Prospective memory 7 years after severe childhood traumatic brain injury – the TGE 2 prospective longitudinal study

Agata Krasny-Pacini, Leila Francillette, Hanna Toure, Dominique Brugel, Anne Laurent-Vannier, Philippe Meyer, Jonathan Evans, Mathilde Chevignard

Prospective Memory seven years after severe childhood traumatic brain injury - the TGE 2 prospective longitudinal study: a brief report.

Title: Prospective Memory seven years after severe childhood traumatic brain injury - the TGE 2 prospective longitudinal study

Running head: Prospective Memory after childhood TBI

Author(s) full name(s) written as First Name then Last Name, and highest academic degree(s):

Agata Krasny-Pacini, PhD[1,2,3], Francillette Leila[4]; Toure Hanna, MD[4,5] ; Brugel Dominique, MD[4,5] ; Laurent-Vannier Anne, MD[4,5]; Meyer Philippe,MD[7], Evans Jonathan, PhD[8], Chevignard Mathilde, PhD[3,4,6]

The name(s) of the institution(s), section(s), division(s), and department(s) where the study was performed and the institutional affiliation(s) of the author(s) at the time of the study:

[1] Outreach Department for Patients With Acquired Brain Injury, University Rehabilitation Institute Clemenceau Strasbourg, France
[2] Pediatric Orthopedics Department, Hautepierre Hospital, Strasbourg University Hospitals, Strasbourg, France;
[3] Sorbonne Universités, UPMC Université Paris 06, Inserm, CNRS, LIB, F-7013 Paris, France
[4] Rehabilitation Department for Children with Acquired Brain Injury; Hôpitaux de Saint Maurice; Saint Maurice; France
[5] Outreach team for Children and Adolescents with Acquired Brain Injury; Saint Maurice Hospitals, Saint Maurice, France
[6] Groupe de Recherche Clinique Handicap Cognitif et Réadaptation – UPMC Paris 6 ; France
[7] Université Descartes Paris5, Hôpital Universitaire Necker, Anesthesiology Department, Pediatric neuro critical care unit 75015 Paris
[8] Institute of Health and Wellbeing, University of Glasgow, The Academic Center, Gartnavel Royal Hospital, Glasgow, United Kingdom

Acknowledgment of financial support, including grant numbers:

This research was co-funded by the French Ministry of Health's general direction of health and direction of research, studies, assessment and statistics, by the national fund for health insurance of salaried workers, the national fund for health insurance of independent workers, by the national fund for solidarity and autonomy and by the national institute for prevention and education for health, in the call for research projects launched by the IReSP in 2011.

We wish to thank Sabine Lancien, Maria de Agostini, Sylvie Escolano, for their participation in the data collection and analyses in the initial inclusion and follow-up of this cohort. We also thank Laurence Watier for her participation in the design and analyses of the results of the 7-year follow-up part of the study.

Explanation of any conflicts of interest: The authors report no conflict of interest

Name, address, business telephone number, and e-mail address of corresponding author:

Dr. Agata Krasny-Pacini (corresponding author)

Institut Universitaire de Réadaptation Clemenceau-Strasbourg

45 bd Clemenceau

67082 Strasbourg, France

E-mail: agatakrasny@yahoo.com

Abstract

Objective: to investigate long term outcome in prospective memory (PM), seven years after childhood severe traumatic brain injury (TBI), in a prospective longitudinal cohort. Participants: 76 young individuals (aged 7-22 years): 39 patients with a severe accidental TBI included prospectively seven years earlier, aged 0-15 years at injury, and 37 controls individually matched on age, gender and parental education. Main outcome measures: three novel short PM tasks varying in the delay, motivation and context (ecological versus paper and pencil task). Results: individuals with severe TBI showed significantly poorer

PM than matched controls in the two low-motivation PM tasks: (1) the ecological long-delay task consisting of sending a letter on a rainy day (p=0.047, odds ratio = 2.6); (2) the non-ecological short-delay task consisting of taking off post-its while identifying facial emotions (p=0.004, r=0.34). Differences in PM on the high motivation were not significant. PM is impaired several years post severe TBI

