a single case study of a patient with mild memory problems together with severe executive deficits. The patient performed well on event-based prospective memory tasks but failed the time-based tasks, that is, tasks requiring higher demands on self-initiated retrieval. This is consistent with Einstein and McDaniel's (1990) view of prospective memory. Cockburn concluded that her patient's prospective memory malfunctioning was partly a result of failure in initiation and partly a failure to inhibit ongoing behavior. She felt poor memory was not the explanation. Kinsella et al. (1996) looked at the interrelationships between self-report, traditional memory tests, and two prospective memory measures. The authors interviewed people with and without traumatic brain injury. In the first prospective memory task, the participants were required to ask for a questionnaire and to remember its purpose at the end of the session. The second prospective memory task required participants to return (by mail) an evaluation form with the date written in the top corner. Although the patients with brain injury performed worse than the control participants on the first task, there were no differences on the second. Kinsella et al. thought this was due to differences in motivation although it is possible that the results were due to the lack of control over strategies used in the second task. This lack of control makes it difficult to compare studies conducted in naturalistic settings. Responses to the self-report questionnaire in the Kinsella et al. study did not correlate with traditional memory tests although there was a correlation with the first prospective memory task. Perhaps self-appraisals of memory functioning might be more closely associated with prospective than traditional memory performance. It is possible that independent raters' scores might have resulted in higher correlations given that patients' awareness of memory deficits could have been impaired. This view is consistent with the findings of Sunderland et al. (1983). They found that patients' questionnaires are inaccurate as a measure of the incidence of memory failures. As responding to the questionnaire is in itself a memory task, people with poor memories may be poorer at recalling instances of memory failure and thus give inaccurate ratings.

The purpose of this study is to (1) investigate the neuropsychological mechanisms involved in prospective memory functioning, (2) determine whether time-based prospective memory tasks are more difficult than event-based prospective memory tasks, and (3) see whether people can compensate for prospective memory impairments with external strategies.

We assessed 36 people with nonprogressive brain injury and 28 non-brain-injured control participants on eight prospective memory tasks. A laboratory setting was chosen so we could observe the aids and strategies people use to help them remember. We used a modified version of the Cambridge Behaviour Prospective Memory Test (CBPMT). Developed originally by Wilson and Evans to evaluate a memory group, the CBPMT was first mentioned in a paper by Kime et al. (1996) in a study using the test as a qualitative instrument to monitor the use of compensatory strategies in a young woman with severe amnesia. For the present study the CBPMT was modified to include four time-based and four event-based prospective memory tasks, according to Einstein and McDaniel's distinction (Einstein & McDaniel, 1990). Half the tasks required a verbal response and half the tasks required a non-verbal response. Participants were allowed to use strategies to help them remember the tasks, for instance by taking notes. We wanted to see whether people with brain injury can improve their prospective memory functioning by the use of external strategies when told they were allowed to use these. We also wanted to determine the characteristics of those who wrote down the tasks. This is something encouraged in rehabilitation yet not always observed in real life.

As prospective memory involves both memory and executive functioning, a number of tests that measure these skills were administered. We wanted to see if there was a relationship between prospective memory performance, and the other measures. We also assessed premorbid and current intellectual functioning, and speed of information processing to see if these abilities influenced prospective memory. Self-reports about memory and executive functioning were collected from participants and their relatives. Results were compared with the participants' prospective memory performance. A description of the formal tests and questionnaires used can be found below. We also wanted to know whether participants found time-based prospective memory tasks harder than event-based prospective memory tasks.

Specific questions the study addressed were as follows:

1. Do people with brain injury perform significantly worse on prospective memory functioning than control participants? If so, can this difference be explained by differences in memory and executive functions, age, sex, years of education, speed of information processing, or premorbid or current intelligence?

2. Does note-taking improve prospective memory performance and what are the characteristics of the people who choose a note-taking strategy, for example, do they have better memory or executive functions?

3. Do people with both memory and executive functioning problems have worse prospective memory functioning than people who have these problems in isolation?

