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Incentive Effects on Event-Based Prospective Memory Performance in Children and Adolescents with Traumatic Brain Injury

Stephen R. McCauley, PhD,

Physical Medicine and Rehabilitation Alliance of Baylor College of Medicine and the University of Texas-Houston Medical School, Houston, TX USA and Department of Pediatrics Hematology-Oncology, Baylor College of Medicine, Houston, TX USA

Mark A. McDaniel, PhD,

Department of Psychology, Washington University, St. Louis, MO, TX USA

Claudia Pedroza, PhD,

Division of Biostatistics at the University of Texas, School of Public Health, Houston, TX USA

Sandra B. Chapman, PhD, and

Center for BrainHealth, Institute of Biomedical Sciences and Technology, University of Texas at Dallas, Dallas, TX, USA

Harvey S. Levin, PhD

Physical Medicine and Rehabilitation Alliance of Baylor College of Medicine and the University of Texas-Houston Medical School, Houston, TX USA

Abstract

Prospective memory (PM) is the formation of an intention and remembering to perform this intention at a future time or in response to specific cues. PM tasks are a ubiquitous part of daily life. Currently, there is a paucity of information regarding PM impairments in children with traumatic brain injury (TBI) and less empirical evidence regarding effective remediation strategies to mitigate these impairments. The present study employed two levels of a motivational enhancement (i.e., a monetary incentive) to determine if event-based PM could be improved in children with severe TBI. In a cross-over design, children with orthopedic injuries and mild or severe TBI were compared on two levels of incentive (dollars versus pennies) given in response to accurate performance. All three groups performed significantly better under the high- versus low-motivation conditions. However, the severe TBI group's *high*-motivation condition performance remained significantly below the *low*-motivation condition performance of the orthopedic injury

Correspondence concerning this article should be addressed to Stephen R. McCauley, Baylor College of Medicine, Houston, TX, Cognitive Neuroscience Laboratory, Department of Physical Medicine and Rehabilitation, 1709 Dryden Road, Suite 725. Voice: 713-798-7479; FAX: 713-798-6898; mccauley@bcm.edu.

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group. PM scores were positively and significantly related to age-at-injury, but there were no age-at-injury or time-postinjury effects. Overall, these results suggest that event-based PM can be significantly improved in children with severe TBI.

Keywords

Event-based prospective memory; Traumatic brain injury; Incentive; Motivation; Memory rehabilitation

Prospective memory (PM, also referred to as the realization of a delayed intention) is commonly defined as remembering to perform an intended action in the future (in contrast to the recall of previously learned information which is termed *retrospective* memory: RM). Such tasks are ubiquitous in everyday life ranging from remembering to keep appointments and taking one's medication to stopping at the grocers to buy milk on the way home or conveying a message to a colleague the next time he or she is encountered (Herrmann, Brubaker, Yoder, Sheets, & Tio, 1999). These examples illustrate two categories of PM tasks: the first two examples reflect time-based tasks (performing an intended action at a certain time or following a specific time interval) and the latter examples reflect event-based tasks (remembering to perform an intended action in response to a certain target event) (Einstein & McDaniel, 1990, 1996). PM failures are quite commonplace in the general population accounting for a reported 50% (Crovitz & Daniel, 1984; West, 1984) to 70% (Terry, 1988) of total memory failures occurring in everyday life which potentially could result in serious consequences (Reason, 1977). Indeed, several researchers have argued that PM may be an essential ability to successfully cope with the challenges of daily living (Harris, 1984; Meacham & Dumitru, 1976; Meacham & Leiman, 1982; Wilkins & Baddeley, 1978; Winograd, 1988). Given the high frequency of PM failures in healthy persons, it is not unreasonable to expect that persons who are neurologically-compromised are at even greater risk of PM lapses. Indeed, Mateer and her colleagues reported that in a sample of adults with TBI, over 47% of the total variance in responses to the Good Samaritan Hospital Memory Questionnaire were accounted for by ratings on items comprising the PM factor (Mateer, Sohlberg, & Crinean, 1987). Thöne and Walther's 2001 study (cited in Thöne-Otto & Walther, 2003) found that in a group of patients with brain injury of mixed etiology, the ability to effectively compensate for PM impairments was a significant predictor of independent living following brain injury; this relation also has been reported in similar studies (Fortin, Godbout, & Braun, 2002; Fortin, Godbout, & Braun, 2003; Wilson, 1987). In an interview study involving children with TBI, parents indicated that some adolescents with TBI exhibited sufficient PM impairments that when coupled with the family's situation (and possibly pre-existing learning and/or behavior problems), serious concerns existed for their child's safety and ability to be left unsupervised (Ward, Shum, Dick, McKinlay, & Baker-Tweney, 2004). The frequency of PM complaints in healthy and neurologically-compromised populations, together with the negative impact of impaired PM on independent living, highlight the practical importance of investigating PM and its possible remediation in such populations. A number of studies to date have investigated the effects of TBI on PM in adults (Cockburn, 1995; Fortin, et al., 2002; Groot, Wilson, Evans, & Watson, 2002a; Hannon, Adams, Harrington, Fries-Dias, & Gipson, 1995; Henry, et al., 2007; Kinsella, et al., 1996; Kliegel, Eschen, & Thöne-Otto, 2004; Knight, Harnett, & Titov, 2005; Knight, Titov, & Crawford, 2006; Louda, Loseva, & Mielke, 2007; Mathias & Mansfield, 2005; Roche, Fleming, & Shum, 2002; Roche, Moody, Szabo, Fleming, & Shum, 2007; Shum, Valentine, & Cutmore, 1999). However, only two experimental studies have been conducted involving children with TBI (McCauley & Levin, 2004; Ward, Shum, McKinlay, Baker, & Wallace, 2007). These experiments, using laboratory event-based PM tasks, revealed that children and adolescents with TBI demonstrated impaired PM