Prospective memory (PM) is the ability to remember to perform intended activities [1]. Children with PM impairment can fail to deliver important messages to parents, forget appointments, or fail to bring necessary items for planned activities. Successful PM requires (a) that you remember what has to be done (this includes remembering the action to be performed and the proper target event) and (b) that you remember to perform the action at the appropriate time or in response to the appropriate target event[2]. PM tasks require retrospective memory to remember the task, but depend on executive functions (EF) [3] for successful goal maintenance, retrieval and execution at the right moment. At least three attributes are accepted as characterizing a PM task[4]: (1) a delay between formation of the intention and the opportunity to carry it out; (2) absence of an explicit reminder to carry out the task at an appropriate moment; (3) the need to interrupt one's ongoing activity in order to carry out the intention.

One of the most influential models of PM is the Multiprocess Framework of McDaniel and Einstein[5]. This framework suggests that there are several ways by which prospective remembering may be achieved and several factors that influence PM performance. Thus, PM may be accomplished by the strategic allocation of monitoring resources (i.e. actively monitoring for PM target cues), or by more automatic memory processes whereby a PM cue automatically triggers memory for the intended action. Probability of remembering is affected by factors such as the importance of the task, PM cue distinctiveness, level of association between cue and intended action, whether the PM cue is focal (i.e. will be encountered and attended to as part of an ongoing task) or non-focal (i.e. is present but not attended to as part of the ongoing task), how demanding the ongoing task is, and the extent of pre-task planning. Most of the studies that have identified these influences on PM performance have, however, involved adults and it is less clear whether the same factors may be relevant to the PM of children.

Although PM problems are reported as a major concern by the parents of children with traumatic brain injury (TBI) [6], there are surprisingly few studies that have evaluated PM in children with TBI (as opposed to adults with TBI [3,7,8]). Ward et al. [9] found that children with TBI had poorer PM than their uninjured peers, and that this may be attributable to worse executive functioning, especially if the PM task is cognitively demanding. Recently, a real cooking task (Children's Cooking Task[10,11]) has been used to explore PM in children with acquired brain injury[12]: it showed a striking impairment in PM, with older (14-20 years) children with brain injuries performing close to young (8-10 years) healthy controls. McCauley et al.[13,14,15] used a monetary incentive to increase children's performance on an event-based PM task consisting of asking the examiner for points (exchangeable for dollars or for pennies) before each new neuropsychological test. Children with severe TBI were impaired on PM. Motivation (dollars versus pennies) influenced PM performance of controls and of children with chronic severe TBI[13], while it had no effect on children with subacute severe TBI[14,15]. However even the chronic severe TBI group performance remained significantly below the low-motivation condition performance of controls.

Limitations of these studies were that they used either a biased sample of children with TBI (recruited from patients referred for rehabilitation) or, for the one prospective study[15], children examined early after their TBI. Therefore, the frequency and degree of PM impairment after severe TBI in the long term is unknown. This is particularly needed information because PM can impair functional memory and daily life even more than episodic memory[6], but most patients in clinical practice (and even in research or legal expertise) are assessed only on the latter.

The aim of this study was to investigate long term PM outcome following childhood severe TBI, using short novel ecological PM tasks in a prospective longitudinal cohort. Our hypothesis were that (1) individuals with a TBI would perform more poorly on all PM tasks; (2) in high motivation task, individuals with TBI would differ less from controls than on low motivation tasks; (3) PM performance would be better in older individuals.

