Journal of the International Neuropsychological Society (2015), **21**, 305–313.

doi:10.1017/S1355617715000211

Prospective Memory Performance in Traumatic Brain Injury Patients: A Study of Implementation Intentions

Giovanna Mioni,[1] Peter G. Rendell,[2] Gill Terrett,[2] AND Franca Stablum[1]

[1]Department of General Psychology, University of Padova, Padova, Italy
[2]School of Psychology, Australian Catholic University, Melbourne, Australia

(RECEIVED October 13, 2014; FINAL REVISION March 3, 2015; ACCEPTED March 4, 2015)

Abstract

Traumatic brain injury (TBI) patients often present with prospective memory (PM) dysfunction. Forgetting to complete tasks may result in a loss of independence, limited employment prospects and anxiety, therefore, it is important to develop programs to improve PM performance in TBI patients. A strategy which may improve PM performance is implementation intentions. It involves making explicit plans specifying when, where and how one will perform a task in the future. In the present study, a group of 36 TBI patients and a group of 34 controls performed Virtual Week using either implementation intentions or no strategy. The results showed that the PM performance of TBI patients was less accurate than controls, in particular when the PM cue was time-based. No effect of implementation intentions was observed for TBI patients, however, controls improved their PM performance when the task was time-based. The findings suggest that strategies to improve PM in this clinical group are likely to be more complex than those that benefit healthy adults and may involve targeting phases of the PM process other than, or in addition to, the intention formation phase. (*JINS*, 2015, *21*, 305–313)

Keywords: Traumatic brain injury, Implementation intentions, Prospective memory, Event-based, Time-based, Virtual Week

INTRODUCTION

Prospective memory (PM) refers to the cognitive ability to form and remember to perform an intended action at a specific moment in the future (Kliegel, McDaniel, & Einstein, 2008; McDaniel & Einstein, 2000). PM has been proposed to be a complex process involving at least four phases (Ellis, 1996; Kliegel, Martin, McDaniel, & Einstein, 2002). In the first phase (intention formation), one has to form the intention, that is, plan which actions shall be performed at what time in the future, and then encode the plan. In the second phase (intention retention), one has to keep the intention in mind while working on other tasks. The third phase (intention re-instantiation) begins when the intended moment for the re-instantiation of the intended action arises. Here, one has to inhibit on-going activities, and re-instantiate the intended plan. In the last phase (intention execution), the intended action has to be carried out as previously planned on one's own initiative. There are two commonly classified types of PM task: event-based and time-based (Einstein & McDaniel, 1990). In event-based PM tasks, a person performs the action when a specific event occurs (e.g., passing on a message when a friend calls); while in time-based PM, the action has to be performed at a specific time in the future (e.g., remembering to meet a friend at 4:00 p.m.) (Einstein & McDaniel, 1990). In event-based PM, the required behavior is prompted by an external cue while in time-based PM a specified behavior is performed at a set time or after the passage of a given amount of time. As such, time-based PM has been argued to impose greater demands on self-initiated control processes due to the absence of any external cue (McDaniel & Einstein, 2000).

Many studies have shown that people with traumatic brain injury (TBI) display poorer PM function than non-clinical controls (Mioni, McClintock, & Stablum, 2014; Shum, Levin, & Chan, 2011). A recent meta-analysis conducted by Shum et al. (2011) showed that people with TBI were less accurate than controls on both event- and time-based PM tasks indicating broad-based PM impairment in this clinical group. These findings are typically attributed to frontally mediated executive dysfunction that affects cognitive processes such as planning and execution of the intended action, target recognition, switching, and interruption of on-going activity (McFarland & Glisky, 2009). Other studies have also systematically explored the effects of various task parameters

Correspondence and reprint requests to: Giovanna Mioni, Department of General Psychology, University of Padova, Via Venezia, 12, 35131, Padova, Italy. E-mail: mioni.giovanna@gmail.com

on PM performance in this clinical group. For example, studies that have manipulated on-going task demands showed that people with TBI performed more poorly than controls in high-demand compared to low-demand conditions (Carlesimo, Formisano, Bivona, Barba, & Caltagirone, 2009; Maujean, Shum, & McQueen, 2003). In addition, a study by Kliegel, Eschen, and Thöne-Otto (2004) investigated which of the four phases of PM (Ellis, 1996; McDaniel & Einstein, 2000) were affected in people with TBI using a complex PM paradigm that required participants to plan and execute multiple PM tasks according to a set of rules while undertaking several ongoing tasks. Results showed that their sample of TBI patients, who had retrospective memory within normal limits but had deficits in executive functions, were impaired in the intention formation, re-instantiation, and execution phases of PM relative to controls. Intention retention was the only phase that was not found to be impaired.

The findings of Kliegel et al. (2004) are important because identifying which phases of PM are impaired in people with TBI has major implications for management and treatment of their PM impairment. PM dysfunction is one of the most common complaints among people with TBI; forgetting to complete a wide variety of PM tasks in everyday life may result in a loss of independence, limited employment prospects and anxiety. Therefore, it is essential that we develop rehabilitation programs to improve PM performance in this clinical group (Bellezza, 1981; Fish, Wilson, & Manly, 2010; Fleming, Shum, Strong, & Lighthouse, 2005; Fleming et al., 2008; Mioni et al., 2014; Potvin, Roulean, Sénéchal, & Giguère, 2011; Thöne-Otto & Walther, 2008; van den Broek, Downes, Jhonson, Dayus, & Hilton, 2000). A strategy which may be used to improve PM performance is *implementation intentions* (Gollwitzer, 1999; Gollwitzer & Brandstatter, 1997). Implementation intentions involves making explicit plans specifying when, where and how one will perform a task in the future (Webb & Sheeran, 2007). Specifically this strategy involves rehearsing a future intention in a specific format: for example, "When I walk past the grocery store, I will buy milk". These mentally rehearsed intentions are intended to commit a person to performing a task in the future by creating a stronger link between the intended PM action (buying the milk) and a future target situation (walking past the grocery store) which is meant to trigger the performance of that task (Gollwitzer, 1999; Gollwitzer & Brandstatter, 1997; McDaniel, Howard, & Butlet, 2008). Gollwitzer (1999) suggests that implementation intentions make the mental representation of the target situation highly activated and consequently easily accessible. This means that when people encounter the target situation, even if they are occupied with another task, the higher salience of that target situation will make it easier for the participant to recall the intended action and perform it, thereby reducing the need to keep the goal in mind (Chasteen, Park, & Schwarz, 2001). Thus, implementation intentions strengthens the encoding of the PM action and cue (Webb & Sheeran, 2007) which promotes automatic retrieval of the intended action (McDaniel et al., 2008) and allows more cognitive capacity to be focused on other tasks because control of behavior is relegated to the environment (Gollwitzer, 1999).