functioning relative to demographically similar orthopedically-injured (OI) controls (McCauley & Levin, 2004) or typically-developing children (TDC) and adolescents (Ward, et al., 2007). One objective of the present experiment was to continue the examination of event-based PM in children and adolescents with TBI. To investigate the extent to which the just-noted TBI-related PM declines are relatively general, we implemented a different event-based task than used in the two previous studies (described in the next section).

Another major question, given the implications of poor PM functioning as noted above, is whether PM deficits can be effectively remediated in children with TBI. There is scant evidence pertaining to this issue, with the few extant studies focusing primarily on the use of reminders. In McCauley and Levin (2004), children were given a reminder of the PM task at some point in the ongoing activity (a word-categorization task). Following the reminder, children with mild TBI improved their PM performance, but children with severe TBI did not improve significantly. Flannery, Butterbaugh, Rice, and Rice (1997) reported a case study in which an on-board computer system that provided task reminders and logged task completion reduced the task reminding rate from over 75% to less than 10% over six months in a 17 year-old patient with a history of spina bifida and hydrocephalus. These findings dovetail with the adult PM rehabilitation literature that has embraced the use of electronic reminders to aid PM (Groot, Wilson, Evans, & Watson, 2002b; Hart, Hawkey, & Whyte, 2002; Hersh & Treadgold, 1994; Kim, Burke, Dowds, Boone, & Parks, 2000; Lynch, 1995; Thöne-Otto & Walther, 2003; van den Broek, Downes, Johnson, Dayus, & Hilton, 2000; Yasuda, et al., 2002). Of course, providing reminders either through human or electronic means may not be convenient or practicable in some contexts. We were thus interested in whether motivational enhancements, in particular incentives, could stimulate improved PM performance in children with TBI. To our knowledge, only one study of PM rehabilitation has used an incentive (Furst, 1986). In this study, points were given for accurate performance and later traded for prizes in a six-week "Memory Derby." However, because all participants received the same incentive schedule, the effect of incentive *per se* could not be evaluated. Moreover, the participants were adults, rather than children. To date, no studies of PM rehabilitation in children have been conducted using motivational enhancements. Consequently, it is not known how incentive techniques would fare toward improving PM following pediatric TBI.