Methods

Participants: Participants were a cohort of children with severe accidental TBI [defined as Glasgow Coma Scale (GCS) score of 8 or lower at admission and/or an Injury severity score[16] > 16], aged 0-15 years at the time of inclusion and recruited between 2005 and 2008 at the pediatric neurosurgical intensive care unit of Paris 5 University "Necker Enfants Malades" Hospital. The main aim of the follow up of this cohort was to assess cognitive functioning, participation and quality of life several years post-severe TBI (manuscripts in preparation). Exclusion criteria at the time of cohort recruitment were: children with no vital signs upon admission, children with non-accidental head injury, previous history of diagnosed neurological, psychiatric or learning disorders. Patients were assessed at seven years post inclusion for PM. By the seven year testing, the sample therefore contained both children (<18 years) and young adults (≥18 years). A population-based group of healthy controls was recruited at the seven year follow up point. Controls were matched individually in terms of age (±3 months of age), gender and parental education (± 2 years of education) with each individual from the TBI group. For controls, the exclusion criteria were the same as for the TBI sample plus the absence of any TBI history. Socio-demographic data collected included language spoken at home, type of schooling and TBI characteristics for the TBI group. This study is part of a larger study, which was approved by the CPP IDF VI ethic committee.

PM tasks: Three ecological tasks of PM were developed for the study. The tasks were embedded in an assessment of outcome and quality of life following TBI that is not reported here. Because PM performance is influenced by motivation[13], by the ecological features of the task (meaningful task versus exercise type task, home versus laboratory context)[17] and by delay[18] between formation of an intention (PM instructions in this case) and the opportunity to carry out the intention, the tasks were designed to vary on these three factors.

Low-motivation, ecological context, ecological task, long delay: the letter task: participants received an envelope with the address of the hospital and were asked to send to the examiner a short note the next time it rained in the place they live. The letter had to contain four pieces of information: name of the participant, date, place and a mention of rain. The participant was also told than even if s/he forgot to send the letter the first time it rained, s/he could still do it later on, the most important thing being to send the letter at some point. Instructions were given twice to the participant during the testing and the examiner checked if the individual had understood and encoded the instructions by asking him/her to repeat them. The task was not explained to parents, but they were warned the participant had a task to do when s/he was at home. They were told that this was the reason why s/he had an envelope for the hospital. They were asked not to help the participant. Data from the letter task was treated as categorical (success or failure) in relation to two components: (1) sending the letter with all adequate information (which comprised a retrospective memory component - the letter content - as with most PM tasks of daily life) and (2) sending the letter irrespective of content (which assessed the prospective component of PM, as the child only had to remember the intention to send a letter).

High-motivation, ecological task, non-ecological context, medium delay task: the amusement park prize-draw competition: at the beginning of the testing, individuals were told they could enter a prize-draw competition to thank them for participating in the study. The examiner showed them a colored entry sheet that mentioned the draw. They were told that they could enter their name for the draw after the end of testing. The prize was two entries for an amusement park of their choice. At the end of the testing (6-7 hours after the instructions for the participants with TBI and 2.5-3 hours after the instructions for the controls who had less tests to complete), the examiner said "ok, we have finished all the tests, well done". If the participant did not ask spontaneously to enter the draw, the examiner made discreetly visible the colored competition entry-sheet so that it came into the participant visual space but without giving it to him/her. If the participant did not react to this visual cue, the examiner used a verbal non-specific cue: "did you want do to something else before leaving?". If this was not enough, the participant was reminded explicitly s/he could enter his/her name for the draw competition. Data from the draw competition PM task was treated as ordinal: 3 points were awarded for individuals succeeding without cues (individuals asking spontaneously to enter the competition at the end of testing); 2 points for individuals needing the visual cue only; 1 point for individuals needing the verbal cue and zero points for individuals needing an explicit reminder to enter their name for the draw. On the competition entry-sheet the participant was instructed to add his/her name and telephone number. In addition, there was an instruction to read and to tell the examiner which amusement park s/he would like to go to if s/he won, and to fold the completed sheet in two for the draw box. These tasks did not constitute PM tasks as they could be carried out immediately, but tested the child's ability to follow through a series of task instructions.