4. Is there a relationship between prospective memory functioning and (1) self reports and (2) reports by carers on everyday memory and executive functioning?

5. Do people have more difficulty on time-based prospective memory tasks than on event-based prospective memory tasks?

METHODS

Research Participants

The sample comprised 36 people with brain injury and 28 control participants. The people with brain injury were recruited from a day center for people with head injury, and a neuropsychological rehabilitation center for people with nonprogressive brain injury. Of the people with brain injury, 26 were male and 10 were female, all were said to have memory problems. Diagnoses were: traumatic brain injury (n = 22), CVA (including subarachnoid hemorrhage) (n = 7), cerebral anoxia (n = 3) encephalitis (n = 2), Korsakoff's syndrome (n = 1), both cerebral tumor and meningitis (n = 1). The majority had sustained a period of coma and had received some formal rehabilitation. For 34 of them, the time between the injury and the testing was at least 6 months (see Table 1).

Table 1. Demographic and clinical details of the two groups of participants

Variable	People with brain injury (N = 36)	Control participants (N = 28)
Age at testing (years)		
M (*SD*)	35.61 (11.06)	35.19 (10.85)
Range	19–60	20–65
Gender		
Male	26	18
Female	10	10
Years of education		
M (*SD*)	12.42 (2.09)	14.08 (3.02)
Range	9–17	10–20
Time since injury (months)		
M (*SD*)	75.56 (87.94)	
Range	0–60	

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Measures

Measure of prospective memory

An extended version of the CBPMT (Wilson & Evans, reported in Kime et al., 1996) was designed for this study. This test takes 40 min and comprises four time-based and four event-based prospective memory tasks (described below). The participants were required to remember to do things while working on intellectually demanding filler tasks. They were able to see the time on a clock and were told they could use any strategy they liked to help them remember the tasks. The instructions were, "You can use any strategy you like to help you remember and use anything on the desk to help you" (paper and a pencil were clearly visible). Some instructions were given at the beginning of the session and others were given during the session.

The CBPMT included the following tasks:

Time-based prospective memory tasks

1. Reminding the tester after 15 min not to forget her key: "In 15 minutes' time, I want you to remind me not to forget my key."
2. Requesting the tester for a newspaper after 20 min: "In 20 minutes' time, please ask me for a copy of the newspaper."
3. After working for 20 min on the first filler task, the person was asked to switch to a second filler task after a further 5 min. A few people had already completed the first filler task within this time period so they were asked to stop the second filler task in 5 min and complete a questionnaire. (The filler tasks were nonverbal reasoning tests taken from commercially available books.)
4. Opening or closing the booklet of the filler task 3 min after the instruction was given: "In 3 minutes' time please close the book you are working on."

Event-based prospective memory tasks

5. Reminding the tester about five hidden objects after the tester said the testing is over (at the end of the session): "When I tell you we have finished this session, please ask me for the objects and tell me where they are hidden."
6. Putting a briefcase under the desk after an alarm rings which was set to ring 5 min after the beginning of the session: "When the alarm rings, please put this briefcase under the desk."
7. Changing pens after having completed seven filler assignments: "When you have completed seven of these puzzles, please change pens."
8. Giving an envelope with "message" written on it to the tester when tester says that there are 10 min left; instruction is given after the timer goes off: "When I tell you there are 10 minutes left, please give me this message."

The eight tasks were not printed on a card. Participants either wrote down the information or tried to remember it.

One point was given for each successfully completed task at the right time or after the right event took place. A total score was calculated and scores for time-based and event-based prospective memory tasks were summed separately for further analysis. In this study the names of the hidden objects and their places were scored separately and could be used qualitatively, but were not included in the total score as inclusion would make this task unequal in difficulty compared to the other tasks. The hidden objects were good for morale as people with brain injury were more likely to remember some of the items and where they were hidden.