In the following experiment we varied motivation by implementing two incentive levels. In the low motivation condition, participants were able to exchange points earned through accurate PM performance for pennies; in the high motivation condition, points could be exchanged for dollar bills¹. *A priori*, several different outcomes seemed possible. In a study of TDC 2 to 4 years of age, PM tasks that were of high interest (reminding the caretaker to buy candy at the store) were remembered 73% of the time with short delays of several minutes and 53% with delays on the order of hours; by contrast, PM tasks that were of low-interest to the children (reminding the caretaker to bring in the washing) met with only 23% success after short delays and 17% success after long delays (Somerville, Wellman, & Cultice, 1983). Based on these findings, one prediction is that children with TBI, despite probable declines in executive or strategic control (not unlike relatively low executive or

¹A *monetary* incentive was specifically chosen as the extrinsic motivator in this study because providing pocket money/allowance is a common technique used by parents to instill the concept of earning income for successful work completed (Neul & Drabman, 2001) which teaches children to successfully meet responsibilities in home and work situations as they mature (Pastore & Friedman, 1992). A majority of parents in Western nations (91% to 99%) believe that 6 to 7 years is an appropriate age range in which to initiate an allowance program (Barnet-Verzat & Wolff, 2002; Furnham, 1999; Furnham & Kirkcaldy, 2000), and adolescents frequently have had one or more part-time jobs, formal or otherwise (e.g., restaurant work, babysitting). Therefore, it is likely that the concept of receiving money for work performed correctly would be familiar to the majority of the study participants. The difference between dollars and pennies serving as differential motivators is admittedly rather arbitrary, but the amounts appear a reasonable starting point to explore the effect of incentives on PM performance in children and adolescents.

strategic processes in 2–4 year old children) will be able to recruit effective strategies to support successful PM, at least for high-incentive tasks. If this was the case, it would be informative from a rehabilitation perspective to determine how substantial increases in PM performance are relative to the low motivation condition, and how the high-motivation performance of children with TBI compares to orthopedically-injured peers. Alternatively, it may be that the requisite strategic processes to enhance event-based PM (i.e., for high-incentive situations) require cognitive control processes that children with TBI are unable to sustain. This possibility stems from studies that have manipulated the importance of the PM task. When faced with a PM task that is important to remember, adults expend cognitive resources to monitor for the target event, creating resource demands that are sufficient to detract from ongoing task performance (Kliegel, Martin, McDaniel, & Einstein, 2001, 2004). If such monitoring strategies are instrumental in enhancing event-based PM, and if such strategies are overly demanding for children with TBI (especially those with severe TBI), then the high motivation condition should not demonstrate significant increases in PM performance relative to the low motivation condition.

Another goal of the present investigation was to provide initial data regarding possible effects of age-at-injury and time-postinjury on event-based PM, which may have important developmental implications for children with TBI. An age-at-injury effect would suggest that event-based PM is an ability that is also susceptible to early diffuse brain insult similar to that found for other cognitive and academic abilities (Anderson & Moore, 1995; Barnes, Dennis, & Wilkinson, 1999; Chadwick, Rutter, Brown, Shaffer, & Traub, 1981; Chadwick, Rutter, Shaffer, & Shrout, 1981; Dennis, Wilkinson, Koski, & Humphreys, 1995; Levin, Ewing-Cobbs, & Eisenberg, 1995). Another possibility is that children with TBI may exhibit slower developmental progress in event-based PM such that, relative to uninjured peers, PM impairments would worsen over time following insult. Neither the McCauley and Levin (2004) nor the Ward et al., (2007) experiments examined these age- and time-related variables. Extrapolating from studies of academic and adaptive functioning in children with TBI (Fletcher, Ewing-Cobbs, Miner, Levin, & Eisenberg, 1990; Thompson, et al., 1994), we also hypothesized significant age-at-injury and time-postinjury effects would be found.

Method

Participants

All participants were fluent in English. Informed consent was obtained from the parent or majority-age adolescent through an informed consent form approved by the Institutional Review Boards of Baylor College of Medicine (BCM) and the University of Texas Southwestern Medical Center. Child assent was obtained in accordance with federal regulations (45 CFR 46.404). Participants were recruited from a retrospective cohort of children who previously had been recruited as part of prospective longitudinal studies of outcome following TBI at Ben Taub General Hospital (Level-1 trauma center), and Texas Children's Hospital in Houston, Texas (both BCM-affiliated hospitals), and also at Parkland Hospital and Children's Medical Center in Dallas, Texas. Children with orthopedic injuries (OI) were recruited through a retrospective cohort, advertisements at local YMCA summer camps, newspaper advertisements, and via the BCM study volunteer website.

