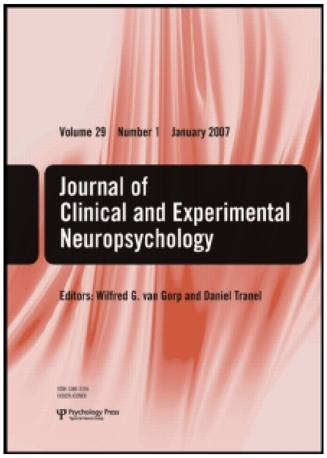

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Traumatic brain injury and prospective memory: Influence of task complexity

Julie D. Henry,[1] Louise H. Phillips,[2] John R. Crawford,[2] Matthias Kliegel,[3] Georgia Theodorou,[2] and Fiona Summers[4]

[1]University of New South Wales, Sydney, Australia
[2]University of Aberdeen, Aberdeen, Scotland, UK
[3]University of Zurich, Zurich, Switzerland
[4]Department of Neurosurgery, University of Aberdeen, Aberdeen, Scotland, UK

A quantitative review indicated that prospective memory impairment is a consistent feature of traumatic brain injury (TBI). However, evidence also suggests that manipulations that increase demands on controlled attentional processes moderate the magnitude of observed deficits. A total of 16 TBI participants were compared with 15 matched controls on a task in which the number of prospective target events was manipulated. This manipulation was of interest because two competing models make different predictions as to its effect on controlled attentional processes. In the context of Smith and Bayen's (2004) preparatory attentional processes and memory processes (PAM) model increasing the number of target events should increase requirements for controlled attentional processing. In contrast, McDaniel and Einstein's (2000) multiprocess framework assumes that distinct target events presented in focal awareness of the processing activities required for the ongoing task are likely to depend on automatic processes. This latter model therefore leads to the prediction that increasing the number of target events should not increase demands upon controlled attentional processes. Consistent with McDaniel and Einstein's (2000) multiprocess framework, TBI patients were significantly and comparably impaired on the one- and the four-target-event conditions relative to controls. Further, TBI deficits could not be attributed to increased difficulty with the retrospective component of the prospective memory task. The practical and theoretical implications of these results are discussed.

INTRODUCTION

Much cognitive research involving traumatic brain injury (TBI) has focused on retrospective memory, and almost invariably it has been reported that TBI is associated with deficits in this aspect of cognition (see DeLuca, Schultheis, Madigan, Christodoulou, & Averill, 2000; Levin, 1991). However, increasingly interest has shifted to investigating *prospective memory*—that is, memory for future intentions. Relative to retrospective memory, prospective memory is believed to be more dependent on self-initiated processes (Craik, 1986). This is because, according to Craik's (1986) theoretical model, recollection is dependent on reconstructing events in memory. It is suggested that this process must be guided either by external cues, or in their absence, by self-initiated cues. In retrospective memory tasks explicit prompts to recall are provided, while in prospective memory tasks the cue is not an explicit request for action, but instead requires either interpretation of an external event or an internal impetus.

It has long been recognized that deficits in retrospective memory may be at least partially responsible for poor prospective memory task

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Address correspondence to Julie D. Henry, School of Psychology, University of New South Wales, Sydney, 2052, Australia (E-mail: julie.henry@unsw.edu.au).

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performance following head injury as a consequence of poor intention retention (see Carlesimo, Casadio, & Caltagirone, 2004; Kliegel, Eschen, & Thone-Otto, 2004). Indeed, Kinch and McDonald (2001) reported that retrospective memory accounted for a significant amount of unique variance in the prospective memory task performance of TBI participants, independently of both anxiety and executive functioning. However, prospective memory impairment in TBI cannot be attributed solely to problems with retrospective memory. Kliegel et al. (2004), for instance, found that TBI participants exhibited prospective memory deficits even in the absence of any retrospective memory impairment and particularly highlighted the role of executive dysfunction as a potential mechanism underpinning poor performance on the prospective component of the task. Indeed, whilst TBI regularly affects the medial and anterior temporal lobes, which are involved in retrospective memory, focal contusions are most frequently found in frontal regions (Levin & Kraus, 1994), which are most clearly associated with deficits in executive control processes (see Crawford & Henry, 2005; Henry & Crawford, 2004a).