Previous studies have demonstrated that forming implementation intentions can significantly increase the likelihood that an intention will be executed and has been shown to facilitate PM performance in healthy older adults (McDaniel et al., 2008; Chasteen et al., 2001; McFarland & Glisky, 2011; Schmidt, Berg, & Deelman, 2001) and clinical populations such as patients with multiple sclerosis (Kardiasmenos, Clawson, Wilken & Wallin, 2008) and frontal lobe damage (Lengfelder & Gollwitzer, 2001). These findings, therefore, suggest that implementation intentions may be a helpful self-regulatory tool (Gollwitzer & Brandstatter, 1997). To date, however, the value of this approach in improving PM performance in people with TBI has not been tested.

The aim of the current study was, therefore, to investigate PM performance in TBI patients with a specific focus on whether implementation intentions improves performance in this clinical group. To assess PM, we used Virtual Week (Rendell & Craik, 2000). Virtual Week has previously been used with people with TBI (Mioni, Rendell, Henry, Cantagallo, & Stablum, 2013) and has been shown to be sensitive to PM impairment in this group. It has also been used in a study by Kardiasmenos et al. (2008) assessing the effectiveness of implementation intentions on PM performance in multiple sclerosis patients.

We had four predictions. First, we expected to find evidence of PM dysfunction in TBI patients compared to controls. Second, we predicted that TBI patients using the implementation intentions strategy would correctly perform a higher proportion of PM tasks compared to TBI patients not using the strategy. Third, we predicted that there would be an improvement in PM performance in controls that used the implementation intentions strategy compared to controls who did not. Finally, we anticipated that both event and time-based PM tasks would benefit from implementation intentions. We expected the improvement in event-based tasks because they have an inherent cue in the environment and implementation intentions arguably heightens the accessibility of those cues. Whereas it is generally thought that time-based tasks lack an inherent cue and require the monitoring of time, in everyday life many time-based tasks are in fact not devoid of social and environmental cues. For example, an action that is required to be performed at 7:00 p.m. is to some extent cued by the activities that occur at that time of day, for example, having dinner. We anticipated, therefore, that implementation intentions would benefit time-based tasks by strengthening the link between the PM action and the environmental and social cues associated with the time of day the PM task is to be performed. These cues in turn trigger awareness of the time of day, and lead to subsequent task execution. Given that Virtual Week simulates everyday life and, therefore, incorporates many of these associated time of day cues, we anticipated improvement in the time-based tasks in Virtual Week, albeit to a lesser extent than the event-based tasks.

METHOD

Participants

Thirty-six TBI patients and 34 controls took part in the study (Table 1). Eighteen TBI patients (13 males, 5 females) and 16 controls (7 males, 9 females) performed Virtual Week in the implementation intentions condition and 18 TBI patients (10 males, 8 females) and 18 controls (10 males, 8 females) performed Virtual Week with no strategy. Findings from the no strategy condition have been previously reported (Mioni et al, 2013).

All participants with TBI had suffered a severe head injury as indexed by their scores on the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974), and were tested at least 6 months post injury. The Level of Cognitive Functioning (LCF; Hagan, Malkmus, Durham, & Bowman, 1979) Scale was also completed by participants at the time of participation in this study. The LCF index is used to assess cognitive functioning in a post-coma clinical sample and to provide a classification of outcome levels (a score = 6 is the pre-requisite for TBI patients to be included in the present study and indicates that the patient gives appropriate responses in familiar contexts but may still have memory problems; Zafonte et al., 1996). Nineteen of the patients had LCF = 6, 15 of the patients had LCF = 7 and 2 of the patients had LCF = 8.

Exclusion criteria included a pre-existing neurological, psychiatric, or developmental disorder, a history of substance or alcohol abuse, or previous head injury, aphasia or severe memory deficit, and a past or current history of psychiatric illness. All clinical participants had computed tomography or magnetic resonance imaging scans that showed damage in frontal areas. Clinical records also showed the TBI patients did not display damage to other areas of the brain, including the temporal lobes. Participants included in the study were all right handed and did not have motor deficits that would have affected performance.

Participants included in the control group had never sustained a TBI and were matched to the clinical participants on age and education (±2 years with respect to the TBI sample).

Separate one-way analysis of variance (ANOVAs) were conducted on age and years of education with *group* (TBI patients, controls) and *encoding condition* (no strategy, implementation intentions) as between factors. No significant differences were found with respect to either age or years of education (all $ps \geq .331$).