TBI severity was determined through the lowest post-resuscitation Glasgow Coma Scale (GCS) score (Teasdale & Jennett, 1974). This sample included children and adolescents ranging in age from 6 to 19 years: 27 children with severe TBI (post-resuscitation GCS < 8), 15 children with mild TBI (post-resuscitation GCS 13–15 without trauma-related abnormalities on computed tomography (CT) scan of the head at hospital admission), and 42 children who sustained OI not involving the head (e.g., broken bones, fractures, etc.) requiring emergency room treatment. All children were recruited a minimum of one year

post-injury for the OI and TBI groups. Children recruited for the OI and TBI groups were excluded if they had a pre-injury history of major psychiatric disorder (e.g., major depression or psychotic disorder), pervasive developmental delay, documented learning or attention disorder, or a prior head injury. Participants in the TBI groups who were on psychostimulant medications (e.g., methylphenidate) were asked, with consent of their parent/guardian and physician, to abstain from taking this medication on the morning of the assessment. This procedure was necessary and acceded to for one child in the mild TBI group and one child in the severe TBI group; according to parent/guardian reports, no other children in the study sample had been prescribed psychostimulants at the time of the assessment.

Prospective Memory Task

The following are the scripts used in the administration of the naturalistic event-based PM task. The child was asked to repeat the instructions to ensure adequate comprehension of the gist of the task. Instructions were repeated as necessary until it was clear that the child understood the task. *High Motivation Condition.* Participants were given the following verbatim instructions: “We will be doing several different types of tests this morning. I want you to listen carefully and every time I say ‘Let’s try something different,’ I would like you to say ‘Please give me three points.’ At the end of testing today, you’ll be able to trade those points in for dollar bills. The more points you get, the more dollar bills you’ll get. Ok, now tell me what it is that I would like you to do.” *Low Motivation Condition.* Participants were given the following verbatim instructions: “We will be doing some more tests. I want you to listen carefully and every time I say ‘Let’s try something different,’ I would like you to say ‘Please give me three points.’” At the end of testing today, you’ll be able to trade those points in for pennies. The more points you get, the more pennies you’ll get. Ok, now tell me what it is that I would like you to do.”

Design and Procedure

The study used a crossover design with two treatments and two periods. The order of motivation conditions (high/low versus low/high) was randomized across all participants. No washout period was included in the design. The extrinsic motivator in the high motivation condition was dollars, and the motivator in the low motivation condition was pennies. While performing other tasks during the assessment battery, the child was asked to respond “Please give me three points” every time the examiner said “Let’s try something different.” The event-based PM cue was presented nonchalantly by the examiner in casual conversation while shuffling between test materials every 20 minutes, with three PM cue presentations in each of the motivation conditions. The battery was standardized so that the same tasks were presented in the same order to each participant during the event-based PM experiment, thereby minimizing ongoing task variability between participants. The scoring algorithm for the PM task was as follows: 2 points were awarded for realizing the delayed intention (PM component) and 2 additional points were awarded for recalling the correct phrase (RM component). Thus, correct responses were awarded 4 points, and responses with incorrect RM content (e.g., “Please give me *five* points” or “Please give me *some* points”) were credited with 2 points. A maximum of 12 points was available in each condition. Participants were paid in cash depending on the number of points s/he actually requested on a 1-to-1 basis (not the event-based PM *scoring* points used for data analysis) at the end of the testing session, well after completing the event-based PM task. The maximum payment for perfect performance under both conditions was \$12.12.

Data Analysis

Statistical significance was defined as $\alpha = .05$ for all analyses unless otherwise specified. Planned comparisons were analyzed holding significance at $\alpha = .05$ and post-hoc

comparisons were adjusted using the Bonferroni correction for multiple comparisons. All analyses were conducted using SAS software, Version 9.1 for Windows (SAS Institute Inc., 2003). Categorical variables were analyzed with chi-square test. Fisher's exact test was used instead of chi-square when proportions were markedly unbalanced (percentages more extreme than 80/20). The data were analyzed as a cross-over design using a mixed model. Sequence (the effect of condition order, i.e., high motivation followed by low motivation or the reverse order) and Period (time factor for repeated measures) effects were included in the model. Sequence was nested within subject and the subject variable was treated as a random effect. Other main effects evaluated included Age-at-Test, Gender, SES (estimated by the mother's education level), Group, Motivation Condition, and the Group $\times$ Motivation Condition interaction.

