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Ecological Prospective Memory Assessment in Children with Acquired Brain Injury using the Children's Cooking Task: Brief Report

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Declaration of interest

The authors report no declarations of interest.

Abstract

Prospective memory (PM) has been shown to be impaired in children with acquired brain injuries (ABI) and is a major concern for parents. Few studies have addressed this issue and most used tasks that are not ecologically valid. The aims of this study were (1) to explore if children who have sustained an ABI suffer PM impairment, measured both by the Children's Cooking task (CCT) PM score and using the 2 PM subtests of the Rivermead Behavioural Memory Test (RBMT), and (2) to explore if the CCT PM score is sensitive to developmental changes in PM in typically developing children and in children with ABI. Fifty-four children with ABI and 33 typically developing controls participated in the study. Children with ABI had significantly lower PM scores and poorer performance in the CCT than their typically developing peers. PM scores increased significantly with age, indicating developmental progress of PM performance.

Introduction

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. PM tasks require retrospective memory to remember the task, but depend on executive functions (EF) [2] for successful goal maintenance, retrieval and implementation at the right moment. PM depends upon frontal lobe integrity[3], with a key role for rostral prefrontal cortex (BA10)[4].

Literature on prospective memory in typically-developing children shows improvement in PM performance across the age range from 2 to 12 years[5,6]: children become increasingly skilled at using external reminders to cue PM and increasingly proficient at applying time-checking strategies. In typically-developing children aged 6-12, performance on EF tasks

such as planning and switching [7], working memory [8], and inhibition [9] is correlated with PM[5]. PM and retrospective memory are not strongly associated in typically developing children[10].

PM has been shown to be impaired in children with brain injuries [11,12], even after cues are given [13], and even under strong incentive conditions [14]. PM problems are reported as a major concern by the parents of children with traumatic brain injury (TBI) [15]. Adult patients with ABI generally obtain lower results than control participants on experimental PM tasks[16], detecting fewer prospective cues and retrieving fewer actions[17]. The majority of memory failures they report are prospective in nature[18]. The capability to compensate for PM deficits in adults significantly predicts the ability to live independently[19]. Parents of children with TBI report serious concerns for their child's safety and ability to be left unsupervised even briefly because of substantial PM impairments[15]. Children with ABI may display normal performance on standard neuropsychological assessment, and still be impaired on functional memory[20] and especially PM.-In spite of these reports, very few standardized tests address PM issues, especially in naturalistic settings[21].

McCauley et al.[11,14,22] 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. Although the incentive was naturalistic, the testing used an office-based setting and a verbal non-ecological task. A promising approach for studying PM is the use of virtual reality and computer games to assess PM (e.g.: TEMP task[23] in adults, simulating driving around shops to prepare a dinner or a holiday; the CyberCruiser[6,5] in children simulating driving a vehicle across a variety of scenes to explore, and requiring to remember to refuel the vehicle after a cue), but unfortunately this approach is not yet used in clinical practice. A functional memory test that has been used in children with acquired brain injuries (ABI)[24,25] is the Rivermead Behavioural Memory Test (RMBT) for Children[26] [27]: it has shown to be sensitive to everyday

memory problems [24,20], and it includes two subtests tapping prospective memory. The RMBT however is an office-based test, performed in a very structured environment, and it may not fully capture children's PM in real, motivating, complex and playful activities. Recently it has been proposed to use a real cooking task (Children's Cooking Task – CCT) to explore EF in children with ABI[28,29], as children find it fun[30] and because cooking is a novel open ended task, requiring adaptability and innovative strategies that challenge the child's EF.

The aims of this study were (1) to explore if children who have sustained an ABI suffer PM impairment, measured both in a complex ecological real life EF task, the Children's Cooking task and using the two PM subtests of the RBMT ; (2) to explore if the CCT PM score is sensitive to developmental changes in PM in healthy controls and in patients with ABI; (3) to replicate the findings that the CCT discriminates children with various types of ABI from typically developing controls[29,28] on a larger number of patients.

Methods

Children were recruited from 3 different regions of France. Inclusion criteria for children with ABI were: age 8-20, a brain injury sustained after birth and prior to the age of 16, at least one year prior to the study, necessitating on-going rehabilitation or follow-up. Exclusion criteria were: severe reading or vision impairment that would impeed the child to read/see the recipe, severe behavior problems, and homogenous intellectual disability (full scale IQ < 70). Exclusion criteria for typically developing controls were diagnosed neurological or psychiatric condition or history, intellectual disbility, inability to attend a mainstream school. All children were divided in 3 age groups (8-10; 11-13 and 14-20 groups).

Eighty-seven children participated in the study, separated in three age-groups: 54 children with ABI [8-10 years (n=10), 11-13 years (n=16) and 14-20 years (n=28)] and 33 typically developing matched controls (n=7, 17, 19 children in each group respectively). There was no

significant difference between groups regarding age or gender (see table 1). Causes of ABI were TBI (N =43), brain tumours (N=7), ischemic or hemorrhagic stroke (N=3), drug intoxication (N=1). Mean age at injury was 8.98 years ±3.35 (range 7 months – 14.4 years). For TBI, mean Glasgow Coma Scale Score was 7.48 ± 3.14 (range 3-15), length of coma was 7.13 days ± 8.5 (range 0-45).