Intellectual functioning measures

Three tests were used to assess intellectual functioning and speed of information processing. The Raven's Standard Progressive Matrices (Raven, 1960) was used to assess current intellectual functioning. The Spot-the-Word subtest of the Speed and Capacity of Language Processing test (SCOLP; Baddeley et al, 1992) was used to estimate premorbid intellectual functioning. The Speed of Comprehension Test subtest of the SCOLP (Baddeley et al., 1992) was used to assess speed of information processing.

Retrospective memory measures

Three tests were administered to assess retrospective memory functioning. The Logical Memory Subtest (immediate and delayed recall) of the Wechsler Memory Scale–Revised (WMS–R, Wechsler, 1987) was used as a verbal memory measure. The Rey-Osterrieth Complex Figure Test (Osterrieth, 1944; Rey, 1964) was used to assess visual memory. Two independent raters scored the drawings and the means were calculated. The Recognition Memory Test (Warrington, 1984) was used to estimate recognition of words and faces.

Working memory, attention and executive functions measures

Six tests that measure working memory, attention, and executive functions were administered. The Digit Span subtest (forwards and backwards) of the WMS-R (Wechsler, 1987) was used to assess working memory and attention. The Color Word Stroop Test (Stroop, 1935) was used to assess selective attention and inhibitory control. The Modified Card Sorting Test (Nelson, 1976) was used to assess executive functioning. The Modified Six Elements subtest of the Behavioural Assessment of the Dysexecutive Syndrome battery (BADS; Wilson et al., 1996) was used to assess the ability to plan, organize and monitor behavior. The Controlled Oral Word Association Test "FAS" (Spreen & Benton, 1977) was used to assess verbal fluency. The Trail Making Test (Reitan, 1958) was used to assess visual search and the ability to switch between numbers and letters.

Questionnaires measuring memory and executive functions

The Everyday Memory Questionnaire (Sunderland et al., 1983) was used to assess failures in everyday memory. A 28-item self-report questionnaire was given to participants who rated how often certain everyday life memory problems had occurred in the past 3 months. Family members, caregivers or friends also rated the frequency of the memory problems of the people with brain injury. The Cognitive Failures Questionnaire (Broadbent et al., 1982) was used to assess errors in attention and executive functioning. In this 25-item self-report questionnaire participants were asked to rate the frequency with which they made everyday errors in the past 2 months. Other reports were by family members of the people with brain injury on a checklist that contains eight items.

The Dysexecutive Questionnaire (Burgess et al., 1998) was used to assess dysexecutive problems. Participants were asked to rate the behavioral, cognitive and emotional problems experienced on a 20-item checklist. This questionnaire was also completed by an independent rater.

The order of testing was as follows: (1) Spot-the-Word from the SCOLP; (2) Speed of Comprehension from the SCOLP; (3) Rey-Osterreith Complex Figure—copy and immediate recall; (4) CBPMT; (5) Rey Figure–delayed recall; (6) Digit Span; (7) Logical Memory–immediate recall; (8) (break) and delayed recall; (9) Modified Card Sorting Test; (10) Stroop; (11) Trail Making Test–A and B; (12) Word Fluency (F, A, S); (13) Modified Six Elements from the BADS; (14) questionnaires (everyday memory problems, Cognitive Failures Questionnaire, Dysexecutive Questionnaire).

Procedure

People with brain injury who met the selection criteria were invited to participate in the study. Following a detailed explanation, written consent was obtained. Participants were assessed individually. Before the session the people with brain injury were asked about memory, attention and concentration difficulties experienced in everyday life. The session took about 2 hr for the control participants. People with brain injury were seen in two or three sessions, depending on their level of fatigue. For the people with brain injury the first two tests were administered in a separate session. The order of the administration was the same for both groups, however.

Statistical Analysis

The two groups were compared on age, gender, speed of information processing, premorbid and current intelligence and years of education to identify any differences across the groups that might influence prospective memory performance. Unless otherwise stated, a t test for independent samples was used to look at group differences. An analysis of covariance (ANCOVA) was used to exclude possible effects of retrospective memory, attention, executive function, speed of information processing (current and premorbid), intelligence and education. Relationships between prospective memory performance and retrospective memory, attention and executive functioning measures were analyzed further with Pearson's correlations. Fisher's test compared correlations between the people with brain injury and control groups and Williams (1959) test was used to compare correlations within group. Means, standard deviations, and ranges of these measures are given in Table 2.