Results

Sample Characteristics

The groups did not differ significantly by Age-at-Test, ($F < 1$), socioeconomic status (SES; $F < 1$), gender, $\chi^2(2, N = 84) = .56, p = .76$, or racial/ethnic composition (Fisher's exact test, $p = .70$; see Table 1). The groups did not differ by Age-at-Injury ($F < 1$) or Time-Postinjury ($F < 1$). The Mild and Severe TBI groups differed significantly for mechanism of injury (see Table 2) in that the Mild TBI group sustained more low-velocity injuries compared to the Severe TBI group (Fisher's exact test, $p < .007$). Participation rates for those in the retrospective cohorts were 23.6% in the OI group, 44.1% in the mild TBI group, and 62.8% in the severe TBI group. There were no significant differences in terms of demographic or injury characteristics between the participants and non-participants in each group.

Prospective Memory Performance

The test for a carryover effect (Motivation Condition $\times$ Order) was not significant ($F < 1$). There was no gender effect ($p = .27$) and no significant effect of SES was found ($p = .63$). The Group $\times$ Motivation Condition interaction was not significant ($F < 1$) and was removed from the model. The model was then run again without this interaction and several significant main effects were found (see Table 3). Adolescents performed better overall compared to younger children. PM performance was better in the high compared to the low motivation condition. Even though the interaction with Group was not significant, planned comparisons were conducted (using the model that included the Group $\times$ Motivation Condition interaction) to confirm that the effect of motivation was significant for each group (statistical significance was maintained at $\alpha = .05$). The high motivation condition produced significant PM improvements relative to low motivation in every group (OI ($t(80) = 3.96, p = .0002$); Mild TBI ($t(80) = 2.44, p < .02$, and Severe TBI ($t(80) = 4.47, p < .0001$; see Figure 1). The Severe TBI group performance in the *high* motivation condition was not significantly different from the Mild TBI group's *low* motivation condition performance ($t(80) = -1.61, p = .11$); however, the Severe TBI group's *high* motivation condition performance was significantly poorer than the OI group's *low* motivation condition performance ($t(80) = -2.57, p < .02$).

Finally, there were differences in PM performance across the groups. Post-hoc analyses revealed that (while holding the level of significance at the Bonferroni-corrected level of $\alpha < .0083$ for multiple comparisons), the OI and Mild TBI groups did not differ from each other under the High ($t(80) = -.27, p = .79$) or Low ($t(80) = -.37, p = .71$) motivation conditions. Both the OI ($t(80) = 5.33, p < .0001$) and Mild TBI groups ($t(80) = 3.78, p = .0003$) performed better than the Severe TBI group in the High Motivation condition, and similar results were found in the Low Motivation condition (OI vs. Severe, $t(80) = 6.47, p < .0001$; Mild vs. Severe, $t(80) = 4.56, p < .0001$).

Age- and Time-Related Effects

The effects of Age-at-Injury and Time-Postinjury were subsequently explored in the TBI groups using separate models which included main effects of Age-at-Test, Gender, SES, Sequence, Period, Group, and Motivation Condition. For the Age-at-Injury model, linear and quadratic terms for Age-at-Injury were evaluated first. The quadratic term was not significant ($F(1, 34) = 2.98, p = .09$) and was dropped from subsequent analyses. The Group $\times$ Age-at-Injury interaction was then tested and it was not significant ($F(1, 34) = 2.63, p = .11$) so it was removed. The final model was run with main effects and there was no effect of Age-at-Injury ($F < 1$). For the Time-Postinjury model, a similar procedure was used. The quadratic term for Time-Postinjury was not significant ($F < 1$) so it was dropped. The Group $\times$ Time-Postinjury interaction was tested and it was not found significant ($F(1, 34) = 1.07, p = .31$) so it was subsequently removed. The last model with main effects was run and there was no effect for Time-Postinjury ($F < 1$). Age-at-Test correlated significantly with Age-at-Injury ($\rho_s = .53, p = .0003$), but not with Time-Postinjury ($\rho_s = .30, p > .05$); Age-at-Injury correlated significantly with Time-Postinjury ($\rho_s = -0.55, p = .0002$). The correlation between Age-at-Test and Age-at-Injury may have attenuated any existing Age-at-Injury effect, but the correlation between these variables was not close to perfect (which would be required to suspect collinearity). Further, removing Age-at-Test from the models actually *decreased* the effect strength of Age-at-Test and Time-Postinjury strongly arguing against the presence of collinearity.