Materials

Prospective memory measure: Virtual Week

To assess PM performance, we used Virtual Week (Rendell & Craik, 2000). Virtual Week is a computer based task that simulates daily life activities using a board game format. Participants move around the board with the roll of a dice; each circuit around the board represents one virtual day. The version used in the present study is an adaptation of the original version translated into Italian, and includes 3 virtual days with 8 PM tasks per day (see Mioni et al., 2013, for similar procedure). Four of the daily PM tasks are regular and four are irregular. The regular tasks simulate the taking of medication while the irregular PM tasks simulate the kinds of occasional tasks that occur as one undertakes normal daily activities and are different each virtual day. The regular tasks comprise two event-based tasks requiring taking antibiotics at breakfast and dinner, and two time-based tasks requiring taking asthma medication at 11:00 and 21:00. These regular tasks were presented at the beginning of each virtual day. Similarly, the irregular tasks comprise two event-based tasks (e.g., “buy a bus ticket when shopping”) and two time-based tasks (e.g., “phone the plumber at 17:00”). Two irregular tasks (one event- and one time-based) were presented at the beginning of each virtual day, just after the presentation of the regular tasks. The two remaining irregular tasks were presented during the virtual day. The delay between task presentation and task execution was different for each irregular task. This was done for two reasons: (1) be more consistent with real-life situations in which activities occur at different points during the day and (2) to avoid creating any regularity in the execution of irregular tasks.

Virtual Week was modified for the current study to enable manipulation of the encoding condition for all the PM tasks. As with the standard condition, participants were informed of each PM task in a computer screen window resembling a task card (Figure 1a and b). The regular task windows were

Table 1. Descriptive statistics for the demographic and clinical characteristics of the groups.

	No strategies		Implementation intentions	
Encoding condition:	TBI patients n = 18	Control group n = 18	TBI patients n = 18	Control group n = 16
Age	31.72 (10.05)	32.00 (10.10)	35.06 (6.30)	35.81 (6.53)
Education	12.22 (3.08)	11.87 (2.89)	11.33 (2.76)	12.56 (2.03)
Gender (males)	10	10	13	7
GCS	4.54 (1.37)	—	5.54 (1.36)	—
PTA (days)	7.15 (5.90)	—	8.00 (3.42)	—
Time since injury (weeks)	66.94 (95.22)	—	100.89 (70.76)	—
LCF	6.72 (.57)	—	6.33 (.97)	—

Note. TBI = Traumatic Brain Injury; GCS = Glasgow Coma Scale; PTA = Post Traumatic Amnesia; LCF = Level of Cognitive Functioning.

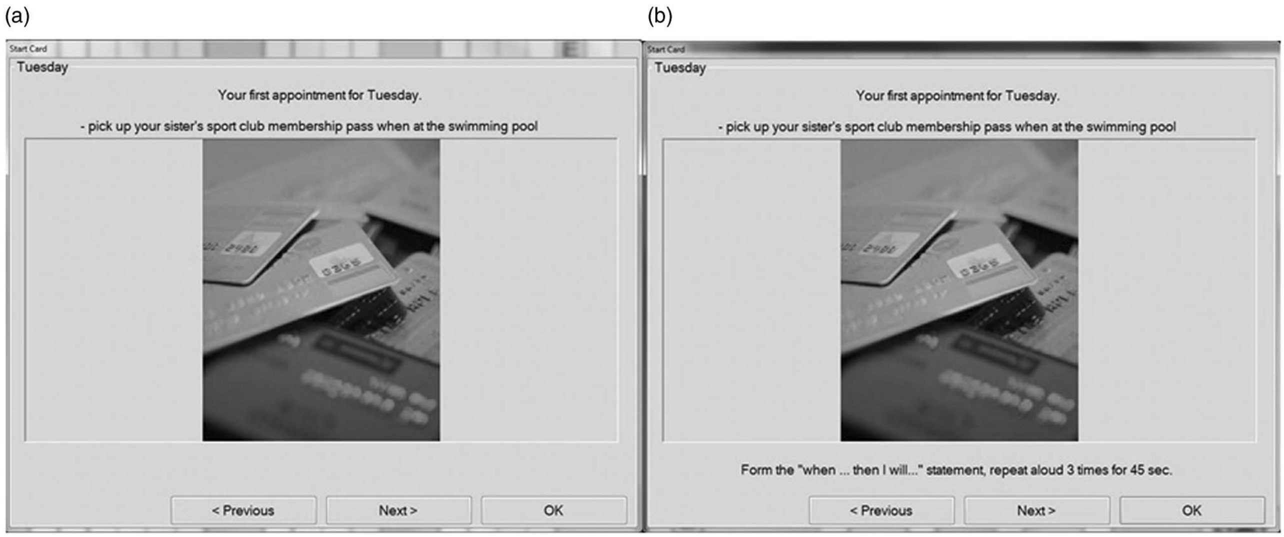

Fig. 1. Task windows for no strategies (a) and for implementation intentions (b) conditions.

presented at the start of each virtual day. The irregular task windows were presented once, at start or during the virtual day that they were to be carried out on. The no strategy condition had the standard Virtual Week task window as shown in Figure 1a. As in standard Virtual Week, participants were instructed to read aloud the Event cards and they controlled the presentation rate through the option to select the "OK" button to close window when ready. In the implementation intentions condition, the task windows (see Figure 1b) for all PM tasks (regular and irregular) were programmed to stay open for 45 s. During the 45-s exposure to each task window, participants were instructed to form an implementation intentions statement relating to the PM task presented on the card. This involved reforming intention into the format of, when I (cue) I will (action) (e.g., "when I'm at the swimming pool I'll pick up my sister's membership card") and were instructed to repeat the statement 3 times out aloud. The implementation intentions strategy was introduced and practiced during the trial virtual day. As in the standard Virtual Week, all participants completed a trial virtual day during which help messages were provided, and the experimenter was available to answer questions. This support did not continue after the trial day, except for the information on the task windows.

Recognition test of PM task content

Immediately following each virtual day, participants completed a recognition test to assess their retrospective memory for the various PM tasks. Successful PM performance requires executing the intended action at the appropriate moment (i.e., prospective component) as well as remembering the specific action to be performed (i.e., retrospective component) (Einstein & McDaniel, 1996). Therefore, PM failure might be due to forgetting the content of the PM action or failing to retrieve and execute the intended action. The recognition test was introduced to further evaluate the source of the PM forgetting. The test required matching each intended action with its cue. Participants were presented with a list of actions, some of which were required during the virtual day while others were distractors (Mioni, Rendell, Stablum, Gamberini, & Bisiacchi, 2014). Performance was analyzed in term of proportion of correct responses for each PM task. (Note: this task was not completed by the "no strategy" participants as they were tested first and this feature was not available on the version of Virtual Week they completed).