A distinction in the literature has been made between time- and event-based prospective remembering. Whereas the former requires the participant to perform a specified behavior after the passage of a given amount of time, for the latter the required behavior is prompted by an external cue. McDaniel, Guynn, Einstein, and Breneiser (2004) suggest that both more automatic reflexive-associative and more controlled processes may be implicated in event-based prospective memory task performance and that the relative prominence of these processes is determined by specific features of the task (see also McDaniel & Einstein, 2000). Since there is considerable evidence that TBI is particularly associated with deficits in controlled resource demanding processing (see, e.g., Henry & Crawford, 2004b; Stuss & Gow, 1992), this framework therefore leads to the prediction that the magnitude of TBI-related deficits on event-based prospective memory tasks will be determined by the extent to which the task depends on more controlled as opposed to relatively more automatic processes.

To summarize the prospective memory research literature to date, Table 1 presents effect sizes for the 11 studies that have previously compared TBI and control participants' performance on a measure of this construct, and from which it was possible to derive precise estimates of effect size. Using a random effects meta-analytic model, and weighting each study for sample size, collapsed across prospective memory type the mean effect size expressed as r was .42 ($SD = .08$), which is a moderate to large deficit according to Cohen's (1977) criteria. Three studies in Table 1 manipulated task complexity in a manner that is likely to increment the involvement of controlled processing in a prospective memory task. Thus, Maujean, Shum, and McQueen's (2003) and Carlesimo et al.'s (2004) studies suggest that (a) an increased delay interval, (b) functional unrelatedness, and (c) increasing the level of cognitive demand in the ongoing task may disproportionately affect TBI participants' performance relative to controls. Whilst it can be seen that Schmitter-Edgecombe and Wright (2004) did not find TBI participants to be differentially affected when peripheral (as opposed to focal) cues were presented, it was suggested that this may have been attributable to the peripheral cue being more salient than anticipated and thus unintentionally invoking relatively more automatic as opposed to more controlled processes.

However, as Schmitter-Edgecombe and Wright (2004) note, further research is needed to delineate the factors that may lead to prospective memory failures in head-injured participants. In the present study a prospective memory task is manipulated using a methodology that has been shown to moderate the magnitude of age effects, but which has not previously been investigated in the context of TBI. Using the paradigm developed by Einstein, Holland, McDaniel, and Guynn (1992), the number of target events to be remembered are manipulated. With respect to this manipulation, first it can be noted that if retrospective memory impairment contributes to the observed TBI effects on prospective memory (PM), then any TBI effects on prospective memory should be related to performance on the retrospective memory component of the task (i.e., retention of the task intention, including recall of the specific target events).

However, differing predictions can be made about whether increasing the number of target events will increase the controlled attentional demands of the prospective memory task. In the context of Smith and Bayen's (2004) preparatory attentional processes and memory processes (PAM) model, increases in the number of prospective target events are likely to impose greater demands on controlled, resource-demanding preparatory attentional processes because it is suggested that rehearsal of the prospective memory target events may engage these processes. This would therefore predict that participants with TBI should be disproportionately impaired on the four- relative to the one-target-event condition. A contrasting model is put forward by McDaniel and Einstein (2000), who argue that prospective memory tasks can

