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Predictors of prospective memory in adults with traumatic brain injury

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Abstract

Previous studies have established that prospective memory is commonly affected following traumatic brain injury (TBI). This study examines whether demographic factors, injury severity and site, executive function, and metacognitive factors predict prospective memory performance in adults with TBI, using a cross-sectional multivariate correlational model. Prospective memory of 44 adults (mean age = 30 years) with severe TBI was measured by the Cambridge Prospective Memory Test (CAMPROMPT) time-based and event-based scores. Using stepwise multiple regression, the time-based score was predicted by the Controlled Oral Word Association Test (COWAT) Animals subtest score, length of post-traumatic amnesia (PTA) and use of note-taking on the CAMPROMPT. The event-based score was predicted by length of PTA and COWAT Animals score. Therefore, patients with longer periods of PTA and executive function impairment may be expected to display poorer prospective memory. Note-taking was associated with improved performance on time-based prospective memory tasks. (*JINS*, 2008, *14*, 823–831.)

Keywords: Memory deficits, Intention, Neuropsychological tests, Chronic brain injury, Rehabilitation, Outpatients

INTRODUCTION

Prospective memory, or the realization of delayed intentions, refers to memory for activities to be carried out in the future. In surveys of people with traumatic brain injury (TBI), prospective memory problems, such as forgetting to telephone a friend or post a letter, have been identified by large percentages of respondents as a significant area of deficit (Hannon et al., 1995; Shum et al., 1999). Despite this, prospective memory research is a relatively new field, with very little literature on the topic prior to the 1970s (Kvavilashvili & Ellis, 1996). Among other authors, Shum et al. (2002) and Martin et al. (2003) have argued that research into prospective memory is of considerable clinical and theoretical relevance, as well as being pertinent to everyday life.

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Research has found that adults with TBI demonstrated significantly greater prospective memory failure compared to matched control participants (Cockburn, 1995; Mathias & Mansfield, 2005; Schmitter-Edgecombe & Wright, 2004; Shum et al., 1999). Prospective memory failures may limit the ability to live independently, as well as affect social and vocational roles (Fleming et al., 2005; Groot et al., 2002). A better understanding of the factors that predict prospective memory function may provide insight into the nature of processes underlying prospective memory. Knowledge of these factors may lead to the development of rehabilitation programs to assist individuals with TBI to function more independently in everyday life (Shum et al., 2002).

Einstein and McDaniel (1990) proposed the distinction between event-based and time-based prospective memory tasks. Event-based tasks are to be carried out when an external event occurs (e.g., giving a message to a friend when you next meet) whereas time-based tasks, which are considered to require a higher level of self-initiated retrieval, involve performing an action at a specific time (e.g., taking medication at 10 am). Differences in the demands of time-based and event-based prospective memory tasks necessitate the separate examination of predictors of these two types of prospective memory.

Einstein and McDaniel (1990) also proposed that prospective memory consists of a retrospective component involving the retention of the action and when it should be carried out, and a prospective component involving retrieval of the action to be performed when the correct moment arrives. However, in studies of prospective memory performance, the factors involved in these theories can prove difficult to isolate (Otani et al., 1997; Palmer & McDonald, 2000), although it is generally accepted that executive functions play an important role (Fish et al., 2007; Kliegel et al., 2004).

By definition, prospective memory involves executive processes such as planning, disruption of ongoing activity, and initiation of an action (Shum et al., 2002), which are generally associated with the frontal lobes (Demakis, 2004). Damage to the prefrontal lobes is common after TBI (Levine et al., 2002), and individuals with TBI are predicted to demonstrate prospective memory impairment resulting from impaired executive functions (Shum et al., 1999, 2002). Imaging studies have reported involvement of the frontal lobes during prospective memory tasks (Burgess et al., 2001; Okudaa et al., 1998). Studies of single participants of small samples with focal frontal lobe lesions have demonstrated deficits in prospective memory performance (Fortin et al., 2002; Palmer & McDonald, 2000). Other studies have predicted performance on prospective memory tasks using scores on standardized tests of executive function (Cockburn, 1995; Groot et al., 2002; Kinch & McDonald, 2001; Kliegel et al., 2004; Martin et al., 2003). Martin et al. (2003) found that executive functioning predicted prospective memory performance, even after controlling for nonexecutive factors, such as level of education. Some studies have found that executive functions are more predictive of time-based than event-based tasks, suggesting that increased self-monitoring involved in time-based prospective memory tasks places higher demand on executive processes (Cockburn, 1995; Groot et al., 2002; Kinch & McDonald, 2001).