Low-motivation, exercise-type, non-ecological context, short delay (retrieve-execute): post-it/faces task: in the last task, the delay was short. For this task, we used two existing tests as the on-going task: the NEPSY-2 affect recognition subtest (< 18 years) and the Bordeaux Faces Test[19] (≥ 18 years). In the adult version and most items of the child version, the individual had to name an emotion by looking at a face. Colored post-its were placed on some pages of these tests. The individuals were told to remove all the post-its apart from the pink ones throughout the task, but only after they had stated the emotion, not before. There were 9 post-its to remove (and 4 pink post-its to leave), placed in pre-determined positions on nine of the 39 (children version) or 40 (adult version) pages of the test. The instruction to take off only post-its of certain colors was meant to increase task difficulty and prevent the individuals from automatizing post-it removal without effortful processing. Face recognition was used as the ongoing task, because we considered this close to everyday life: usually face recognition happens conjunctively with complex reasoning ("what have I said? Is he angry or sad?"), prospective memory or multitasking (thinking of the bus arriving in 5 minutes while searching for keys and trying to figure out if our companion is cross following the previous conversation).

Participants: Eighty-one children were included at the acute stage of TBI between January 2005 and December 2008. Causes of accidental TBI were motor vehicle accidents and falls. Sixteen children died during acute care, leaving 65 children entering the follow-up. Most children (83%) received multidisciplinary rehabilitation after acute care, similar to that described by Chevignard et al[20]. By seven years post-injury, 26 were lost to follow-up, leaving 39 patients, aged 7-22 at PM assessment. Three of them could not be tested for PM (one was too fatigued, one had a severe depression, one agreed to participate initially and then refused to finish the testing).

Statistical analysis: All analyses were performed with IBM SPSS 21. Individuals with severe TBI participating in the study were compared to individuals lost to follow-up, by Mann-Whitney tests on GCS score, coma length, age at injury, and one-year post injury intellectual quotients and executive functioning[21]. Further, Chi squared test was used to compare participants for language spoken at home, gender and parental education (defined as high if above high school or low if high school and below). The same tests were used to compare the participating severe TBI group to the control group on age at testing, parental education, gender and language spoken at home. Controls and individuals with TBI were compared for categorical PM data using Chi squared test. Effect size was calculated by odds ratios. The draw competition PM data was ordinal and therefore analyzed also using Mann-Whitney test. The Post-it task yielded a score of number of post-its taken out which was analyzed between groups using Mann-Whitney tests because score distribution was not normal, and effect size was calculated using $r = \frac{z}{\sqrt{N}}$ and interpreted according to Cohen's guidelines[22]. Additionally, among each group (TBI and controls), adults' performance was compared to childrens' performance using Mann-Whitney test or Fisher's exact test.

Results and Discussion

Individuals remaining at 7 years follow-up did not differ significantly from those lost to follow-up on GCS score, coma length, parental education, language used at home, age at injury, nor on their one year post-injury intellectual quotients and executive functioning (all ps>0.05). Detailed description and results of IQ and EF used at one year follow-up can be found elsewhere[21]. Most individuals (26) were still children at the time of the study but 13 had become young adults. Thirty-seven controls were recruited (two controls could not be recruited within the time frame of the study). There was no significant difference between the TBI and the control groups on gender, age at testing, parental education, and language spoken at home (see table 1).

	Individuals with severe TBI	Controls	p
N	39	37	-
Age mean in years (SD)	15.1 (4.4)	15.1 (4.8)	.97
Gender (N female/N male)	13/26	13/24	.53
Parental education (high school and below; N, %)*	19 (49%)	13 (35%)	.17
Language spoken at home (French exclusively, N, %)	22 (56%)	26 (72%)	.20
Schooling: Ordinary schooling/Specialized schooling/ Finished education (%)**	61.5/23.5/15	100/0/0	<0.001
Age at injury in years (SD)	8.9 years (4.5)	-	
GCS score (SD)	6.5 (1.4)	-	
Initial coma length in days (SD)	6.4 (5)	-	

GCS: Glasgow Coma Scale

* Each control was matched individually to one patient in terms of age, gender and parental education. However, due to recruitment difficulties of individuals from parental very low education background, the last 4 controls had to be matched more loosely on parental education.

**Controls could not be matched for type of schooling as the exclusion criteria excluded controls with neurological and learning disorders and therefore children needing special schooling were excluded.

Table 1: Demographic variables of the TBI and the control groups and injury variables of the TBI group.

PM tasks: Results are summarized in Table 2.