TABLE 1
Studies that have previously assessed PM performance in relation to TBI

	TBI characteristics				*Effect size*	
Study	*N*	*Years since injury*	*Severity*	*Notes*	*EB*	*TB*
Carlesimo et al. (2004)	16	2.1	Severe	Related actions 10-min delay (LD)	.43	.72
	16[a]			Unrelated 10-min delay	.69	.73
	16[a]			Related 45-min delay	.62	.77
	16[a]			Unrelated 45-min delay (HD)	.72	.65
Cockburn (1996)	8	0.4	N/S	3 TB tasks, 2 EB tasks.	.42	.51
Hannon et al. (1995)	15	3.0	"Significant"	Mix of short-term TB and EB	.59	
	15[a]			Name/date correct		.41
	15[a]			Questionnaires returned		.07
Kinch & McDonald (2001)	13	0.2	Severe	Composite score	.20	.50
Kinsella et al. (1996)[b]	24		Severe	Questionnaires returned		.47
	24[a]			Forms returned		.38
Kliegel et al. (2004)	7	3.5	Severe	Intention formation	.52	
	7[a]			Intention retention	.38	
	7[a]			Intention reinstantiation	.80	
	7[a]			Execution: intention fidelity	.47	
	7[a]			Execution: switching	.42	
Knight et al. (2005)	25	9.5	Severe	Video-based PM task	.48	
Mathias & Mansfield (2005)	25		Moderate & severe	Belonging test (EB); Timer (TB)	.14	.37
	25[a]			Appointment (EB); Envelope (TB)	.30	.40
	25[a]			Delayed message (EB)	.00	
Maujean et al. (2003)	14	0.8	Severe	Low cognitive demand (LD)	.27	
	14[a]			High cognitive demand (HD)	.57	
Schmitter-Edgecombe & Wright (2004)	24	9.0	Severe	Focal-cue (LD)	.29	
	24[a]			Peripheral cue (HD)	.23	
Shum et al. (1999)	12	2.0	Severe	Embedded in knowledge test.	.35	.50

Note. To be included in this table, studies had to have (a) a participant group consisting entirely of adults who had sustained a TBI, as well as (b) a healthy control group free from neurological or psychiatric disease. Each study also had to include (c) an objective behavioral measure of prospective memory, (d) precise statistics convertible to effect size *r*, (e) have been published, (f) in English, (g) in a journal. Five studies present effect sizes for both time- and event-based prospective memory. Collapsed across these studies, time-based prospective memory is substantially more impaired as indexed by the weighted mean effect size (*r*s = .37 and .55, respectively). Since time-based prospective memory tasks are generally considered to involve more self-initiated processing than do event-based tasks (Craik, 1986), the above result supports the idea that TBI participants have particular difficulties with the implementation of internal intentions. TBI = traumatic brain injury. PM = prospective memory. EB = event based. TB = time based. HD = high demand. LD = low demand. N/S = not stated.
[a]Participants already entered in table. [b]For Kinsella et al.'s (1996) article, effect sizes for the first prospective memory task were derived by calculating the χ^2 statistic associated with the observed versus the expected frequencies for TBI and control participants who completed the prospective memory task completely correctly (in the first task, requesting the questionnaire and remembering the purpose), versus all other responses. For the second prospective memory task, the χ^2 value was calculated comparing participants who (a) returned the form with the date written, versus (b) all other responses.

be carried out using either automatic monitoring, where cues "pop into mind," or instead by strategic, effortful monitoring, where cues are actively searched for during the ongoing task. Since McDaniel and Einstein (2000) assume that distinct target events presented in focal awareness of the processing activities required for the ongoing task are likely to depend on automatic processes, this leads to the prediction that increasing the number of target events should not disproportionately impair TBI participants' performance.

In the present study we therefore manipulated the number of target events to be acted upon in a prospective memory task in a TBI population. Importantly, these target events were all presented in focal awareness in relation to the ongoing task processing requirements. As discussed, if retrospective memory impairment contributes to the observed TBI effects on PM then any TBI effects on prospective memory should be related to whether participants are able to recall the task instructions. With respect to the prospective component of the task, if increasing the number of target events increases requirements for controlled attentional processing (Smith & Bayen, 2004) then TBI participants should be disproportionately impaired when there is a greater number of targets.

In contrast, if increasing the number of focal target events still loads relatively automatic aspects of prospective processing (McDaniel & Einstein, 2000) then there should be no disproportionate impairment in TBI participants.