The ability to remember effectively in everyday life depends on metacognitive factors, such as the ability to monitor ongoing performance, the ability to predict what amount of information can be remembered, and knowing when to use a memory aid (Knight et al., 2005). This level of self-awareness, which is assumed to come about through a lifetime of experience and feedback, is abruptly lost following the cognitive changes often seen in TBI (Knight et al., 2005; McGlynn & Schacter, 1989). Reduced self-awareness into one's own abilities is associated with neurological damage to the frontal lobes (Prigatano, 1991), as well as being attributed to psychological defence mechanisms (Varney & Menefee, 1993). A small number of studies have consistently shown that self-awareness of prospective memory is reduced after TBI (Hannon et al., 1995; Knight et al., 2005; Roche et al., 2002). Self-awareness may affect a patient's willingness to participate in rehabilitation programs, which may influence their functional outcomes (Fleming et al., 2005). Therefore, it is relevant to include metacognitive factors as potential predictors of prospective memory after TBI.

Much of the research to date on has focused on establishing a relationship between prospective memory and TBI. Only a small amount of research has moved beyond comparing persons with TBI to matched controls, to consider which TBI-related factors as well as demographic variables, predict prospective memory performance (e.g., Kinch & McDonald, 2001; Martin et al., 2003). In addition, among these studies none has included these factors together as a set of predictors and evaluated their unique contribution in predicting prospective memory performance. To gain a better understanding of the causes of impaired prospective memory, this study examined whether demographic and injury-related factors, executive functions, and metacognitive skills predict the performance of adults with TBI on a standardized prospective memory assessment. It was hypothesised that participants with more severe TBI, frontal lobe injuries, more impaired executive function, and lower levels of metacognitive skills would demonstrate poorer prospective memory performance.

METHODS

Design

A cross-sectional multivariate correlational model was used to identify the extent to which demographic, injury severity and site, executive functioning, and metacognitive factors predict prospective memory performance in adults with TBI living in the community.

Participants

Forty-four participants were recruited from a Brain Injury Rehabilitation Unit at a major metropolitan hospital in Australia, as part of a larger randomized clinical trial. Persons included in the study were required to be aged between 18 and 60, with a diagnosis of moderate or severe TBI, and living in the community. Participants were excluded if they were more than five years post injury, living in residential care, or if they had severe behavioral or communication deficits that would compromise engagement in a rehabilitation program (as advised by the hospital occupational therapist). Persons displaying low-level arousal, severe amnesia or confusion (i.e., not emerged from post-traumatic amnesia when assessed on the Westmead PTA scale), or with a significant diagnosed premorbid psychiatric or neurological disorder were also excluded.

The 37 male and 7 female participants were aged between 19 and 57 years (M = 29.64, SD = 11.29). Participants were diagnosed with moderately severe to very severe TBI, with number of days in post-traumatic amnesia (PTA) ranging from 2 to 152 (M = 47.89, SD = 35.41) and a mean Glasgow Coma Score (GCS) at the scene of injury of 7.08

($SD = 3.89$). The most frequent mechanism of injury was through motor vehicle accidents (38.6%). Injuries were also sustained through motorbike accidents (15.9%), falls (13.6%), bicycle accidents (11.4%), assault (6.8%), pedestrians hit by a vehicle (4.5%), and sporting accidents (4.5%).