	Individuals with severe TBI	Controls	Test statistic
Letter Task			
% individuals who succeeded to send the letter with all information required	20%	49%	$\chi^2(1) = 6.68$, $p=0.01$* odds ratio = 3.7
% individuals who succeeded to send a letter, irrespective of adequate content	44%	68%	$\chi^2(1) = 3.96$, $p=0.047$* odds ratio =2.6
Prize Draw Competition			
% individuals who spontaneously entered their name for the draw	28%	27%	U=660, z=-0.07, p= 0.94 $\chi^2(3) = 2.30$, $p=0.51$
% individuals who needed ***visual*** cues to enter their name for the draw	19%	14%	
% individuals who needed ***verbal*** cues to enter their name for the draw	31%	46%	
% individuals who needed an explicit reminder to enter their name for the draw	22%	13%	
Post-it Task			
% individuals who totally forgot to take out the post-its	36%	13%	U=420.5, z=-2.87, p= 0.004*, r=0.34 $\chi^2(2) = 8.43$, $p=0.015$*
% individuals who remembered to take off all required (non-pink) post-its	28%	60%	
% individuals who partially remembered to take off required (non-pink) post-its	36%	27%	

TABLE 2 : Results of Prospective Memory tasks in the TBI group and the control group

Letter task – Overall, 56 % of participants sent a letter. Individuals with TBI failed significantly more on both the prospective and the retrospective component of the task. One letter from a control contained weather and date information but no name and therefore it was not included in the analysis. If an individual had sustained a TBI he was 2.6 times more likely to forget to send the letter and 3.7 times less likely to send a letter with all required information.

Amusement park prize-draw task - Although unequal delay between instructions and opportunity to carry out the intention may have disadvantaged the individuals with TBI on this task, there was no significant difference between individuals with TBI (Mean Rank = 36.8) and controls (Mean Rank =37.16) in the prize-draw competition (U=660, z=-0.07, p= 0.94).

Capacity to follow the 5 instructions to enter the draw: When entering the amusement park draw competition, individuals with TBI managed to follow less instructions (fill in name, read instructions, fill in table with phone number, state the amusement park they would like to go to, fold the participation sheet for the draw) than controls (mean in TBI group = 3.7, mean in controls = 4.2; Mann-Whitney U=452.5, z= -2.20, p= 0.028, r=0.26).

Post-it Task- Individuals with TBI remembered to take out significantly less post-its (Mean = 5.06, SD = 4.07) than their matched controls [Mean = 7.35, SD = 3.07, (U=420.5, z=-2.87 , p= 0.004, r=0.34)]. Apart from one control who took out all four pink post its, individuals respected the rule of leaving the pink post its equally well in the TBI and the control group (p = 0.16). Performance on the on-going tasks (emotion recognition) was not significantly different between controls and individuals with TBI (p=0.11 for children and p = 0.12 for adults).

Demographic and injury effects: None of the PM tasks was influenced by parental education, initial GCS or coma length. In the whole sample, individuals whose parents had higher education (Mann-Whitney

U=789, z=2.28, p= 0.023, r=0.27) and who spoke exclusively French at home (Mann-Whitney U=377, z=-2.34, p= 0.019, r=0.28) followed more instructions.

Age at testing effects: Children performed poorer than young adults on the Post-it Task, irrespective of injury status (in the TBI group: Mann-Whitney U=210, z=2.61, p=0.009, r=0.38; in the typically developing controls: Mann-Whitney U=237, z=2.69, p=0.007, r=0.44). On the prospective component of the letter task (sending a letter irrespective of content), there was a trend for adults to perform better than children in both groups (Fisher's exact test = 0.068 in the TBI group and 0.084 in the typically developing controls group). There was no difference between younger and older participants for the prize-draw competition and the overall letter task.

Regarding the study hypothesis, individuals with severe TBI showed significantly poorer PM than matched controls in the two low-motivation PM tasks. Differences in PM on the high motivation task were not significant. Developmental effects varied across tasks: children performed poorer than young adults on the Post-it Task, irrespective of injury status; there was no difference between younger and older participants for the other tasks.