METHOD

Participants

A total of 16 adults (14 males, 2 females) who had sustained a TBI were recruited from the outpatient records of the Department of Neurosurgery, Aberdeen Royal Infirmary. None reported a history of psychiatric disease or a premorbid history of alcohol or drug addiction. Subjects with comorbid neurological conditions (e.g., premorbid seizure disorders, stroke, etc.) were also excluded. For most patients Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) scores were available, and these are reported in Table 2. When evaluating injury severity, GCS scores ranging from 3 to 8 are considered severe, 9 to 12 as moderate, and 13 to 15 as mild (see Lezak, Howieson, & Loring, 2004). Other clinical features taken from the patients' medical records as well as demographic characteristics and results from an earlier cognitive assessment are also shown in Table 2.

The majority of control participants were friends, relatives, or caregivers of the TBI participants. The remainder were recruited from the Public Participation Panel at the University of Aberdeen. Whilst TBI and control participants did not differ significantly with regard to age, gender, or education, there were slightly more females in the control group (10 males, 5 females). TBI participants and controls were closely matched for age ($M=44.4$, $SD=13.4$ versus $M=48.4$, $SD=14.79$, respectively) and education ($M=12.2$, $SD=3.00$ versus $M=12.4$, $SD=3.12$, respectively). All participants received remuneration to cover travel expenses. Ethical approval was provided by the Grampian Research Ethics Committee, and all participants gave informed consent prior to their inclusion in the study.

All TBI and control participants included in this study had previously taken part in one other testing session approximately two months earlier for a separate study (Henry, Phillips, Crawford, Theodorou, & Summers, 2006), from which performance on measures of executive functioning and premorbid IQ were available. Relative to the control sample, TBI participants exhibited deficits of a moderate to large magnitude on a standard measure of verbal fluency, collapsed across three phonemic and three semantic fluency probes; $t(27)=2.43$, $p=.022$, $r=.42$, and were similarly impaired on an alternating fluency variant that imposes greater demands upon mental set switching; participants were required to alternate

TABLE 2
Clinical and demographic characteristics of the TBI participants

Participant number	*Age*[a]	*Education*[a]	*Gender*	*Cause of injury*	*Injury site (CT or MRI scan)*	*GCS score*	*Time post injury*[a]	*NART*	*Standard fluency*	*Alternating fluency*
1	20	13	F	Assault	—	14	1.5	36	73	14
2	49	11	M	Assault	—	14	5	33	78	13
3	56	20	M	Fall	—	—	2	47	99	18
4	29	11	M	MVA	—	—	2	37	99	18
5	46	10	M	Fall	Left temporal	13	4	35	38	9
6	51	15	M	MVA	Subarachnoid	6	2.5	37	69	13
7	28	11	M	MVA	—	7	8	24	18	2
8	61	10	M	Explosion	—	14	5	28	77	17
9	27	11	M	MVA	Right frontal & parietal	8	2.5	9	64	15
10	55	16	M	MVA	Left cerebrum	7	11	43	82	14
11	56	10	F	Fall	Left temporal	14	2	39	81	15
12	32	15	M	Fall	Bilateral–frontal	15	2.5	—	—	—
13	53	13	M	Uncertain[b]	—	—	3	43	128	18
14	36	10	M	MVA	—	—	1	40	72	17
15	54	10	M	Falling object	Right frontal	14	1	21	59	16
16	57	10	M	Fall	Bilateral frontal	14	2	26	50	12

Note. For all the cognitive measures, data presented refer to total number of items correct on each of the measures of interest, and thus higher scores denote better performance. GCS refers to Glasgow Coma Scale (Teasdale & Jennett, 1974); MVA refers to motor vehicle accident; — indicates that this information was not available; NART refers to National Adult Reading Test. TBI = traumatic brain injury.

[a]In years. [b]Participant does not recollect cause of injury, and there were no witnesses to the injury.

between generating words on the basis of phonemic and semantic criteria; $t(27) = 2.37$, $p = .025$, $r = .42$. Thus, the present sample of TBI participants is characterized by a moderate level of executive impairment. The two groups were comparable in terms of level of premorbid IQ as indexed by the National Adult Reading Test; $t(29) = 0.98$, $p = .337$, $r = .18$ (Nelson, 1982). In the present study "filler" tasks embedded between the different prospective memory tasks included the Auditory Verbal Learning Test (AVLT). TBI participants did not differ significantly on total recall across the first five trials of the AVLT, $t(29) = 1.17$, $p = .251$; $r = .22$.