Procedure

TBI participants in the implementation intentions condition were tested in a quiet room at Arep Onlus di Villorba, Treviso, Italy and controls were tested in their own houses. The PM task (Virtual Week) was presented on a 15-inch computer screen and participants were seated at a distance of approximately 60 cm from the screen. Testing was conducted in a single experimental session (approximately 90 min). All participants provided informed consent, and the study was conducted in compliance with the ethical principles set in the Helsinki Declaration (59^{th} WMA General Assembly, Seoul, 2008).

RESULTS

PM Accuracy

The key dependent measure was the proportion of correct responses on the PM task. This was the number correct, expressed as a proportion of the six PM tasks scheduled for each of the four specific categories of tasks: regular event, regular time, irregular event, and irregular time. These data were analyzed with a $2 \times 2 \times 2 \times 2$ mixed ANOVA with the between-group variables *group* (TBI patients, controls) and

https://doi.org/10.1017/S1355617715000211 Published online by Cambridge University Press

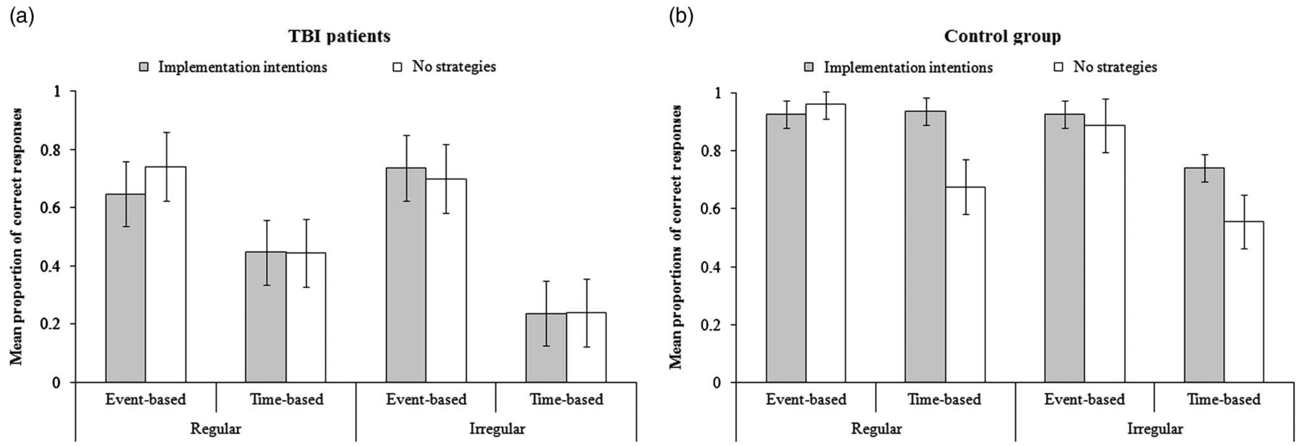

Fig. 2. Mean proportion of correct responses for traumatic brain injury (TBI) patients (a) and controls (b) as a function of prospective memory (PM) task (regular, irregular), PM cue (event-based, time-based) and encoding condition (no strategies, implementation intentions). The error bars indicate ±1 *SE*.

encoding condition (no strategy, implementation intentions), and within-group variables *PM task* (regular, irregular) and *PM cue* (event-based, time-based) (see Figures 2a and 2b for the data as function of these variables). For all ANOVAs conducted in study, *post hoc* analyses were performed with a Bonferroni correction to reduce the Type I error rate, and the effect size was estimated with partial eta squared (η^2_p).

The results showed that there were significant main effects of group [$F(1,66) = 71.78$; $p < .001$; $\eta^2_p = .521$] (TBI patients $M = .52$; controls $M = .83$), PM task [$F(1,66) = 22.18$; $p < .001$; $\eta^2_p = .252$] and PM cue [$F(1,66) = 148.97$; $p < .001$; $\eta^2_p = .693$], however, there was no main effect of encoding condition ($p = .18$; $\eta^2_p = .027$). The two-way interactions PM cue × encoding condition [$F(1,66) = 7.28$; $p = .009$; $\eta^2_p = .099$], and PM target × PM cue [$F(1,66) = 24.85$; $p = .001$; $\eta^2_p = .274$] were significant. Also the interaction group × PM cue [$F(1,66) = 12.83$; $p = .001$; $\eta^2_p = .163$] was significant. Tests of simple effects showed that controls were more accurate than TBI patients on both event- and time-based PM tasks; moreover, all participants had better performance on event-based than time-based tasks. Of interest, the TBI patients, compared to controls, showed a greater impairment in time-based tasks.

Of interest, the interaction group × PM cue × encoding condition [$F(1,66) = 4.40$; $p = .040$; $\eta^2_p = .062$] was significant and trumps the two way and main effects. To better understand the data, PM performance was analyzed separately for TBI patients and controls with a 2 × 2 × 2 mixed ANOVA with the between-group variable *encoding condition* (no strategy, implementation intentions) and within-group variables *PM task* (regular, irregular) and *PM cue* (event-based, time-based).

TBI patients

The results showed that there were significant main effects of PM task [$F(1,34) = 8.69$; $p < .006$; $\eta^2_p = .204$] and PM cue [$F(1,34) = 104.88$; $p < .001$; $\eta^2_p = .755$]; a significant interaction between PM task × PM cue [$F(1,34) = 15.07$; $p < .001$; $\eta^2_p = .307$] was also found with TBI patients much more accurate on regular than irregular tasks, and more accurate on event-based than time-based. However, there was no main effect of encoding condition ($p = .82$; $\eta^2_p = .002$) and no other significant interactions were found (all *p*s > .31) (Figure 2a).