This is to our knowledge the largest cohort of patients having sustained severe childhood TBI. Most cohorts usually include heterogeneous samples of children with a range of TBI severity, where severe TBI are usually relatively few. It is also to our knowledge the first cohort study that assessed PM at long-term post injury. The prospective longitudinal nature of this study was expected to capture more positive outcomes compared to retrospective studies based on the inclusion of patients in rehabilitation departments; nonetheless PM impairment appeared significant. This should raise awareness about frequent PM deficits, that are not explored by usual memory tests used in children and adults, and that should be given more attention, given the consequences of PM deficits on everyday life.

Our result are consistent with previous publications on both developmental[23] and clinical samples[13] that showed that deficits in PM performance may be reduced under high motivation conditions. The lack of age effects in the high motivation condition may have been due to an unequal degree of motivation, as the experimenter noted qualitatively that younger children seemed more enthusiastic about the prize-draw, while some young adults and adolescents appeared less interested (one did not even want to enter the draw). An unequal motivation effect was probably also present for the letter task, which was designed to be a low motivation condition: children aged 7-10 seemed very proud to have a letter to write and post and many parents reported the enthusiasm of their child for the task. Also, we cannot exclude that parents helped their children with the letter task, because young children are not expected to send a letter on their own and it may have seemed natural for their parents to help them despite the examiner's explanations. There were some indications, albeit not statistically significant, that younger children had more difficulties than older children on the letter posting task. This may simply have been because younger children are less familiar with posting letters than older children and adults. Unusual PM cues that have fewer general associations than more familiar cues are considered to be more likely to prompt PM task performance[2] but less is known about the effect of familiarity of the intended action, particularly in children, something which needs to be explored further.

Whether PM improves with age is still a matter of debate. Small children as young as two can succeed in PM if motivation is high (remind their Mum to buy them sweets)[23]. Age effects that have been documented in the literature may be entirely attributable to factors such as: (1) unequal difficulty of the on-going task, allowing less attentional resources to PM tasks in younger children; (2) retrospective memory component; (3) motivation. When taking these into account (adapting ongoing task difficulty to the child's age, verifying if PM failure is not due to the retrospective memory component that is known to be weaker in younger children, creating tasks that are highly motivating for children), age effects of PM are typically small[24]. This is in line with our findings, as the prize-draw competition showed no difference between age groups.

<u>Limitations:</u> The way the tasks were designed did not allow to systematically evaluate the three variables of delay, motivation and context, because comparable conditions were not constructed for each of the two conditions of the three variables. The differences observed between the high and low motivation tasks may be due to unequal task difficulty and not the motivation factor per se. Therefore, it is difficult to draw firm conclusions, on how motivation and the other factors influenced PM. Most tasks generated

categorical or ordinal data that did not allow assessment of PM impairment severity. The advantage of using these three different 1-item PM tasks that tried in different ways to be close to real life (ecological context of the letter task, ecological real-life activity of entering an amusement park draw, use of joint facial recognition and PM task similar to real life conditions) was counterbalanced by the question of reliability and validity of those tasks. However, this study was not aiming at precisely characterizing and quantify PM impairment but rather provide pilot data on PM without relying on usual paper-and-pencil tests that underestimate PM deficits[12] or don't even screen for PM impairment. It would have been interesting to assess PM using questionnaires of PM in daily life completed by parents, which was not possible in this study, as families already had several questionnaires and interviews to complete for other parts of the study. The burden of assessment would have been too high. Also, because all individuals were assessed 7 years post injury, those injured youngest had also the youngest age at testing; therefore, age at injury effects could not be explored (would have been confounded with developmental effects). Finally, it would be interesting to explore if poorer EF contributed to poorer PM performance as the role of EF in PM in children is a matter of debate[24] and to explore if poorer retrospective memory or attentional resources could account for the differences in PM observed in our tasks.