Discussion

In the present study, we investigated the effect of an extrinsic motivator (i.e., monetary incentive) on event-based PM performance in children and adolescents with TBI. Consonant with prior literature in pediatric TBI and PM, children with severe TBI responded to fewer event-based PM cues than children with OI and mild TBI (McCauley & Levin, 2004), or TDC (Ward, et al., 2007). Consistent with one of the hypotheses developed in the introduction, the results indicate that higher incentives improve PM in children with mild or severe TBI. Given the clear difficulties that children with severe TBI displayed with this PM task and others (McCauley & Levin, 2004; Ward, et al., 2007), it is noteworthy that a motivational technique improved performance for these children. This result suggests that children with severe TBI can improve their PM performance, but it remains to be determined if this was due to the initiation and recruitment of PM strategies or to the general effects of increased arousal in response to reward. This also opens the question regarding the effect incentives have on performance of the ongoing task in children with TBI which remains to be addressed by future investigations. Although these children demonstrated substantial improvement under high motivation conditions, their performance nevertheless fell short of the OI and the mild TBI groups' performances under comparable conditions.

These results are encouraging as they are the first to examine the efficacy of a monetary incentive on event-based PM in children with TBI. While the choice of dollars versus pennies to distinguish high versus low motivators is arbitrary, it is a reasonable starting point. It remains to be seen if other classes of extrinsic or intrinsic motivators could significantly improve event-based PM in pediatric TBI. Moreover, these results also support the idea that motivation is an important factor to consider in PM research of TDC and children and adolescents with OI (Baddeley, 1990; Best, 1992; Einstein & McDaniel, 1996; Gentry & Herrmann, 1990; Winograd, 1988) as the event-based PM cue response rate was significantly improved by a high-value incentive in the OI group.

It should be noted that there was no significant difference in PM performance between the OI and mild TBI groups, a departure from previous findings which was due, perhaps, to the absence of monetary incentives in previous studies. One other potentially important feature

of the two previous studies finding PM deficits for children with mild TBI is that the PM cue was a stimulus dimension that was not related to the demands of the ongoing activity. For instance, in McCauley and Levin (2004), the PM target cue was any word presented in blue (perceptual dimension), which was not pertinent to the ongoing category-decision activity (requiring semantic processing). In Ward et al. (2007) the PM target cue was italicized letters (perceptual dimension), whereas the ongoing activity was lexical decision (requiring semantic processing). Accordingly, the PM cues in these studies were not focal to the ongoing activity (see McDaniel & Einstein, 2007, for detailed development of this theoretical idea). Such nonfocal event-based PM tasks appear to be more difficult than are PM tasks in which the PM cue is focal to the ongoing activity (see e.g., Einstein, et al. 2005; McDaniel, Einstein, & Rendell, 2008), and more importantly for present purposes, one recent study found that young children demonstrated worse PM relative to older children for nonfocal but not for focal PM tasks (Stokes, Pierrousakos, and Einstein, 2005; as cited in McDaniel & Einstein, 2007). This theoretical analysis, and the related finding with children, raises the possibility that the current absence of a PM deficit for children with mild TBI was a consequence, at least in part, of the presence of a focal PM cue. Arguably, the present experiment provided a PM cue that was focally processed in the course of the experimental activities. Specifically, the PM cue was the phrase “Let’s try something different,” a phrase that was uttered by the experimenter during the course of the experimental activities to alert the children that they would be transitioning to a different ongoing task. Thus, the children were processing the meaning of the phrase as part of the ongoing task activities, and this meaning also served as the PM cue. It remains for further research to more directly demonstrate that TBI-related PM deficits for children with mild TBI may be attenuated or eliminated in event-based PM tasks with focal cues.

There was not a significant gender effect which is consistent with the absence of any reported gender effects in the adult PM literature (Einstein & McDaniel, 1990; Kidder, Park, Hertzog, & Morrell, 1997; Maujean, Shum, & McQueen, 2003) or the few studies that examined gender effects in the pediatric PM literature (Kerns, 2000; Kerns & Price, 2001). Although SES and other non-injury variables are known to affect outcomes of children with TBI (Taylor, 2004; Taylor, et al., 1999; Taylor, et al., 2002; Yeates, et al., 1997), no significant effect of SES on event-based PM performance was found. To our knowledge, no other studies of PM in children with or without TBI have included SES in their analyses, thus preventing comparison.