Computerized tomography (CT) scan reports made by a radiologist or neurologist at the time of hospitalization were used to classify the site of any localized lesions in the brain. A researcher with a degree in anatomical science categorized report data according to the presence/absence of frontal and temporal damage. If clarification of any statements made in the reports was required a specialist doctor was consulted. It would have been preferable to access original imaging data, but these were not available to the researchers. Participants were classified as having localized damage to the frontal lobes (20.5%), or temporal lobes (18.2%), damage to both frontal and temporal areas (34.1%), or other damage (27.3%). An independent samples *t* test was carried out to compare groups of participants with localized frontal (50.0%) *versus* nonfrontal damage (50.0%). The results indicated that the groups did not differ significantly in age ($t(42) = -0.96$; $p = 0.34$), years of education ($t(39) = -1.42$; $p = 0.16$), number of days in PTA ($t(33) = -0.31$; $p = 0.76$), or IQ score (nonfrontal = 101.55, frontal = 103.68; $t(42) = -0.50$, $p = 0.62$). Chi-square analysis also indicated that groups did not differ significantly in gender ($\chi^2(1) = 1.53$; $p = 0.22$). The same *t* test was also carried out for groups of participants with localized temporal (47.7%) *versus* nontemporal damage (52.3%). Again, no significant difference was found in age ($t(42) = 1.30$; $p = 0.20$), years of education ($t(39) = -1.01$; $p = 0.32$), number of days in PTA ($t(33) = -0.09$; $p = 0.93$) or IQ score (nontemporal = 101.52, temporal = 103.81; $t(42) = -0.53$, $p = 0.60$). Chi-square analysis indicated that groups did not differ significantly in gender ($\chi^2(1) = 0.30$; $p = 0.59$).

The majority (86.4%) of participants were of Caucasian background, with other ethnicities including Asian (6.8%), Aboriginal or Torres Strait Islander (2.3%), Pacific Islander (2.3%), and African (2.3%). Participants' preinjury occupations were classified as students (22.7%), clerical, sales, and service workers (22.7%), tradespersons (18.2%), laborers (11.4%), professionals (6.8%), retired, homemaker, not working or receiving a pension (6.8%), associate professionals (4.5%), production and transport workers (4.5%), and managers and administrators (2.3%). The average number of years of education was 11.60 ($SD = 2.10$), ranging from 6 to 16 years. Participants IQ scores were measured using the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999), returning a mean IQ score of 102.61 ($SD = 14.09$).

Measures

Outcome variables

Prospective memory functioning was measured using the Cambridge Prospective Memory Test (CAMPROMPT) (Wilson et al., 2005). This test was developed from a modified version of the Cambridge Behavioral Prospective Memory Test, used in a study by Groot et al. (2002), and has since been standardized and normed for adults over the age of 16 (Wilson et al., 2005). In this test, participants are asked to remember to carry out three time-based and three event-based tasks at different times, while performing a filler activity, using both verbal and written instructions. The participants are allowed to spontaneously use strategies, such as taking notes, to help them remember. The CAMPROMPT generates scores on time-based and event-based subscales, each scoring a maximum of 18, with higher scores reflecting better prospective memory performance.

Nonparametric investigations of CAMPROMPT scores have revealed significant group differences according to age, use of note-taking strategies and estimated IQ in non-injured controls (Wilson et al., 2005). The construct validity of the CAMPROMPT has also been supported by significant correlations between CAMPROMPT scores and scores on the Rivermead Behavioral Memory Test, which comprises retrospective and prospective memory tasks (Wilson et al., 2005). Significant relationships have also been found with tests of executive function, including attention, executive processing, and speed of verbal information processing (Wilson et al., 2005). The two subscale scores, time-based and event-based scores, were used as the outcome measures in this study.

Predictor variables

Predictor variables were classified into three subsets: Demographic/Injury-related, Executive Function, and Metacognitive variables, representing the three areas being investigated.

Demographic/injury-related variables. Demographic variables included participant age and years of formal education. Injury severity variables included inpatient length of stay (LOS) in days, and number of days in PTA. Information on PTA was recovered from patient records using the Westmead PTA Scale which has demonstrated reliability (Geffen et al., 1994; Shores et al., 1986). Site of injury was classified as frontal or nonfrontal and temporal or nontemporal.

Executive function variables

The following two neuropsychological tests were used to collect data on the participants' executive functioning.