Materials and procedure

The methodology used by Einstein et al. (1992) was closely adhered to, with the exception that a within-subject design was used, with the 42 trials split into two blocks of 21 trials (i.e., the four-target-event-based prospective memory condition was embedded in one block of 21 trials, the one-target condition embedded in the other block).

A computer program written in Superlab was created, with the materials and procedure for the prospective memory task based on those used previously by Einstein et al. (1992) and Cherry et al. (2001). Thus, the stimuli used in the ongoing short-term memory (STM) task were 60 words selected from the Snodgrass and Vanderwart (1980) corpus, disallowing words from the same taxonomic categories as the target words.

Participants were tested individually on a personal computer. They were told that the study was interested in any potential effects of TBI on STM, and that they would be shown a short set of words to recall when prompted. Participants were told that there was evidence that STM can be improved by organizing words into chunks, and that they were to try and use this strategy of chunking to help them recall words. Participants were then told that a secondary goal of the study was to examine the ability to remember to do things in the future. As noted, the present study used a within-subjects design. However, to control for potential order effects, the order in which participants encountered each of the two conditions was counterbalanced. Participants were told to press a response key on the keyboard, whenever they encountered a particular target word. Participants were given only one target word to recall in the one-target condition (rake) and four target words to recall in the four-target condition (fork, truck, nose, soap). All participants were asked to repeat these instructions back to the experimenter to ensure that they fully understood the task requirements and could recall the target word(s) before being asked to complete three practice trials. Participants were not told how many target events would occur, but across both conditions, three target events occurred. In the four-target condition, three of the four target words were randomly selected to appear as the target events. Within each of the trial blocks, the word set containing the target word was randomly assigned to one of two middle positions.

Participants were then given three practice STM trials. On each trial, a preparatory message was shown briefly, the word set was presented (all items were presented simultaneously, but one second was allowed for each individual item), and a "recall now" prompt appeared, which remained on the screen for 1.5 s per item. Participants orally recorded as many items from the set as they could, and their responses were tape-recorded. Word-set size was randomly determined on each trial. However, deficits in short-term memory are a pervasive feature of TBI (see, e.g., Lezak et al., 2004). Indeed, although in the present study the difference between patients and controls on the AVLT did not attain statistical significance, TBI patients did nevertheless perform more poorly on this measure ($r = .22$; according to Cohen's (1977) criteria this qualifies as a deficit of a small magnitude). Therefore, in an attempt to equate STM performance across the TBI and control groups, word set size ranged from four to nine words per trial for the controls, and three to eight words per trial for the TBI participants. This methodology has previously been used to equate STM performance across younger and older groups (Cherry et al., 2001; Einstein et al., 1992). Proceeding from one trial to another was not dependent on the speed of participants' responding, but instead occurred according to a set of interval, inclusive of two 10-s intervals that were given to provide participants with breaks one third and two thirds of the way through the test trials. This means that the total time to complete each block of 21 test trials was 6.1 min for the controls and 5.2 min for the TBI participants.

After completing the three practice trials, participants were told that later on they would be asked to complete a STM task that would be just like the practice task, but in the meantime they were to complete a different task. Participants were not told that they would not be reminded about the prospective memory task. These filler tasks (naming and facial perception tasks) took approximately 15 min to complete. Participants were then asked to return to the STM task. A delay between PM instructions and execution was used in order to make the task more demanding and to avoid floor effects in the control group—there is evidence that even short delays considerably increase the difficulty of PM tasks (e.g., Einstein, McDaniel, Manzi, Cochran, & Baker, 2000). The filler tasks that were selected were relatively nonchallenging and were used to control the time it took to return to the STM task and to equate participants' experiences during this delay interval. It was reiterated that participants were to try and use a "chunking" strategy when recalling the words, but the prospective memory task instructions were not repeated.