Adding z scores gives a total score giving each test variable equal weight. Each variable is deemed equally important in determining the construct score, for example, Logical Memory and Digit Span Backward are equally important theoretically in determining retrospective memory. Regression would give unequal weights so some scores would be deemed to be more influential in determining retrospective memory than others. This appears to be theoretically counterintuitive.

People with brain injury and control participants were compared on prospective memory performance. The two groups were successfully matched on age [$t(62) = -0.22$, $p = .83$] and gender (Yates corrected $\chi^2 = .17$, $df = 1$, $p = 0.68$) but the controls had more years of education [$t(46) = -2.49$, $p < .05$]. A t test for independent samples showed that people with brain injury performed significantly worse on the prospective memory tasks compared with control participants [$t(53) = -6.39$, $p < .001$].

Controls had higher estimated premorbid intelligence as measured by the SCOLP [$t(55) = -3.26$, $p < .01$], higher current intelligence as measured by the Raven's Standard Progressive Matrices [$t(60) = -3.24$, $p < .01$] and faster speed of information processing [$t(59) = -11.01$, $p < .001$].

The difference in prospective memory scores between the control participants and people with brain injury is not accounted for by differences in SCOLP, Raven's Standard Progressive Matrices or years of education, but is explained by speed of information processing as shown in Table 3.

There is a significant positive relationship between prospective memory and each of SCOLP, Raven's Standard Progressive Matrices and speed of information processing in control participants and Raven's Standard Progressive Matrices in the people with brain injury. The association between prospective memory and speed of information processing is stronger in the control group than in the group with brain injury. These results are also given in Table 3.

Relationships between prospective memory and other cognitive functioning measures

Significant relationships were found between CBPMT scores and a number of retrospective memory, attention and executive function tests as shown in Table 3. The correlations between each of the memory, attention and executive functions with prospective memory in Table 3 are the same in

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Table 2. Summary measures for various tests

Test	Maximum Score	People with brain injury			Control participants		
		M	*SD*	Range	*M*	*SD*	Range
CBPMT	(8)	4.50	2.29	0–8	7.29	1.12	4–8
Logical Memory (immediate recall)	(50)	17.87	7.15	3–37	18.22	8.16	10–38
Logical Memory (delayed recall)	(50)	13.39	9.59	0–36	22.33	6.82	14–36
Rey Figure recall	(36)	14.93	7.64	3–32	23.58	7.68	8.25–33
Recognition Memory Test–Words	(50)	43.38	6.90	27–50	48.83	1.82	44–50
Recognition Memory Test–Faces	(50)	36.13	7.11	23–48	45.39	2.87	38–49
Digit Span forward	(12)	7.13	2.07	4–11	8.22	2.29	5–12
Digit Span backward	(12)	5.91	1.93	3–10	6.72	1.90	4–11
Stroop (raw score)	(112)	87.43	22.76	42–112	105.89	89.75	82–112
Modified Card Sorting Test (categories)	(6)	4.78	1.54	1–6	5.89	0.32	5–6
Trail Making Test A	(∞)	51.39	22.34	26–126	29.11	10.26	15–49
Trail Making Test B	(∞)	151.70	117.13	61–572	60.27	27.76	35–124
FAS	(∞)	34.04	11.71	13–65	46.89	10.86	30–69
Six Elements	(4)	2.65	1.30	0–4	3.83	0.38	3–4
Self: EMQ	(∞)	87.68	43.90	4–179	50.46	25.20	7–95
Carer: EMQ	(∞)	93.16	41.03	34–174			
Self: CFQ	(100)	−1.19	11.02	−25–19	−4.25	8.16	−19–14
Carer: CFQ	(100)	2.24	3.71	−5–8			
Self: DEX	(100)	32.77	14.45	1–59	24.46	11.60	7–47
Carer: DEX	(100)	41.12	14.99	15–71			
SCOLP	(60)	47.09	6.88	31–57	51.54	3.80	44–59
Raven's Standard Progressive Matrices	(60)	40.77	10.01	20–58	47.54	7.65	26–58
Speed of Information Processing	(100)	39.71	15.06	17–89	83.04	15.01	44–100

people with brain injury and controls except for the Rey Figure which has a higher association with prospective memory in the people with brain injury and speed of information processing which has a higher association in controls.