Trail Making Test. The Trail Making Test is frequently included in neuropsychological test batteries as a measure of executive function (Tombaugh, 2004). Test A involves drawing lines sequentially connecting 25 encircled numbers distributed on a sheet of paper, whereas Test B requires the participant to connect numbers and letters alternately (e.g., 1, A, 2, B, 3, C, etc.). Scoring for both tests is recorded as number of seconds taken to complete each trial, with lower scores representing better performance (Strauss et al., 2006). The Trail Making Test has been found to have adequate test-retest reliability and to be sensitive to the effect of brain injury (Strauss et al., 2006). For the purposes of this study, the difference score between the two tests (i.e., time B minus A) was used as this is regarded as isolating the executive component of the task (Strauss et al., 2006).

Controlled Oral Word Association Test (COWAT)—F, A, S, and Animals Subtests: The COWAT is used to investigate verbal fluency, and requires the participant to spontaneously produce as many words as possible within a limited period of time (Spreen & Strauss, 1998). The number of admissible words generated for each category becomes the score, with higher scores indicating greater verbal fluency. The F, A, and S subtests measure phonological fluency (naming of proper nouns starting with F, A, and S), and the three subtests are added to provide an FAS score, while the Animals subtest measures semantic fluency (naming of animals) and is scored individually (Harrison et al., 2000). Data were entered as two variables, the FAS subtest scores and the Animals subtest score. The COWAT has demonstrated sensitivity to reductions in verbal fluency in all groups, as well as sensitivity to severity of injury (Iverson et al., 1999).

Metacognitive variables

Metacognitive variables included one measure of self-awareness and two measures of strategy use.

Comprehensive Assessment of Prospective Memory (CAPM)—Part A (Frequency scale). The CAPM Frequency Scale is a self-report questionnaire consisting of 39 questions, which measures perceived prospective memory failure for basic and instrumental activities of daily living (BADL and IADL, respectively) (Roche et al., 2002). The CAPM has two versions, a participant self-report version and a significant others' version in which relatives/significant others rate the performance of the participant based on their observations. Questionnaire responses range from 1 to 5 for each item, where 1 equals *no prospective memory failure* and 5 equals *consistent prospective memory failure*. Self-awareness scores are obtained by subtracting the participant's score from the significant other's score for both the BADL and IADL components, with a positive figure indicating impaired self-awareness. Reliability and normative data have been established for Part A of the CAPM (Chau et al., 2007).

CAMPROMPT Note-taking. Whether or not note-taking strategies were spontaneously used by the participant on the CAMPROMPT was recorded as a dichotomous variable.

Diary Entries. A second measure of strategy use in everyday life was the average number of diary entries in the month preceding the assessment. Recording average weekly diary entries has been found to be a useful objective means of quantifying the use of an organizational device in TBI research (Ownsworth & McFarland, 1999). Participants were provided with a diary for the four-week period leading up to the assessment date. The diaries were then examined to determine the average number of valid entries per week over the four-week period. The average number of diary entries per week was then calculated, and used to assess participants' strategy use.

Procedure

Ethical clearance was obtained from relevant hospital and university ethics committees prior to commencement of this study. After obtaining informed consent, participants were sent a package containing a diary and a cover letter requesting them to use the diary to assist with managing everyday tasks and appointments for the next four weeks. Participants were also contacted at this time to make an appointment for the assessment. The individual assessment sessions were from 1.5 to 2 hours each in length, and were conducted by a psychologist in a quiet assessment room. The order of assessment was: (1) CAPM; (2); CAMPROMPT; (3) WASI–Vocabulary subtest; (4) WASI–Matrix Reasoning subtest; (5) Trail Making Test A; (6) Trail Making Test B; (7) COWAT. If a relative or significant other was able to attend the appointment with the participant, they were asked to complete the CAPM significant other's questionnaire. The questionnaire was posted to those relatives who were unable to attend, with instructions for completion and a reply paid envelope for its return. Demographic and injury severity data were collected through interviews with the participants and their relatives, as well as through reviewing the participant's medical records.