Following completion of the STM task, participants were asked whether, in addition to recalling the STM word sets, they remembered what else they were supposed to do to ascertain whether any prospective failures were attributable to deficits in recollecting the prospective memory test instructions. So that participants would not prioritize the prospective memory over the STM task in the subsequent STM trial, participants were also asked whether or not they believed that the chunking strategy had improved their STM performance.

Participants were then given a break of approximately 20 min, before being given instructions for the second STM task. The methodology adopted here was identical to that described previously, except that participants who were told that there was one target event (i.e., rake) in the first block were now told there were four (i.e., fork, truck, nose, soap), and vice versa, and two different filler tasks were used (a measure of retrospective memory and another measure of face perception). Again, these filler tasks took approximately 15 min to complete.

RESULTS

Prospective memory

Table 3 summarizes *M*s and *SD*s for task performance in the two groups. Prospective memory performance was quantified in terms of the number of correct responses. A response was considered to be correct if it was made prior to the end of the specific trial in the block of trials in which the target item appeared. It can be seen that for both the one- and the four-target conditions of the event-based prospective memory task, TBI participants performed more poorly than controls. Finding less variability in the patient sample relative to the control sample is atypical, and in the present sample it can be seen that this was true of the response latencies across both the one- and the four-target-event conditions. It is likely that this is attributable to the fact that the analyses focused on response latency involved leaving nonresponders out of the calculations. Thus, the TBI participants who performed most poorly were effectively omitted from the analyses related to response latency, and the data reported in Table 3 pertaining to response latency refer to 15 controls and 10 patients for the one-target-event condition, and 14 controls and 9 TBI participants for the four-target-event conditions. TBI and control participants did not differ significantly in terms of response latency in the one-target-event condition, $t(23) = -1.17$, $p = .253$; $r = .24$, or in the four-target-event condition, $t(21) = 0.36$, $p = .720$, $r = .08$.

In terms of the mean number of correct responses, TBI participants performed more poorly than controls in both the one-target-event and the four-target-event conditions. Since a high proportion (73%) of the controls performed at ceiling on the one-target-event condition, nonparametric χ^2 tests of independence were conducted to assess whether the two groups differed significantly in performance on the two-event-based prospective memory tasks. The data used to complete these analyses are reported in Table 4.

For both the one- and the four-target-event conditions, the number of participants who correctly responded to any of the target events was

TABLE 3
Means for the prospective and retrospective memory measures

		Control		*TBI*	
	Dependent measure	*M*	*SD*	*M*	*SD*
One-target condition	Prospective memory correct responses	2.7	0.62	1.7	1.44
	Short-term memory (% correct)	70.4	9.63	72.3	16.17
	Latency to respond to target event (s)	3.1	2.07	4.1	1.63
Four-target condition	Prospective memory correct responses	1.9	0.99	1.2	1.33
	Short term memory (% correct)	69.6	8.73	71.8	14.67
	Latency to respond to target event (s)	4.5	2.71	4.2	1.89
Retrospective component of PM task	One-target condition: Target word recalled (max. 1)	0.9	0.26	0.9	0.44
	Four-target condition: Target words recalled (max. 4)	1.6	1.30	1.6	1.71

Note. TBI = traumatic brain injury. PM = prospective memory.

TABLE 4
Data used for chi-square analyses comparing TBI participants with controls on the prospective and retrospective component of the PM task

		One target event		*Four target events*	
	Dependent measure	*Control*	*TBI*	*Control*	*TBI*
PM task	More than one correct on PM task	15	10	14	9
	All three correct	11	8	5	6
Retrospective component of PM task	More than one target event recalled	14	14	11	10
	All of the target events recalled	—	—	1	4

Note. It should be noted that for some of the comparisons of interest expected frequencies in particular cells were less than five: The conclusions derived from the inferential statistical test results remain unchanged if Fisher's Exact Test, which is robust to these violations, is used to conduct these analyses. Similarly, conclusions remain unaltered if Yates's correction for small samples is applied. TBI = traumatic brain injury. PM = prospective memory.