Controls

The results showed that there were significant main effects of PM task [$F(1,32) = 15.34$; $p < .001$; $\eta^2_p = .323$], PM cue [$F(1,32) = 47.45$; $p < .001$; $\eta^2_p = .597$] and encoding condition [$F(1,32) = 10.60$; $p = .003$; $\eta^2_p = .249$]. The interactions PM task × PM cue [$F(1,32) = 11.30$; $p = .002$; $\eta^2_p = .261$] and PM cue × encoding condition [$F(1,32) = 14.67$; $p = .001$; $\eta^2_p = .314$] were significant. Of interest, the interaction PM task × PM cue × encoding condition [$F(1,32) = 4.49$; $p = .042$; $\eta^2_p = .123$] was also significant (Figure 2b). Tests of simple effects showed that controls were more accurate when the task was event-based compared to time-based, for the no strategy condition, for both regular and irregular tasks. In the implementation intentions condition, controls were equally accurate on event-based and time-based regular tasks; whereas, for irregular tasks, better performance was observed on event-based compared to time-based. Among control participants, implementation intentions benefitted performance on both regular and irregular time based tasks.

Recognition test of PM task content

The second dependent measure was the proportion of correct responses on the recognition test of PM task content involving matching the PM action with the PM cue. This was the number correct, expressed as a proportion of the six PM tasks scheduled for each of the four specific categories of tasks: regular event, regular time, irregular event, and irregular time. These data (see Table 2) were analyzed with a 2 × 2 × 2 mixed ANOVA with

Table 2. Performance (proportion of correct responses) on the PM task and the Recognition test of PM task content, as a function of group (TBI patients, controls), PM task (regular, irregular) and PM cue (event-based, time-based).

		TBI patients		Control group	
		PM accuracy	Recognition test	PM accuracy	Recognition test
		M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Regular:	Event	.65 (.22)	.69 (.43)	.93 (.11)	1.00 (.00)
	Time	.45 (.30)	.78 (.37)	.94 (.09)	.98 (.06)
Irregular:	Event	.73 (.17)	.84 (.27)	.93 (.11)	.98 (.08)
	Time	.24 (.20)	.60 (.35)	.74 (.15)	.92 (.12)

the between-group variable group (TBI patients, controls) and within-group variables PM task (regular, irregular) and PM cue (event-based, time-based). This replicated the ANOVA conducted for PM accuracy except it was conducted only with the implementation intentions condition, as data for this recognition test of PM content were only available for this encoding condition.

The analyses showed that there was a significant main effect of group [$F(1,32) = 17.09$; $p < .001$; $\eta^2_p = .348$] (TBI patients $M = .73$; $SD = .36$; controls $M = .97$; $SD = .02$), but group did not interact with any other variable. Group was not a significant two way interaction with PM task, [$F(1,32) = 0.10$; $p = .757$; $\eta^2_p = .003$] or PM cue, [$F(1, 32) = 0.16$; $p = .757$; $\eta^2_p = .005$] and there was not a significant three way interaction, [$F(1,32) = 2.86$; $p = .100$; $\eta^2_p = .082$]. The other two variables were not significant main effects: PM task [$F(1,32) = 0.50$; $p = .484$; $\eta^2_p = .015$] and PM cue [$F(1,32) = 1.97$; $p = .170$; $\eta^2_p = .058$]. However, these two variables significantly interacted, [$F(1,32) = 4.86$; $p = .035$; $\eta^2_p = .132$] (see Table 2). Tests of simple effects showed that all participants for event-based tasks, did not differ on regular *versus* irregular but for the time-based tasks, participants recognized more PM content on regular than irregular PM tasks. Moreover, participants on regular tasks did not differ on event-based compared to time-based, but on irregular tasks, participants recognized more event-based tasks than time-based tasks.

To provide some context for performance on the recognition test of PM task content, Table 2 presents the results for this test along with the PM accuracy results. An inspection of Table 2 indicates that prospective memory accuracy was lower than accuracy for the task content. The differences are generally larger for the TBI patients than for the control group.

DISCUSSION

The present study investigated PM performance in people with TBI relative to healthy controls, and in particular whether implementation intentions improves PM performance. Our results confirmed previous findings of poorer PM performance in TBI patients compared to controls (Mioni et al., 2013; Shum et al., 2011), most notably on time-based tasks (see also Kinch & McDonald, 2001; Mathias & Mansfield, 2005). Poorer performance on time-based, compared to event-based tasks was expected because time-based tasks require more self-initiated processes while event-based tasks have an associated external cue to help recall the task to be performed (McDaniel & Einstein, 1993; McDaniel, Glisky, Rubin, Guynn, & Routhieaux, 1999; McFarland & Glisky, 2009).

Contrary to expectations the TBI patients did not improve their PM performance when using the implementation intentions strategy on either event-based or time-based tasks. These findings are in contrast to studies with healthy older adults (Chasteen et al., 2001; McDaniel et al., 2008; McFarland & Glisky, 2011; Liu & Park, 2004; Schmidt et al., 2001) and some clinical populations (Kardiasmenos et al., 2008; Lengfelder & Gollwitzer, 2001) that did find implementation intentions improved PM performance, but are similar to some studies with very old adults that reported no benefit (McDaniel & Scullin, 2010; Schnitzspahn & Kliegel, 2009). However, improved performance using implementation intentions was reported for the control group for time-based tasks. This improvement suggests that enhanced encoding of the PM action and cue that results from applying the implementation intentions strategy was beneficial for this group. Although a similar improvement was not observed for the control group on event-based tasks this is most likely because they performed close to ceiling (92% correct) on the event-based PM tasks when using no strategy. As such, the potential for implementation intentions to improve performance was limited. The TBI group was not at ceiling (71%) on the event-based PM tasks when using no strategy and thus ceiling effects do not account for the lack of improvement by TBI group when using implementation intentions. The lack of improvement by TBI on time-based PM tasks was also not due to ceiling effects (34% correct when using no strategy).