The data from the participants who did or did not take notes as a strategy to help them remember the prospective memory tasks, were analyzed separately. This analysis resulted in even stronger relationships between these measures and prospective memory functioning.

The test scores were transformed into standard scores. This was done using the control data and applying the formula, "patient score minus control group mean divided by control group standard deviation." We wanted to see whether retrospective memory and executive functions combined had a bigger relationship with prospective memory than retrospective memory and executive functions in isolation. We chose this method rather than regression because *z* scores ensure each test score is on the same scale. Each score is therefore treated in the same way. Difference from the control mean is measured in terms of number of standard deviations.

Standard deviations allow us to know if a change on a score is high or low, for example, a difference of 3 units is large if the *SD* of the control score is small (e.g., 1) but is minuscule if the control *SD* was 36, say, thus we take into account the signal-to-noise ratio.

The standard scores (*z* scores) of Logical Memory (delayed recall), Digit Span Backward, Trail Making Test Part B, and the Modified Card Sorting Test (number of categories obtained) were calculated. The retrospective memory standard scores were added to the attention and executive functions standard scores. Pearson's correlations were made to calculate the relationship between the added memory/executive functions scores and prospective memory scores as measured by the CBPMT. Table 4 gives the associations of three standardized tests, both individually and summed with standardized Logical Memory (delayed recall), and prospective memory. Digits Backward, MCST, TMT Part B and Logical Memory are all associated with prospective memory individually. Logical Memory is also associated with prospective memory when combined with each of the other scores. There are no differences between the summed scores' relationship with prospective memory and that of its components and prospective memory.

Logical Memory, Modified Card Sorting Test and Trail Making Test Part B each accounted for between 15 and 27% of variation in CBPMT scores in the people with brain injury group and between 14 and 31% of variation in non-note-takers.

Partialing out executive memory from retrospective memory and vice versa does decrease the association of each with prospective memory but still gives correlations with prospective memory of at least .30. People with brain injury scores greater than 2 standard deviations from the control mean were deemed impaired. Using this criterion one participant was found to be impaired on both Digit Span

Table 3. Relationships between performance on traditional tests, years of education and prospective memory functioning

	People with brain injury			Control participants				
Test	*n*	Pearson's *r*	Adjusted CBPMT mean	*n*	Pearson's *r*	Adjusted CBPMT mean	Difference in *r*	CBPMT difference
Logical Memory I (immediate recall)	35	.37*	4.46	28	.46**	7.32	−.09	−2.86***
Logical Memory II (delayed recall)	35	.44**	4.94	28	.55**	6.72	−.11	−1.78***
Rey Figure Delayed Recall	36	.49**	4.84	28	.09	6.85	.40*	−2.01**
RMT words	23	.53**	4.95	20	.13	6.70	.40	−1.75**
RMT faces	23	−.19	4.77	20	.22	6.92	−.41	−2.15**
Digit Span Forward	36	.39	4.65	28	.37*	7.09	.02	−2.44***
Digit Span Backward	36	.39*	4.68	28	.44*	7.06	−.05	−2.38**
Stroop Test Color Word	33	.46**	4.85	25	.55**	6.84	−.09	−1.99***
MCST	35	.54**	4.83	28	.20	6.82	.34	−1.99***
TMT Part A	35	−.17	4.79	28	−.32*	7.05	.15	−2.26***
TMT Part B	35	−.50**	4.98	28	−.49**	6.82	−.01	−1.84***
Word Fluency FAS	35	.40**	4.69	26	.11	6.94	.29	−2.25***
Six Elements Test	31	.21**	4.60	27	−.19	7.12	.40	−2.52***
SCOLP	35	.29	4.69	28	.42*	7.03	−.13	−2.34***
Raven's Standard Progressive Matrices	34	.34*	4.85	28	.43*	6.86	−.09	−2.00***
Years of education	36	.19	4.61	28	.30	7.15	−.11	−2.54***
Speed of Processing	33	.17	5.11	28	.57***	6.51	−.40*	−1.41