compared with the number of participants who responded to none of the target events. For the one-target-event condition, whilst all 15 control participants responded correctly to at least one target event, only 10 of the 16 TBI participants did. This difference was significant; $\chi^2(1, N=31)=6.96$, $p < .01$. The corresponding effect size (expressed as Cramer's ϕ, the nonparametric analogue to r) was .47. The two groups did not differ significantly in terms of the proportion who were fully accurate (i.e., correctly responded to all three target events); $\chi^2(1, N=31)=1.76$, $p > .05$, $\phi = .24$. In the four-target-event condition, controls were significantly more likely to correctly respond to one or more of the prospective memory target events; $\chi^2(1, N=31)=5.68$, $p < .05$, $\phi = .42$, but again there was no difference between the two groups in terms of the proportion who were fully accurate; $\chi^2(1, N=31)=0.06$, $p > .05$, $\phi = .04$. The effect sizes of TBI participants' deficits on the one- and four-target conditions are very similar (i.e., .47 for one-target and .42 for four-target conditions). Finally, it should be noted that none of the participants made any false positive responses (pressing the key to a nontarget word) in the one-target-event condition. Whilst control participants made significantly more false positive responses in the four-target-event condition relative to TBI participants, this was unrelated to participants' number of correct target events recalled (all rs < .21).

To investigate the degree to which the observed prospective memory deficits were moderated by retrospective memory impairment, the next set of analyses focused on whether TBI participants differed from controls in their capacity to recall the prospective memory test instructions, following completion of the prospective memory task. Chi-square analyses indicated that there was no significant effect of group in terms of number of participants who could recall the target event in the one-cue condition versus the number of participants who could not; $\chi^2(1, N=31)=0.30$, $p > .05$, $\phi = .10$.

Next, it was investigated whether there were any differences between TBI participants and controls in the capacity to recall (a) one or more target events for the four-target-event condition, and (b) all four target events for the four-target-event condition. There were no group differences for either of these comparisons; $\chi^2(1, N=31)=0.42$, $p > .05$, $\phi = .10$; $\chi^2(1, N=31)=1.93$, $p > .05$, $\phi = .25$. TBI and control participants also did not differ significantly in terms of the mean number of target events retrospectively recalled in the four-target-event condition (Kolmogorov–Smirnov $Z=0.51$, $p=.957$.

The two groups did not differ significantly in terms of STM performance (i.e., the ongoing task in the prospective memory paradigm) in either the one- or the four-target-event condition: one-target condition, $t(29)=-0.38$, $p=.706$, $r=.07$; four-target condition, $t(29)=-0.51$, $p=.617$, $r=.09$; independent t tests were used for these comparisons since the distribution of test scores on the STM test was normal. For means and standard deviations of STM performance see Table 3.

Finally, in the one-cue condition the same cue appears three times while in the four-cue condition three of the cues appear only once. It might be argued that the cue will become more discrepant in the one-cue condition across repeated presentations and that this will serve to improve performance across repeated presentations of the same target by increasing the automaticity of the responses. Since TBI participants are presumed to have particular difficulty with controlled resource-demanding processes this would predict that their performance may improve disproportionately relative to controls over repeated presentations of the same cue. Chi-square analyses were conducted comparing prospective memory between TBI participants and controls separately for each of the three presentations of the prospective memory cue in the one-cue condition (with whether participants remembered to respond or not used as the dependent measure). These results suggest that the discrepancy of the prospective memory cue was not a factor influencing performance (ϕ s = .47, .25, and .39 for the first, second, and third presentation of the prospective memory cue in the one-target-event condition, respectively).

DISCUSSION

The results of the present study are consistent with other research demonstrating that impaired prospective memory is a pervasive feature of TBI, documenting a deficit of a moderate to large magnitude even on a measure where the level of demand implicit in the task can be considered low. Moreover, since the two groups were very closely equated for performance on the STM task in which the prospective memory tasks were embedded, the group differences on the measures of prospective memory cannot be attributed to TBI participants experiencing increased difficulty with the ongoing task.