It appears then that implementation intentions benefits controls but not TBI patients. One possible contributing factor to the failure of the TBI patients to benefit from implementation intentions may be a deficit in retrospective memory. This claim is supported by the pattern of results showing that the TBI patients did not retain the content of the PM tasks as well as the controls. However, the TBI patients did remember the content of more PM tasks than they successfully completed, indicating that retrospective memory deficits do not completely explain their inability to benefit from the implementation intentions strategy. It should, however, be noted that data regarding the recall of the content of the PM tasks were only available for the implementation intention groups. Future studies should also collect these data for the no-strategy condition to allow investigation of the extent to which TBI patients differ to controls in their retention of PM task content when implementation intentions are not applied to more fully investigate the impact of the strategy.

Over and above retrospective memory deficits, other possible explanations should be considered to explain the lack of facilitative effects for the TBI patients. For example, it could be that while implementation intentions may have improved encoding during the intention formation stage for this group, which in turn facilitated retrieval at the re-instantiation phase, difficulties with these processes may not have been the source of the TBI group's PM deficit. For example, it is possible that difficulties with the execution phase played a key role in maintaining the poorer PM performance of the clinical group. In keeping with this argument, Kliegel et al. (2004) reported that TBI patients were less accurate than controls in the execution phase of PM. Furthermore, TBI patients have been shown to display dysfunctions in planning and executing tasks (Gouveia, Brucki, Malheiros, & Bueno, 2007; Mattson & Levin, 1990; McDonald, Flashman, & Saykin, 2002), deficits which are likely to negatively impact PM performance especially during the execution phase. If difficulties with execution play a major role in the poorer PM of TBI patients, performance is unlikely to be substantially improved by strategies such as implementation intentions which enhance encoding. It is possible then that encoding difficulties may not be the most critical factor driving PM deficits among TBI patients, and as such this aspect of PM may not be the most useful one to target for intervention for this clinical group.

Alternatively, it is possible that difficulties at the intention formation phase as well as deficits in later phases of PM such as execution are all playing a part in poorer PM performance among TBI patients. In this case, improving encoding alone may not be sufficient to offset the additional influence of difficulties with these later phases. Future studies should, therefore, be undertaken to disentangle the contribution of each PM phase and to identify whether improving PM performance in patients with TBI requires strategies that target individual phases (other than intention formation), or need to simultaneously target a combination of phases.

Another possible reason why implementation intentions did not improve PM performance in our TBI patients may be related to the fact that we applied it in the form of a verbal strategy only. Of interest, it has been suggested that not only vocalizing the statement (as was done in the present study), but also visualizing the intended action, improves PM performance. McDaniel et al. (2008) suggested that both the visualization and the verbal statement are beneficial for PM performance, paralleling the success of using dual codes (visual and verbal) in studies of retrospective memory (Paivio, 1971). However, the findings from previous studies are somewhat inconsistent regarding this issue, with some studies reporting beneficial effects of combining implementation intentions and visualizing strategies (Chasteen et al., 2001; Kardiasmenos et al., 2008; Liu & Park, 2004; McDaniel et al., 2008; McDaniel & Scullin, 2010) but others reporting no improvement from the combination of the two strategies (Cohen & Gollwitzer, 2008; McFarland & Glisky, 2012; Gollwitzer & Brandstätter, 1997). For example, in a study by Chasteen et al. (2001) healthy older adults improved on PM after being instructed to visualize the appropriate circumstances for carrying out the planned task and to state aloud the intention to do so. On the other hand, McFarland and Glisky (2012) did not report any benefit to PM performance from combining the implementation intention statement with visualization compared to vocalizing the implementation intention statement only.

Nevertheless, future studies with TBI patients should consider the inclusion of other strategies such as visualization of the PM action together with the verbal statement required by the implementation intentions strategy to investigate whether this additional element improves PM in people with TBI. The potential value of this approach is highlighted by the results of Potvin et al.'s (2011) training study with TBI patients which showed positive effects of visual imagery techniques on PM. TBI patients in this rehabilitation program reported less everyday PM failures following the training and these benefits were also observed by their relatives. Adopting a training approach incorporating a visualization element may, therefore, be a valuable avenue to pursue in the future. Further research is, however, needed in general to disentangle the relative merits of visualization and verbal statements, especially given that rehearsing the verbal statement alone was effective for the controls in this study.

Finally, the severity of brain injury (measured with GCS and clinical records) in the TBI sample should be also considered in the interpretation of our findings. Considering that PM is a higher order cognitive process (Kliegel, Martin, McDaniel, & Einstein, 2002; Martin, Kliegel, & McDaniel, 2003), it is possible that the TBI patients did not have adequate cognitive resources, for example, in relation to attentional capacities, to benefit from the implementation intention strategy (see Meeks & Marsh, 2010). Indeed there is some evidence that PM impairment observed in TBI patients may reflect lapses of attention (Mioni, Stablum, McClintock, & Cantagallo, 2012; Mioni et al., 2014). Further research assessing the potential influence of compromised attentional resources and other aspects of executive functions on PM performance in this clinical group would, therefore, be valuable.

In conclusion, the current study is the first to investigate whether implementation intentions improves PM in patients with TBI. The results showed that while controls benefitted from the strategy, the TBI patients did not. These findings are important in highlighting that strategies to improve PM in this clinical group are likely to be more complex than those that benefit healthy adults. Future research should focus on teasing out the contribution of all phases of the PM process

https://doi.org/10.1017/S1355617715000211 Published online by Cambridge University Press

including the later phases such as intention execution, and should consider whether extending the instructions to include visualization is helpful. Overall, although the sample would ideally have been larger, the present study provides a valuable starting point for future studies aiming to develop specific interventions to minimize the negative impact of persistent PM failures among TBI patients which in turn will increase their capacity to cope with the demands of daily life.