Limited information is available regarding age-at-injury and time-postinjury effects on a number of areas of cognitive functioning in children following TBI. The current study is the first known to explore these effects on event-based PM in pediatric TBI. Contrary to our hypotheses, there was no effect of age-at-injury or time-postinjury for event-based PM. This was unexpected as previous research has indicated that, on the whole, the immature brain appears to exhibit greater vulnerability as opposed to plasticity in response to early *diffuse* insult. It is reasonably well-established in the pediatric TBI literature that children seriously injured in infancy or early childhood are more likely to be cognitively compromised than when injured in later childhood or adolescence (Anderson & Moore, 1995; Barnes, et al., 1999; Chadwick, Rutter, Brown, et al., 1981; Chadwick, Rutter, Shaffer, et al., 1981; Dennis, et al., 1995; Levin, et al., 1995). There is also evidence to suggest that a mild TBI sustained in the preschool years may result in persistent cognitive deficits as well (Gronwall, Wrightson, & McGinn, 1997). Some areas of cognition appear to be especially susceptible to early insult including perceptual-motor skills (Anderson & Moore, 1995; Dennis, 2000), language (Chapman, 1995; Chapman, Levin, Wanek, Weyrauch, & Kufera, 1998; Chapman, et al., 2001; Chapman, et al., 1997; Ewing-Cobbs, Levin, Eisenberg, & Fletcher, 1987; Ewing-Cobbs, Miner, Fletcher, & Levin, 1989), attention (Dennis, et al., 1995; Kaufmann, Fletcher, Levin, Miner, & Ewing-Cobbs, 1993), and metacognition (Dennis, Barnes,

Donnelly, Wilkinson, & Humphreys, 1996). Although more study is needed, our results suggest that event-based PM *may* be an area of cognitive functioning that is not especially susceptible to early brain insult, but one that is sensitive to injury severity. It should be noted that the youngest children with TBI in the current sample was 6 years old and the inclusion of more children at a younger age-at-injury may yet demonstrate an age-at-injury effect. The degree to which age-at-injury and time-postinjury effects could be detected may depend on other event-based PM task parameters which were not directly explored in this study (e.g., naturalistic vs. experimental design, level of cognitive demand of the ongoing tasks, etc.). Time-postinjury effects are rarely studied in pediatric TBI (Taylor & Alden, 1997). Results from the current study suggest that there is not a substantial effect of time-postinjury, but it must be kept in mind that all of the participants in the TBI groups were at least one year postinjury. This suggests that once recovery has largely “stabilized” by the end of the first or second year postinjury (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2000; Ewing-Cobbs, et al., 2004; Ewing-Cobbs, et al., 1997; Ewing-Cobbs, Fletcher, Levin, Iovino, & Miner, 1998; Levin, et al., 1995; Taylor, et al., 1999; Taylor, et al., 2002; Yeates, et al., 2002), event-based PM performance in children with severe TBI may not continue to lag behind (compared to children with OI) at an accelerating rate which has been found in studies of adaptive and cognitive functioning following TBI (Fletcher, et al., 1990; Thompson, et al., 1994).