The manipulation of interest in the present study was the comparison involving one versus four target events. Both TBI and control participants correctly responded to fewer target events in the four-target than in the one-target-event condition. However, there was no evidence that relative to healthy controls TBI participants were differentially impaired in their capacity to respond to four target events. These results therefore contrast with research involving older adults (Einstein et al., 1992).

The current manipulation also increased monitoring load from one to four target events, thus potentially increasing controlled, effortful demands on the prospective memory component of the task (Smith & Bayen, 2004). The lack of interaction between participant group and number of targets could lead to one of two interpretations. First, TBI effects on prospective memory are not attributable to strategic monitoring ability. This would be a surprising finding, as it would run contrary to a large body of research indicating substantial deficits of controlled strategic processing following TBI (see, e.g., Henry & Crawford, 2004b; Kliegel et al., 2004). Indeed, as noted previously, the TBI participants included in the present study presented with marked deficits on measures that have proven to be very sensitive to executive dysfunction (fluency).

A second interpretation is that increasing the number of targets did not cause greater strategic processing and monitoring. As noted previously, McDaniel and Einstein (2000; see also McDaniel et al., 2004) propose that increasing the number of targets might not cause greater controlled attentional load in a prospective memory task, if the target events are presented in focal awareness of the ongoing task-processing requirements. In the current setting, the relatively poor performance of both groups on the prospective memory component of the four-target task, along with relatively good performance on the ongoing STM task in this condition, suggests that most participants may have taken a relatively automatic, noneffortful approach to the increased prospective memory demands. This is in line with predictions from the multiprocess model as the prospective memory targets were distinct words presented in the focus of ongoing task processing demands. The lack of difference in TBI effects in one- and four-word conditions is therefore consistent with the possibility that this manipulation did not increase controlled processing behavior in the task.

These results can be contrasted with findings involving older adults (Einstein et al., 1992). In comparison with their younger counterparts, older adults were found to be disproportionately impaired on the four- relative to the one-target-event condition. However, in contrast to the TBI participants in the present study, older relative to younger adults in Einstein et al.'s (1992) study also exhibited substantial deficits in retrospective memory for the target events. In the present study, TBI and control participants were equivalent in their recall of test instructions for both conditions. Indeed, when participants' capacity to recall the test instructions was assessed following completion of each condition, the mean number of target events recalled following completion of the task was identical for TBI and control participants in each of the two conditions. Therefore, it is suggested that it was the increased demands on retrospective (but not prospective) memory in the four-target-event condition that primarily underlay the age effects observed in Einstein et al.'s (1992) study.

The deficit observed in the TBI group even when retrospective memory demands were very low (i.e., the one-target-event condition) also suggests that retrospective memory impairment is not the major factor underpinning the observed prospective memory deficit. As noted, whilst 90% of TBI participants and controls were able to retrospectively recall the prospective memory instructions for the one-target-event condition, there was a significant difference between the two groups in actual implementation of the prospective memory instructions.

These results highlight the need to more precisely delineate which manipulations of prospective memory differentially affect TBI relative to control participants. It would be particularly useful to apply other prospective memory manipulations, which are believed to increase effortful strategic monitoring load to a TBI population. Identifying which factors moderate prospective memory impairment in TBI is critical if more effective rehabilitative techniques are to be developed, for as Shum, Fleming, and Neulinger (2002) note (p. 13): "In terms of rehabilitative technique for memory impairment, although much has been written about interventions for retrospective memory, there is relatively little evidence to guide practice for prospective memory."

The current results suggest that increasing the number of target events in a prospective memory task does not necessarily increase the strategic attentional demands of the task. The lack of interaction between TBI status and number of prospective memory targets in the current study is most likely due to the relatively automatic monitoring strategy adopted by all participants in the four-target condition. The results also indicate that in this particular study failures of retrospective memory are not the major cause of TBI-related impairment in prospective memory. This is important because, unlike retrospective memory, prospective memory is not routinely assessed in individuals with TBI. The magnitude of the deficits seen on even simple prospective memory tasks and the consistency of the prospective memory deficits in this group (see Table 1) indicate the importance of assessing this capacity.

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