ACKNOWLEDGMENTS

There are no financial or other relationships that could be interpreted as a conflict of interest affecting this manuscript. This research received no specific grant from any funding agency, commercial or not-for-profit sectors. The authors gratefully acknowledge Martina Michielin who helped in testing the participants, Barbara De Silvestri, Erika Bertucci and Raffaella Manente and the participants and their families and friends who co-operated in the present study.

REFERENCES

Bellezza, F.S. (1981). Mnemonic devices: Classification, characteristics, and criteria. *Review of Educational Research*, *51*, 247–275. doi:10.3102/00346543051002247

Carlesimo, G.A., Formisano, R., Bivona, U., Barba, L., & Caltagirone, C. (2009). Prospective memory in patients with severe closed head injury: Role of concurrent activity and encoding instructions. *Behavioural Neurology*, *22*, 101–110. doi:10.3233/BEN-2009-0251

Chasteen, A.L., Park, D.C., & Schwarz, N. (2001). Implementation intentions and facilitation of prospective memory. *Psychological Science*, *12*, 457–461. doi:10.1111/1467-9280.00385

Cohen, A.L., & Gollwitzer, P.M. (2008). The cost of remembering to remember: Cognitive load and implementation intentions influence ongoing task performance. In M. Kliegel, M.A. McDaniel & G.O. Einstein (Eds.), *Prospective memory: Cognitive, neuroscience, developmental, and applied perspectives* (pp. 367–390). Mahwah, NJ: Erlbaum.

Einstein, G.O., & McDaniel, M.A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *16*, 717–726. doi:10.1037/0278-7393.16.4.717

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

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

Fish, J., Wilson, B.A., & Manly, T. (2010). The assessment and rehabilitation of prospective memory problems in people with neurological disorders: A review. *Neuropsychological Rehabilitation*, *20*, 161–179. doi:10.1080/09602010903126029

Fleming, J.M., Shum, D., Strong, J., & Lighthouse, S. (2005). Prospective memory rehabilitation for adults with traumatic brain injury: A compensatory training program. *Brain Injury*, *19*, 1–13. doi:10.1080/02699050410001720059

Fleming, J.M., Riley, L., Gill, H., Gullo, M.J., Strong, J., & Shum, D. (2008). Predictors of prospective memory in adults with traumatic brain injury. *Journal of the International Neuropsychological Society*, *14*, 823–831. doi:10.10170S1355617708080971

Gollwitzer, P.M. (1999). Implementation intentions: Strong effects of simple plans. *American Psychologist*, *54*, 493–503. doi:10.1037/0003-066X.54.7.493

Gollwitzer, P.M., & Brandstatter, V. (1997). Implementation intentions and effective goal pursuit. *Journal of Personality and Social Psychology*, *73*, 186–199. doi:10.1037/0022-514.73.1.186

Gouveia, P.A.R., Brucki, S.M.D., Malheiros, S.M.F., & Bueno, O.F.A. (2007). Disorders in planning and strategy application in frontal lobe lesion patients. *Brain and Cognition*, *63*, 240–246. doi:10.1016/j.bandc.2006.09.001

Hagan, C., Malkmus, D., Durham, P., & Bowman, K. (1979). Levels of cognitive functioning. In Rancho Los Amigos Hospital. *Rehabilitation of the head injured adult: Comprehensive physical management*. Downey, CA: Professional Staff Association of Rancho Los Amigos Hospital.

Kardiasmenos, K.S., Clawson, D.M., Wilken, J.A., & Wallin, M.T. (2008). Prospective memory and the efficacy of a memory strategy in multiple sclerosis. *Neuropsychology*, *22*, 746–754. doi:1 0.1037/a0013211.

Kinch, J., & McDonald, S. (2001). Traumatic brain injury and prospective memory: An examination of the influences of executive functioning and retrospective memory. *Brain Impairment*, *2*, 119–130. doi:10.1375/brim. 2.2.119

Kliegel, M., Eschen, A., & Thöne-Otto, A.I.T. (2004). Planning, and realization of complex intentions in traumatic brain injury and normal aging. *Brain and Cognition*, *56*, 43–54. doi:10.1016/j.bandc.2004.05.005

Kliegel, M., Martin, M., McDaniel, M.A., & Einstein, G.O. (2002). Complex prospective memory and executive control of working memory: A process model. *Psychologische Beiträge*, *44*, 303–318.

Kliegel, M., McDaniel, M.A., & Einstein, G.O. (2008). *Prospective memory: Cognitive, neuroscience, developmental, and applied perspective*. Mahwah, NJ: Lawrence Erlbaum.

Lengfelder, A., & Gollwitzer, P.M. (2001). Reflective and reflexive action control in patients with frontal brain lesions. *Neuropsychology*, *15*, 80–100. doi:10.1037/0894-4105.15.1.80

Liu, L.L., & Park, D.C. (2004). Aging and medial adherence: The use of automatic processes to achieve effortful things. *Psychology and Aging*, *19*, 318–325. doi:10.1037/0882–7974.19.2.318

Martin, M., Kliegel, M., & McDaniel, M.A. (2003). The involvement of executive functions in prospective memory performance of adults. *International Journal of Psychology*, *38*(4), 195–206.