$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Backward and Logical Memory (delayed recall) and no participants were impaired on both Trail Making Test Part B and Logical Memory (delayed recall). These low numbers precluded any comparisons involving those with dual impairments on these tests. The nine participants with brain injury with impairments on both the Modified Card Sorting Test and Logical Memory (delayed recall) did have a lower prospective memory score than the eleven with just a single impairment using a Mann-Whitney test ($z = 3.14$, $p < .01$). An analysis of covariance was also applied comparing the prospective memory scores from the group with brain injury with the control participants adjusted for individual tests. These results can be seen in Table 3. People with brain injury and control groups differ when adjusted for each of the retrospective memory, attention and executive function tests in Table 3 but not when adjusted for them all at once [$F(1,26) = 1.28$, $p > .2$].

Prospective memory and compensatory strategies

Thirteen of the 36 people with brain injury and 14 of the 28 control participants made use of the materials on the table to take notes spontaneously to help them remember the prospective memory tasks.

A *t* test for independent samples showed that participants who took notes performed significantly better on the prospective memory test than participants who did not take notes [$t(62) = -3.26$, $p < .01$]. When the group was divided into four subgroups: (1) *people with brain injury note-takers*, (2) *people with brain injury non-note-takers*, (3) *control note-takers*, and (4) *control non-note-takers*, the results showed that the control participants who took notes performed most successfully ($M = 7.79$, $SD = .43$). Second were the non-note-taking control participants ($M = 6.79$,

Table 4. Correlations of tests, individually and summed with Logical Memory (LM), with prospective memory

Test	*n*	Sum	Alone	Difference	Sum − (LM alone)	LM only
Digit Span Backward	35	.51**	.39*	.12	.07	.44**
MCST	34	.60**	.57**	.03	.16	.44**
TMT Part B	34	.56**	.50**	.06	.12	.44**

$^*p < .05$. $^{**}p < .01$.

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SD = 1.37), third the note-taking people with brain injury ($M = 5.54$, $SD = 1.85$), and fourth the non-note-taking people with brain injury ($M = 3.91$, $SD = 2.33$) (see Figure 1). Note-takers had higher CBPMT scores than non-note-takers [$F(1,60) = 8.37$, $p < .01$], irrespective of whether they were people with brain injury or controls [$F(1,60) = .48$, $p > .4$] (see Fig. 1).

A Yates corrected χ^2 test showed that people with brain injury were no more likely than control participants to make use of notes ($\chi^2 = .74$, $df = 1$, $p = .38$). Current IQ predicted note-taking [$t(32) = -2.12$, $p < .05$] but premorbid IQ [$t(33) = -1.16$, $p > .2$], years of education [$t(34) = -1.81$, $p > .05$], age [$t(34) = .06$, $p > .9$], Logical Memory (delayed recall) [$t(33) = .09$, $p > .9$] and executive function as measured by Trail Making Test Part B [$t(33) = 1.50$, $p > .1$] did not. A two-way ANOVA showed that there was no interaction between notes and group on age [$F(1,60) = .04$, $p = .84$], education [$F(1,60) = 1.04$, $p = .31$], premorbid intelligence [$F(1,59) = .11$, $p = .74$], current intelligence [$F(1,58) = .01$, $p = .92$], retrospective memory [$F(1,59) = 2.14$, $p = .15$] or executive functions [$F(1,59) = .86$, $p = .36$].

Table 5 gives the correlations between prospective memory and three questionnaire ratings for controls, people with brain injury and their carers. The self-ratings of people with brain injury are based on 34 people, the control self-ratings are based on 28 people and the carer ratings are based on 25 people. There was no difference in correlations between prospective memory and ratings on any questionnaire in people with brain injury, controls and carers.