Data Analysis

All data were analysed using SPSS (version 14). Data were screened for accuracy of data entry, missing values, skewness, and outliers. One univariate outlier was detected for each of three variables (viz., inpatient length of stay, COWAT (FAS) score, and average number of diary entries per week). The influence of these outliers was reduced by changing them to one unit larger than the next most extreme score in the distribution (Tabachnick & Fidell, 2007). Given the sample size, not all of the variables can be included in regression analyses. Correlations between measures of prospective memory and the other variables were, therefore, inspected to select four or five variables from three sets of variables (demographics/injury-related; executive functioning, and metacognitive factors) as predictors of prospective memory performance. Stepwise multiple regression analyses were used because our interest was in identifying important predictors (Tabachnick & Fidell, 2007). For the regression analyses, cases were deleted pairwise as a result of some missing data (see Table 1). Alpha levels for all analyses were set at 0.05.

RESULTS

Means and standard deviations for all variables are presented in Table 1. Participant's mean total scores on the

Table 1. Means and standard deviations for all variables

Variable	*N*	*M*	*SD*
Dependent variables			
CAMPROMPT: time-based score	44	10.77	4.45
CAMPROMPT: event-based score	44	13.55	3.84
Demographic/injury related subset			
Age of participant (years)	44	29.64	11.29
Years of education	41	11.60	2.10
Inpatient length of stay (days)	38	70.34	75.71
PTA (days)	35	47.89	35.41
Localized frontal damage (dummy coded)	22 out of 44		
Localized temporal damage (dummy coded)	21 out of 44		
Executive function subset			
Trail Making B–A (seconds)	43	63.09	38.66
COWAT (FAS)	44	27.27	10.71
COWAT (Animals)	44	17.68	5.13
Metacognitive subset			
CAPM self-awareness score	36	0.38	0.87
Average diary entries per week	43	2.22	2.95
CAMPROMPT note-taking (dummy coded)	20 out of 44		

CAMPROMPT time- and event-based scores were 10.77 and 13.55, respectively, which represents a poor level of prospective memory performance (Wilson et al., 2005).

Correlations with CAMPROMPT scores

Table 2 displays the correlations between CAMPROMPT scores and demographic/injury-related variables, executive function variables, and metacognitive variables. Of the demographic/injury-related variables, length of PTA correlated significantly with the two CAMPROMPT variables and localized frontal damage correlated significantly with event- but not time-based CAMPROMPT score. Executive function variables that were significantly related to time- and event-based CAMPROMPT scores included Trail Making Tests B–A and COWAT (Animals). COWAT (FAS) score was found to correlate significantly with event- but not time-based CAMPROMPT score. Use of note-taking strategies on the CAMPROMPT was the only variable from the metacognitive subset that correlated significantly with the two CAMPROMPT variables. Average number of diary entries per week was found to correlate significantly with time- but not event-based CAMPROMPT score.

Table 2. Correlations between predictor variables and CAMPROMPT scores

	CAMPROMPT scores	
	Time	Event
Demographic/injury severity Variables		
Age of participant (years)	.00	−.29
Years of education (years)	.09	.23
Inpatient length of stay (days)	−.14	−.15
PTA (days)	−.41*	−.50**
Localized frontal damage	−.20	−.30*
Localized frontal damage	−.06	−.04
Executive function variables		
Trail Making B–A	−.41**	−.46**
COWAT (FAS)	.27	.33*
COWAT (Animals)	.47**	.46**
Metacognitive variables		
CAPM self-awareness score	−.27	−.12
Average diary entries per week	.31*	.17
CAMPROMPT note-taking	.41**	.33**

** $p < .01$. * $p < .05$.

Predictors of Time- and Event-Based CAMPROMPT scores

Stepwise multiple regression analyses were carried out for the two CAMPROMPT scores with length of PTA, localized frontal damage, Trail Making B–A, COWAT (Animals), and CAMPROMPT note-taking as predictors (See Table 3). In the first multiple regression ($R^2 = .42$, $p = .001$), COWAT (Animals) score ($\beta = .29$, $p = .062$), length of PTA ($\beta = -.34$, $p = .022$), and CAMPROMPT note-taking ($\beta = .33$, $p = .032$) contributed significantly to the prediction of CAMPROMPT time-based score. In the second multiple regression ($R^2 = .38$, $p = .001$) with CAMPROMPT event-based score as the dependent variable, length of PTA ($\beta = -.42$, $p = .07$) and COWAT (Animals) score ($\beta = .37$, $p = .017$) entered successfully into the model.