There are some limitations in this study that warrant brief discussion. Firstly, the study design was cross-sectional and retrospective which may have led to selection biases. A more precise examination of the recovery of event-based PM impairments in the acute postinjury phase to at least one year after insult and further exploration of age-at-injury and time-postinjury effects in event-based PM could be performed in a prospective, longitudinal design. The study to achieve this is currently underway. An assessment of RM was not performed to assess the degree to which poor RM accounted for impaired PM performance. Previous studies have found that PM and RM are not strongly related in adults and healthy elderly (Brandimonte & Passolunghi, 1994; Driscoll, McDaniel, & Guynn, 2005; Einstein & McDaniel, 1990; Huppert & Beardsall, 1993; Kidder, et al., 1997; Kvavilashvili, 1987; Maylor, 1990; McDaniel & Einstein, 1993; Salthouse, Berish, & Siedle, 2004) or in TDC (Kvavilashvili, Messer, & Ebdon, 2001). While there is evidence that these two memory types are closely related quite early in development, they tend to dissociate quickly (Guajardo & Best, 2000; Rother & Best, 1993). However, studies of adults with TBI have yielded contradictory findings on the relation between PM and RM (Groot, et al., 2002a; Henry, et al., 2007; Mathias & Mansfield, 2005). Any attempt to generalize these conflicting results in adults with TBI to children with TBI is unwise, so it remains an open question as to what degree PM functioning in children with TBI is dependent on RM and medial temporal lobe integrity. Future studies of PM in children with TBI should take this and other cognitive functioning into account to further delineate the direct effects of TBI on event-based PM. *Conclusions* In conclusion, the current study has provided additional evidence that children and adolescents with severe TBI have impaired event-based PM relative to those with mild TBI and OI controls. One important new finding is that this impairment can be significantly improved through the use of a monetary incentive, though not to the levels of children with OI. Further, children with mild TBI also benefit from monetary incentive, comparable to performance levels of OI controls. Contrary to expectation, main effects of age-at-injury and time-postinjury were not significant. These results provide a promising new technique that could be implemented straightforwardly in rehabilitation programs to effectively reduce PM impairments in children and adolescents with severe TBI.

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Figure 1.

Although the Group $\times$ Motivation Condition interaction was not significant, event-based prospective memory least-squares mean scores by Group and Motivation Condition are shown here to illustrate the significant improvement within each group under the High- vs. Low-Motivation conditions. Error bars represent standard errors.

Demographic and Injury Data

Variable	OI (n = 42)			Mild TBI (n = 15)			Severe TBI (n = 27)			df	F	p
	M	SD	Range	M	SD	Range	M	SD	Range			
Age-at-Injury	10.2	3.3	3–17	9.5	4.8	1–15	8.8	3.5	2–14	2.81	1.12	.33
Age-at-Test	13.4	2.8	6–19	14.3	3.0	9–19	13.1	3.3	6–18	2.81	.82	.44
Time-Postinjury	3.2	2.6	1–11	4.8	4.5	1–15	4.3	3.0	1–10	2.81	1.81	.17
SES	13.3	1.6	12–16	13.1	1.4	12–16	12.6	2.7	4–18	2.81	.87	.42
GCS	--	--	--	14.9	0.3	14–15	5.6	2.0	3–8	--	--	--
	AA	H	C	AA	H	C	AA	H	C	df	χ^2	p
Race	12 (28.6%)	6 (14.3%)	24 (57.1%)	2 (13.3%)	4 (26.7%)	9 (60.0%)	8 (29.6%)	5 (18.5%)	14 (51.9%)	4	2.25	.69
	F	M		F	M		F	M				
Gender	19 (45.2%)	23 (54.8%)		7 (46.7%)	8 (53.3%)		10 (37.0%)	17 (63.0%)		2	.56	.76

Age-at-Injury, Age-at-Test, and Time-Postinjury variables are in years. SES = Socioeconomic status estimated through mother's highest level of education in years GCS = Glasgow Coma Scale score AA = African-American; H = Hispanic; C = Caucasian

F = Female; M = Male

Table 2

Mechanisms of Injury for the Mild and Severe TBI Groups

Mechanism	Mild TBI (<i>n</i> = 15)	Severe TBI (<i>n</i> = 27)
MVA	4 (26.7%)	13 (48.2%)
MCA	0 (0%)	1 (3.7%)
RV	0 (0%)	2 (7.4%)
Auto-Bicycle	4 (26.7%)	2 (7.4%)
Fall	2 (13.3%)	1 (3.7%)
Hit by Falling Object	2 (13.3%)	0 (0%)
Sports/Play	3 (20%)	1 (3.7%)
Auto-Pedestrian	0 (0%)	7 (25.9%)

Fisher's exact test, *p* < .007

MVA = Motor vehicle accident MCA = Motorcycle accident RV = Recreational or off-road vehicle

Table 3

Type III Tests of Fixed Effects for Event-Based Prospective Memory

Source	df	F	P
Age-at-Test	1, 77	5.62	.02
Gender	1, 77	1.24	.27
SES	1, 77	.23	.63
Sequence	1, 77	.03	.87
Period	1, 82	.63	.43
Group	2, 77	26.94	< .0001
Motivation Condition	1, 82	41.30	< .0001

SES = Socioeconomic status estimated through mother's highest level of education in years