The post-it task could be argued to reflect rather a dual task (dependent more on working memory ability than prospective memory), as the target (non-pink post-its) were relatively frequent (9 targets out of 40 pages), while other experimental laboratory PM tasks tend to use less frequent targets (e.g.: 2 out of 13[25], 1 out of 20[26]) but not always (e.g.: 3 out of 10[1]). Probably, the higher the number of target stimuli, the more the task relies on working memory, because the frequent target acts as a constant reminder of the intention and is therefore kept in the attentional focus of working memory[27]. On the other hand, if the target is infrequent, as the on-going task proceeds, the intention drops progressively to lower attentional levels. Further, dual task performance is more about switching between two activities while PM more about delaying an intention until a favorable moment to execute it is encountered. Our post-it task may have better assessed PM if the target stimuli were less frequent. Further, because children had to switch between facial recognition, post-it removal and pink post-it inhibition of removal, the task evaluated probably both working memory and PM. The post-it task was complex, with the element of removing post-its on some pages, but not removing the pink ones. To some extent the task may have been considered 'non-focal'[28] in that the ongoing task (face emotion recognition) did not require conscious attention to the post-its, though they were present during the course of the task. For non-focal tasks it is suggested that a greater degree of strategic monitoring is required, as memory associations with the intended action are not triggered automatically[5]. Given that executive skills develop with age, this may explain why the young adults were better than the children in both the TBI and control groups. Similarly given the common impact of TBI on EF, this may explain why the TBI group were poorer than the control group.

Implications: There is now more evidence that PM is a common sequelae of childhood severe TBI[6,12,13], that can persist over time. When assessing sequelae post TBI, the evaluation should include an assessment of PM in addition to classical episodic memory assessment, especially in legal expertise in order not to underestimate memory impairment in daily life. When PM is found impaired, interventions should aim at using high motivation tasks/incentives for most essential PM tasks of daily life as motivation may be an enhancer of PM performance[13]. However other methods should also be considered (e.g. pager, alarms), given the frequent overall PM impairment.

Conclusions: Across the large age span of 7-22, individuals with severe TBI systematically recruited for a longitudinal prospective follow-up showed significantly poorer PM seven years' post-injury than matched controls in two PM tasks. The ecological task consisting of sending a letter on a rainy day, showed significant differences both in its PM component (sending the letter irrespective of adequate content), and the overall task (sending the letter containing all adequate information). Individuals with TBI had more difficulty performing a simple PM task while identifying facial emotions. Performance on a high motivation PM task did not differ from controls. High motivation conditions may enhance PM. More ecological tests of PM should be designed and administered to assess PM after childhood severe TBI.

References

1. Kliegel M, Jäger T. The effects of age and cue-action reminders on event-based prospective memory performance in preschoolers. Cognitive Development. 2007;22:33–46.

2. Einstein GO, McDaniel MA. Normal aging and prospective memory. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1990;16:717.

3. Fish J, Wilson BA, Manly T. The assessment and rehabilitation of prospective memory problems in people with neurological disorders: A review. Neuropsychol Rehabil. 2010;20:161–79.

4. Ellis J, Kvavilashvili L. Prospective memory in 2000: Past, present, and future directions. Applied Cognitive Psychology. 2000;14:S1–S9.

5. McDaniel MA, Einstein GO. Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. Applied cognitive psychology. 2000;14:S127–S144.

6. Ward H, Shum D, Dick B, McKinlay L, Baker-Tweney S. Interview study of the effects of paediatric traumatic brain injury on memory. Brain Injury. 2004;18:471–95.

7. Shum D, Fleming J, Neulinger K. Prospective memory and traumatic brain injury: A review. Brain impairment. 2002;3:1–16.

8. Shum D, Levin H, Chan RCK. Prospective memory in patients with closed head injury: A review. Neuropsychologia. 2011;49:2156–65.

9. Ward H, Shum D, McKinlay L, Baker S, Wallace G. Prospective Memory and Pediatric Traumatic Brain Injury: Effects of Cognitive Demand. Child Neuropsychology. 2007;13:219–39.

10. Chevignard MP, Catroppa C, Galvin J, Anderson V. Development and Evaluation of an Ecological Task to Assess Executive Functioning Post Childhood TBI: The Children's Cooking Task. Brain Impairment. 2010;11:125–43.