The only association found was between EMQ carers' ratings and prospective memory. There is also no difference found in the association of EMQ carer ratings and prospective memory and that of Logical Memory (delayed recall) with prospective memory (difference = $-.01$, $p > .9$).

Time-based and event-based prospective memory performance

We used a repeated measures ANOVA as all participants carried out both time- and event-based measures. This showed that there was a significant difference in performance on time-based and event-based prospective memory tasks [$F(1,62) = 10.48$, $p < .01$] which did not differ with group [$F(1,62) = .01$, $p > .90$]. The table below shows the means on the time-based tasks and event-based tasks for both people with brain injury and the control groups (see Table 6).

Time-based and event-based tasks have statistically significant correlations of at least .30 in absolute value with Logical Memory (delayed recall), Rey Figure, Recognition Memory Test for Words and Faces, Digit Span Forward and Backward, Stroop, Modified Card Sorting Test, Trail Making Test Parts A and B, FAS, and the Six Elements Test. The weakest relationship is with Logical Memory (immediate recall) for both (time: $r = .24$, $p > .05$; event: $r = .28$, $p < .05$). The time-based and event-based correlations do not differ in magnitude statistically on any test.

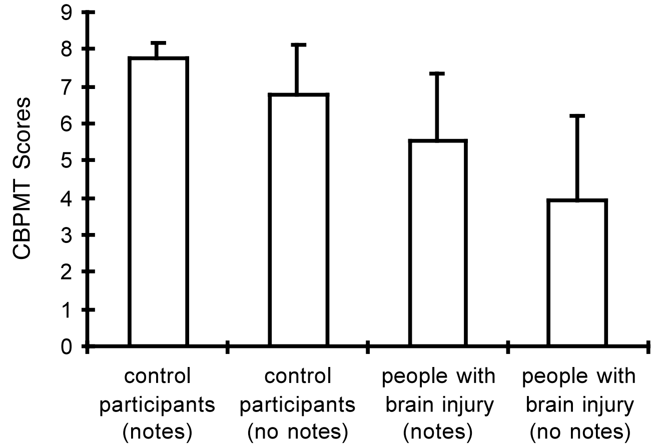

Fig. 1. The effect of note-taking on CBPMT scores by people with brain injury and control participants.

DISCUSSION

In this study people with brain injury and control participants were compared on a test of prospective memory functioning. The results show that control participants performed significantly better than people with brain injury on the prospective memory tasks, a difference that could not be explained by differences in age, gender, years of education, pre-morbid or current intellectual functioning individually, but could be explained by speed of information processing individually. However, analysis shows that differences in prospective memory performance could also be explained by differences in performance on formal tests of retrospective memory, attention, and executive functioning together, but not individually. The performance of people with brain injury on the prospective memory tasks also correlated significantly with everyday memory evaluations by the family members or caregivers. However, within this group, better memory, attention and executive function is associated with

Table 5. Questionnaire rating correlations with prospective memory

Questionnaire	PBI	Controls	Difference
EMQ			
Self-rating	−.31	−.11	−.20
PBI *vs.* carers	−.31	−.47* (carer)	.16
Controls *vs.* carers	−.11	−.47* (carer)	.36
CFQ			
Self-rating	.08	−.25	.33
PBI *vs.* carers	.08	−.14 (carer)	.22
Controls *vs.* carers	−.14 (carer)	−.25	.11
DEX			
Self-rating	−.30	−.29	−.01
PBI *vs.* carers	−.30	−.08 (carer)	−.22
Controls *vs.* carers	−.08 (carer)	−.29	.21

*$p < .05$.