DISCUSSION

The purpose of the study was to determine whether demographic, injury-related, executive function, and metacognitive factors predict prospective memory following TBI. Time-based prospective memory was predicted by injury severity as measured by length of PTA, executive function skills as represented by scores on the COWAT Animals subtest, and metacognitive skills as measured by note-taking on the CAMPROMPT. Event-based prospective memory was predicted by length of PTA and executive function skills as measured by the COWAT Animals subtest.

Both types of prospective memory were associated with length of PTA, with participants with longer periods of PTA having poorer prospective memory. Previous studies have established the utility of PTA as a measure of injury severity and to predict a range of functional outcomes (Asikainen et al., 1998; Ellenberg et al., 1996; Wenden et al., 1998), and the results of the present study concur with this evidence. Increased length of PTA has been associated with reduced speed of information processing and retrospective memory impairment following emergence from PTA (Geffen et al., 1991; Haslam et al., 1994), but previous studies have not looked specifically at the relationship with prospective memory.

One measure of executive function, the COWAT Animals subtest, was shown to predict both time- and event-based prospective memory. The unique significant contribution of COWAT Animals suggests that aspects of semantic verbal fluency are involved in prospective memory. Performance on the COWAT requires the ability to spontaneously come up with responses according to certain requirements or rules. Similarly, a prospective memory task demands spontaneous retrieval of an intention according to requirements (e.g., every 5 min or in response to a cue). The current findings did not support previous research that executive functions are more predictive of time-based than event-based prospective memory and this may reflect limited power of the current study.

These findings concur with previous research on executive functions and prospective memory following TBI. Groot et al. (2002) used correlations to examine relationships between scores on neuropsychological tests and scores on an earlier version of the CAMPROMPT, and found significant relationships between the two. However, no regression analyses were carried out in this study. Both the Kinch and McDonald (2001) and Martin et al. (2003) methods involved entering executive function measures into multiple regressions. In these two studies, executive function was found to predict significant unique variance of time-based and event-based prospective memory for a TBI sample (Kinch & McDonald, 2001) and a noninjured adult sample (Martin et al., 2003). In addition to executive function variables, Kinch and McDonald (2001) entered covariates such as retrospective memory, anxiety, depression, and level of education, while Martin et al. (2003) also investigated age effects. Like the Kinch and McDonald study, a strength of the current study is combination of range of other predictors alongside executive function to evaluate their unique contribution in predicting prospective memory performance.

This study extended current understanding of prospective memory problems following TBI by examining the contribution of metacognitive factors. Strategy use on the CAMPROMPT significantly predicted time-based prospective memory replicating the findings of Groot et al. (2002) that note-taking significantly improved CAMPROMPT performance. Note, however that participants were not trained in specific compensatory strategies for prospective memory problems before testing, although some may have been given general memory strategies at an earlier stage of rehabilitation. Measuring spontaneous strategy use without training may have limited utility, as participants might be aware of their difficulties, but might not understand the benefits of keeping a diary or taking notes. Diary use did not predict prospective memory performance in this study; possibly because diary use is more effective for long term, everyday prospective memory activities in naturalistic settings, such as keeping appointments (Schmitter-Edgecombe et al., 1995), and not necessarily directly helpful with performance on a neuropsychological test such as the CAMPROMPT. Clearly, the nonrandomized cross-sectional nature of the study limits the conclusions that can be drawn about the effect of diary use on prospective memory performance. Possibly those participants who engaged in diary use in the baseline period did so because they were prompted by family members, and not because they showed better self-initiated strategy use. Further intervention studies are needed to understand the effectiveness of diary use as a strategy to improve prospective memory. CAPM self-awareness scores also did not correlate with prospective memory performance. To date, no other studies appear to have examined relationships between prospective memory performance and measures of self-awareness. This may reflect the difficulty of reliably and objectively measuring self-awareness, because of its intrinsic nature and limitations associated with the use of significant others' reports to generate difference scores (Fleming et al., 1996).