Mathias, J.L., & Mansfield, K.M. (2005). Prospective and declarative memory problems following moderate and severe traumatic brain injury. *Brain Injury*, *19*, 271–282. doi:10.1080/02699050400005028

Mattson, A.J., & Levin, H.S. (1990). Frontal lobe dysfunction following closed head injury. A review of the literature. *The Journal of Nervous and Mental Disease*, *178*, 282–291. doi:10.1097/00005053-199005000-00002

Maujean, A., Shum, D., & McQueen, R. (2003). Effect of cognitive demand on prospective memory in individuals with traumatic brain injury. *Brain Impairment*, *4*, 135–145. doi:10.1375/brim.4.2.135.27024

McDaniel, M.A., & Einstein, G.O. (1993). The importance of cue familiarity and distinctiveness in prospective memory. *Memory*, *1*, 23–41. doi:10.1080/09658219308258223

McDaniel, M.A., Glisky, E.L., Rubin, S.R., Guynn, M.J., & Routhieaux, B.C. (1999). Prospective memory: A neuropsychological study. *Neuropsychology*, *13*, 103–110. doi:10.1037/0894-4105.13.1.103

McDaniel, M.A., Howard, D.C., & Butler, K.M. (2008). Implementation intentions facilitate prospective memory under high attention demands. *Memory and Cognition*, *36*, 716–724. doi:10.3758/MC.36.4.716

McDaniel, M.A., & Einstein, G.O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology*, *14*, 127–144. doi:10.1002/acp.775

McDaniel, M.A., & Scullin, M.K. (2010). Implementation intention encoding does not automatize prospective memory responding. *Memory and Cognition*, *38*, 221–232. doi:10.3758/MC.38.2.221

McDonald, B.C., Flashman, L.A., & Saykin, A.J. (2002). Executive dysfunction following traumatic brain injury: Neural substrates and treatment strategies. *Neurorehabilitation*, *17*, 333–344.

McFarland, C.P., & Glisky, E.I. (2009). Frontal lobe involvement in a task of time-based prospective memory. *Neuropsychologia*, *47*, 1660–1669. doi:10.1002/acp.775

McFarland, C.P., & Glisky, E.I. (2011). Implementation intentions and prospective memory among older adults: An investigation of the role of frontal lobe function. *Aging, Neuropsychology, and Cognition*, *18*, 633–652. doi:10.1080/13825585.2011.613449

McFarland, C.P., & Glisky, E.I. (2012). Implementation intentions and imagery: Individual and combined effects on prospective memory among young adults. *Memory & Cognition*, *40*, 62–69. doi:10.378/s13421.011-0126-8

Meeks, J.T., & March, R.L. (2010). Implementation intentions about nonfocal event-based prospective memory tasks. *Psychological Research*, *74*, 82–89. doi 10.1007/s00426-008-0223-x

Mioni, G., McClintock, S.M., & Stablum, F. (2014). Understanding, assessing and treating prospective memory dysfunctions in traumatic brain injury patients. In F. Sadaka & T. Quinn (Eds.), *Traumatic brain injury* (pp. 401–436). Rijeka, Croatia: InTeck publication. doi:10.5772/57307

Mioni, G., Rendell, P.G., Henry, J.D., Cantagallo, A., & Stablum, F. (2013). An investigation of prospective memory functions in people with traumatic brain injury using Virtual Week. *Journal of Clinical and Experimental Neuropsychology*, *35*, 617–630. doi:10.1080/13803395.2013.804036

Mioni, G., Rendell, P.G., Stablum, F., Gamberini, L., & Bisiacchi, P.S. (2014). Test-retest consistency of Virtual Week: A task to investigate prospective memory. *Neuropsychological Rehabilitation*, *28*, 1–29. doi:10.1080/09602011.2014.941295

Mioni, G., Stablum, F., McClintock, S.M., & Cantagallo, A. (2012). Time-based prospective memory in severe traumatic brain injury patients: The involvement of executive functions and time perception. *Journal of the International Neuropsychological Society*, *18*, 697–705. doi:10.1017/S13556177120003060

Paivio, A. (1971). *Imagery and verbal processes*. New York: Holt, Rinehart, & Winston.

Potvin, M.J., Roulean, I., Sénéchal, G., & Giguère, J.F. (2011). Prospective memory rehabilitation based on visual imagery techniques. *Neuropsychological Rehabilitation*, *21*, 899–924. doi:10.1080/09602011.2011.630882

Rendell, P.G., & Craik, F.I.M. (2000). Virtual week and actual week: Age-related differences in prospective memory. *Applied Cognitive Psychology: Special issue: New Perspectives in Prospective Memory*, *14*, S43–S62. doi:10.1002/acp.770

Schmidt, I.W., Berg, I.J., & Deelman, B.G. (2001). Relations between subjective evaluations of memory and objective memory performance. *Perception and Motor Skills*, *93*, 761–776. doi:10.2466/pms.2001.93.3.761

Schnitzspahn, K.M., & Kliegel, M. (2009). Age effects in prospective memory performance within older adults: The paradoxical impact of implementation intentions. *European Journal of Aging*, *6*, 147–155. doi:10.1007/s10433-009-0116-x

Shum, D., Levin, H., & Chan, R.C.K. (2011). Prospective memory in patients with closed head injury: A review. *Neuropsychologia*, *49*, 2156–2165. doi:10.1016/j.neuropsychologia.2011.02.006

Teasdale, G., & Jennett, B. (1974). Assessment of coma and impaired consciousness: A practical scale. *Lancet*, *2*, 81–84.

Thöne-Otto, A.I.T., & Walther, K. (2008). Assessment and treatment of prospective memory disorders in clinical pratice. In M. Kliegel, M.A. McDaniel & G.O. Einstein (Eds.), *Prospective memory: Cognitive, neuroscience, developmental, and applied perspective* (pp. 321–345). Mahwah, NJ: Lawrence Erlbaum.

van den Broek, M.D., Downes, J., Jhonson, Z., Dayus, B., & Hilton, N. (2000). Evaluation of an electronic memory aid in the neuropsychological rehabilitation of prospective memory deficits. *Brain Injury*, *14*, 455–462. doi:10.1080/026990500120556

Webb, T.L., & Sheeran, P. (2007). How do implementation intentions promote goal attainment? A test of component processes. *Journal of Experimental Social Psychology*, *43*, 295–302. doi:10.1016/j.jesp.2006.02.001

Zafonte, R.D., Hammond, F.M., Mann, N.R., Wood, D.L., Black, K.L., & Millis, S.R. (1996). Relationship between Glasgow coma scale and functional outcome. *American Journal of Physical Medicine and Rehabilitation*, *75*, 364–369.