11. Chevignard MP, Servant V, Mariller A, Abada G, Pradat-Diehl P, Laurent-Vannier A. Assessment of executive functioning in children after TBI with a naturalistic open-ended task: A pilot study. Developmental Neurorehabilitation. 2009;12:76–91.

12. Krasny-Pacini A, Servant V, Alzieu C, Chevignard M. Ecological prospective memory assessment in children with acquired brain injury using the Children's Cooking Task. Dev Neurorehabil. 2015;1–6.

13. McCauley SR, McDaniel MA, Pedroza C, Chapman SB, Levin HS. Incentive effects on event-based prospective memory performance in children and adolescents with traumatic brain injury. Neuropsychology. 2009;23:201–9.

14. McCauley SR, Pedroza C, Chapman SB, Cook LG, Vásquez AC, Levin HS. Monetary incentive effects on event-based prospective memory three months after traumatic brain injury in children. J Clin Exp Neuropsychol. 2011;33:639–46.

15. McCauley SR, Pedroza C, Chapman SB, Cook LG, Hotz G, Vásquez AC, et al. Event-based prospective memory performance during subacute recovery following moderate to severe traumatic brain injury in children: Effects of monetary incentives. J Int Neuropsychol Soc. 2010;16:335–41.

16. Baker SP, O'Neill B, Haddon W, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974;14:187–96.

17. Ceci SJ, Bronfenbrenner U. "Don't forget to take the cupcakes out of the oven": prospective memory, strategic time-monitoring, and context. Child Dev. 1985;56:152–64.

18. Rendell PG, Vella MJ, Kliegel M, Terrett G. Effect of delay on children's delay-execute prospective memory performance. Cognitive Development. 2009;24:156–68.

19. Etchepare A, Merceron K, Amieva H, Cady F, Roux S, Prouteau A. Évaluer la cognition sociale chez l'adulte : validation préliminaire du Protocole d'évaluation de la cognition sociale de Bordeaux (PECS-B). Revue de neuropsychologie. 2014;6:138–49.

20. Chevignard M, Toure H, Brugel DG, Poirier J, Laurent-Vannier A. A comprehensive model of care for rehabilitation of children with acquired brain injuries. Child Care Health Dev. 2010;36:31–43.

21. Krasny-Pacini A, Chevignard M, Lancien S, Escolano S, Laurent-Vannier A, De Agostini M, et al. Executive function after severe childhood traumatic brain injury – Age-at-injury vulnerability periods: The TGE prospective longitudinal study. Annals of Physical and Rehabilitation Medicine [Internet]. 2016 [cited 2016 Sep 13];Available from: http://linkinghub.elsevier.com/retrieve/pii/S1877065716303426

22. Cohen J. Statistical Power Analysis for the Behavioral Sciences, Second Edition. Routledge; 1988.

23. Somerville SC, Wellman HM, Cultice JC. Young Children's Deliberate Reminding. The Journal of Genetic Psychology. 1983;143:87–96.

24. Kvavilashvili L, Kyle F, Messer DJ. The development of prospective memory in children: Methodological issues, empirical findings, and future directions. In: Prospective memory: Cognitive, neuroscience, developmental, and applied perspectives. Matthias Kliegel, Mark A. McDaniel and Gilles O. Einstein; 2008. p. 115–40.

25. Mahy CEV, Moses LJ. Executive functioning and prospective memory in young children. Cognitive Development. 2011;26:269–81.

26. Kvavilashvili L, Messer DJ, Ebdon P. Prospective memory in children: the effects of age and task interruption. Dev Psychol. 2001;37:418–30.

27. Oberauer K. Access to information in working memory: Exploring the focus of attention. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2002;28:411–21.

28. Einstein GO, McDaniel MA, Thomas R, Mayfield S, Shank H, Morrisette N, et al. Multiple Processes in Prospective Memory Retrieval: Factors Determining Monitoring Versus Spontaneous Retrieval. Journal of Experimental Psychology: General. 2005;134:327–42.