Table 3. Summary of multiple regression analyses for time- and event-based CAMPROMPT scores

Time-based score (DV)	R^2	p	Variable/s entered	sr^2	p
Time-based	.42	.001	COWAT Animals	.07	.062
			Length in PTA	.11	.022
			CAMPROMPT note-taking note-taking	.10	.032
Event-based	.38	.001	Length of PTA	.17	.007
			COWAT Animals	.13	.017

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Exploration was made into the effects of frontal and temporal lobe damage on prospective memory performance. The presence of localized frontal damage was significantly correlated with event-based prospective memory performance, although it was not as important as other variables as a predictor in the regression, possibly because of the small sample size. A further limitation was the reliance on CT scan reports rather than original scans, which would be more reliable and valid. Nevertheless, this significant correlation is consistent with the association between executive functions and prospective memory and with imaging studies showing the role of the frontal lobes in prospective memory performance (Burgess et al., 2001; Okudaa et al., 1998; Simons et al., 2006). On time-based prospective memory, participants with frontal injuries performed at a lower level, but this difference was not statistically significant. Unlike previous studies (e.g., Shum et al., 1999), the CAMPROMPT allows test takers to take notes. In the current study quite a number of participants chose to take notes (20 out of 24). For individuals with frontal lesions, 9 out of 22 took notes and for individuals without frontal lesions 11 out of 22 took notes. In addition, the effect of note-taking on time-based scores was larger than that on event-based scores (medium *vs*. large). Taken together, this might explain the impaired performance of the frontal group on the event-based, but not the time-based, score.

Localized temporal damage was not significantly correlated with prospective memory performance. While this may suggest that the retrospective recall component of prospective memory mediated by the temporal lobes is less important to successful completion of prospective memory tasks, the fact that participants with severe persistent post-traumatic amnesia were excluded from the study probably contributes to the lack of effect in the temporal/nontemporal damage comparison.

Clinically, the findings suggest that patients with longer periods of PTA and executive function impairments can be expected to display poorer prospective memory, and therefore may need to be targeted for specific prospective memory rehabilitation. The study also adds support to Groot et al.'s (2002) finding that note-taking improves performance on prospective memory tasks. Unlike injury severity factors, which are fixed, the use of strategies such as note-taking is one area that is amenable to rehabilitation and therefore, training for strategy use should be considered when developing rehabilitation programs.

The generalizability of the findings is limited by the small number of participants (n = 44). Data were missing for some variables due to reliance on retrospective records and difficulty contacting participants' significant others, resulting in a reduced participant to variable ratio. Measures were taken to reduce the effect of the small sample size, such as entering only variables with significant correlations with the outcome variables into the regression model.

Only two measures of executive function were examined in this study and more research is needed to examine the relationship between prospective memory performance and other executive functions such as working memory and inhibition of prepotent responses. Fish et al. (2007) looked at the relationships between an everyday time-based prospective memory task and various neuropsychological test scores, and found a significant association. To further clarify the relationships between prospective memory and the variables identified as significant predictors, it would be interesting to select tasks or tests that provide component scores (e.g., retrospective component, detection of cues, retrieval of intentions) rather than overall prospective memory scores. For an example of a study that allows for differentiation between prospective memory scores, see the study by Kliegel et al. (2004) using the complex prospective memory test.

The current study found that spontaneous use of note-taking significantly predicted prospective memory performance, although participants did not receive any specific prospective memory training in note-taking strategies prior to assessment. Thus, research that investigates the impact of compensatory strategy training on prospective memory performance in patients with TBI may be fruitful. Fish et al. (2007) examined the effect of compensatory training on everyday prospective memory performance and found a significant improvement using a content-free cueing strategy. To date, however, very little research has investigated the effect of prospective memory rehabilitation programs for people with TBI and this remains an area of need for future research (Fleming et al., 2005).

CONCLUSION

This study aimed to identify demographic, injury severity and site, executive function, and metacognitive factors that predict prospective memory performance after TBI. The findings suggest that prospective memory is affected by injury severity, executive functions, and note-taking, as well as by the involvement of the frontal lobes. This study contributes to the small but growing body of information about the prospective memory performance of people with TBI; in particular, the combination of measures from three different domains allowed evaluation of the unique contribution of these variables to prospective memory performance following TBI. However, further research with larger samples of participants is required to support these results, and to investigate the effect of rehabilitation programs which aim to improve prospective memory performance following TBI.

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