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Table 6. Participants' performance on event-based and time-based tasks with and without making use of notes

Range 0–4	All people with brain injury *M* (*SD*)	All controls *M* (*SD*)	People with brain injury–no notes *M* (*SD*)	People with brain injury–notes *M* (*SD*)	Controls–no notes *M* (*SD*)	Controls–notes *M* (*SD*)
Event-based tasks	2.42 (1.30)	3.82 (.55)	2.09 (1.41)	3.00 (.82)	3.64 (.74)	4.00 (.00)
Time-based tasks	2.08 (1.18)	3.46 (.74)	1.83 (1.07)	2.54 (1.27)	3.14 (.86)	3.79 (.43)
CBPMT	4.50 (2.29)	7.29 (1.12)	3.91 (2.33)	5.54 (1.85)	6.79 (1.37)	7.79 (.43)

better prospective memory. The results of this study support the assumption that both retrospective memory and executive functions are important underlying mechanisms in prospective memory functioning. People with brain injury as well as control participants found time-based tasks more difficult than event-based tasks. This is consistent with the findings of Cockburn (1995) who described a case study of a patient with mild memory problems but severe dysexecutive problems who failed the time-based tasks yet successfully completed the event-based tasks. The higher demands on executive functioning and inhibitory control mechanisms in the time-based tasks might make them more difficult than event-based prospective memory tasks. But also a higher load on retrospective memory could contribute to its difficulty as one has to remember the time to perform the action as well as its content (one has to remember to remember). If the retrospective component of the prospective task is complex, correlations between the retrospective and prospective memory tasks are likely (e.g., Einstein et al., 1995). What characterizes time-based tasks? Do these tasks place high demands on executive functions, memory, or both, or other things such as monitoring the time? The relationships between traditional memory tests and time-based and event-based prospective memory tasks were calculated separately. We found that the weakest relationships were between the time-based and event-based prospective memory tasks and Logical Memory (immediate recall). The time-based and event-based tasks had the same correlations with retrospective memory, attention, and executive function tasks, suggesting that both memory and executive functioning play crucial roles in prospective memory. The fact that both groups had more difficulty with the time-based prospective memory tasks than the event-based prospective memory tasks is consistent with findings by Einstein and McDaniel (1990) and Cockburn (1995). The first suggested that time-based tasks place higher demands on self initiated retrieval and are therefore more difficult, whereas Cockburn suggests that inhibitory control mechanisms also play a key role. Our findings support this latter suggestion. In one instance people with both retrospective memory and executive function problems, performed worse on the prospective memory tasks than people who had these problems in isolation. The correlations of the added memory and executive functions scores are slightly higher than those of their components with prospective memory, but are not significantly higher. It is possible that visuoperceptual, visuospatial and language functioning also affect prospective memory but this would require a further study. The same is true of the effects of mood. None of the present participants had obvious language deficits or marked depression.

An important finding from a rehabilitation point of view is that note-taking significantly benefited prospective memory functioning. Neither age, years of education (premorbid), intelligence, memory or executive functions predicted note-taking but current intelligence did. The decision to take notes might have been influenced by a personality factor such as motivation, or compliance with the testing. Or it might have been due to (mis)understanding the instructions. For people with brain injury, the decision to take notes might also have been influenced by the amount and quality of rehabilitation received. Strategies taught during rehabilitation might have been transferred to natural settings and to other test settings. Further research will be necessary to investigate what the exact underlying factors are that predict note taking.

As failures in prospective memory could threaten independent living, it could be important to detect these failures and investigate what can be done to improve prospective memory functioning. At present there is a relative lack of standardized tests of prospective memory in the clinical literature and, the development of valid and reliable measures of prospective memory may prove of significant utility in the assessment and treatment of a wide range of people suffering memory deficits (Kinsella et al., 1996). It is proposed that the test used in this study, the Cambridge Behavioural Prospective Memory Test (CBPMT), could, with further development, be a suitable measure to fulfil this need. The tasks in the CBPMT have high face validity and resemble everyday situations. It can be used to assess and evaluate prospective memory performance over time and monitor the process of rehabilitation. It can be used as a learning tool for people to investigate the use of compensatory strategies and see whether they can transfer these to everyday living. This test could be a starting point of more research in the clinical population. Further research will be needed in a larger sample to measure the test–retest and interrater reliability of this tool. Also further research is needed to study the effects of filler task difficulty on prospective memory performance.

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