All children with ABI had been recently (< 6 months) assessed for general intellectual ability, using the age-appropriate Wechsler Scales (WISC III, WISC IV or WAIS III) prior to inclusion in the study, and the assessment was recorded for each patient. WISC III was used for children who were part of a cohort study that used WISC III as a follow-up measure. When the neuropsychological assessment had included the 2 PM sub-tests of the Rivermead Battery Memory Test (RBMT) [26] [27], results were also recorded. In the "remembering a hidden belonging" sub-test, an object is hidden, and the subject is required to ask for it at the end of the test session and to remember where it was hidden. In the "remembering an appointment" sub-test, an alarm is set to ring after 20 minutes, and the child is required to ask a specific question when the alarm goes off. The total of both PM tasks raw scores was used to screen for a possible correlation with the CCT PM score.

Prospective memory (PM) was assessed in all children using the Children's Cooking Task (CCT)[28,29]. In the CCT, children have to prepare a real chocolate cake and a fruit cocktail following a structured, photo-cued, child-friendly recipe contained in a cookbook including distracters. Instructions for all the key steps are clearly stated, with a picture for each step, although some actions embedded in a step are not necessarily explicitly detailed, in order to assess children's adaptability to the context (e.g.: using straw to open and empty an apple juice pack into a glass). The CCT can be performed from the age of eight. Scoring is based on the number of errors and qualitative data (goal achievement, occurrence of dangerous behaviours, spontaneous initiation of both recipes and necessity of an adult intervention to

prevent task failure or consequences of a dangerous behaviour). Details of CCT scoring can be found in the CCT scoring manual (unpublished, available from the last author) and previous publications about the test[28,29]. Normative data is not available yet. The CCT has good inter-rater and test–retest reliability, high internal consistency, as well as good discriminant and concurrent validity[28].

Four PM tasks are embedded in the CCT instructions, although the original CCT scoring had not used these tasks for a specific PM subscore: (1) making a fruit cocktail after finishing the chocolate cake; (2) putting the dirty disches in the sink; (3) putting the rubbish in the bin; (4) telling the examiner that the task is finished. These 4 PM tasks are explicitly mentioned to the child before the start of the task, and they are written in the instruction sheet that is given to the child and placed in front of him/her during the whole duration of the test ("Today, you will prepare a chocolate cake and a fruit cocktail …. please place everything that needs to be washed in the sink and the rubbish in the bin... Tell me when you have finished"- refer to Chevignard et al.[29] for complete detailed instructions). Furthermore, before beginning the task the child is asked to summarise the instructions; thus ensuring the child has understood and remembered them.

Scoring for PM tasks was developed as follows: 0: failure to achieve: 1: achieved after a **specific** cue is given ("look at the instructions, you have forgotten something"); 2: achieved after a **non-specific** cue ("are you sure you have finished?"); 3: achieved spontaneously (without any cue). The CCT manual provides examiners with a progressive range of cues to be given to the child if s/he forgets one of the PM tasks after finishing the chocolate cake. The final score for all four PM tasks developed for this study ranged from 0 to 12. With this scoring system, a PM score < 8 showed inability to react to non-specific cues.

Observation and scoring were performed by three different examiners (AKP, VS, CA), who received a specific training on the use of the CCT and regularily consulted the author of CCT (MC). Ambigous behaviour scoring was discussed with the author of CCT (MC).

Data were analyzed by IBM SPSS statistic 19, using non parametric statistics, as the number of errors in the CCT was not normally distributed. In order to compare children with ABI to controls, a Mann-Whitney U test for independent samples was used for quantitative data (number of errors on CCT, task duration, PM score) with reported standardized test statistic (Z). For CCT qualitative data, a Fisher exact test was used with reported Cramer's V as measure of effect size (range 0 and 1). Differences between age groups were explored by Kruskal-Wallis test and Jonckheere test to screen for trend. A Bonferroni adjustment was used for multiple comparison of PM scores between controls and children with ABI for 3 age groups with a significance level of 0.05/3 = 0.017 . Correlations between CCT PM score, number of errors in the CCT, RMBT PM subtests scores and age were analyzed by Spearman correlation coefficient.

Results and Discussion

Total number of errors – replication of earlier findings: ABI and controls significantly differed on the total number of errors in the CCT (see table 1) (p<0.001), replicating earlier findings that children with ABI are severely impaired on ecological EF assessment using real cooking[29,28]. The number of errors in the CCT showed a developmental trend in typically developing children: as children grew older, they made less errors (Jonckheere test J=-3.16; p = 0.002), with a significant difference in the number of errors across age groups (Kruskal Wallis test, H(2)=11.6; p=0.003). Children with ABI also showed a developmental effect on number of errors in the CCT (Jonckheere test J= -3.39; p = 0.001), with a significant difference in the number of errors across age groups (Kruskal Wallis test, H(2)=11.4, p=0.003). Further there

was a significant medium size negative correlation between the total number of errors and age, both in controls (r=-0.561; p=0.001) and children with ABI (r=-0.502; p<0.001), indicating that as children grow older, they make less errors in the CCT. This is consistent with literature on progressive maturation of EF [31,32].

	ABI [mean (SD)]	Controls [mean (SD)]	Effect size and significance †
N	54	33	
Age (years)	13.3 (3.05)	12.5 (2.40)	p=0.13
Sex (% boys)	64	61	p=0.5
CCT Prospective Memory Score (/12)	8.6 (2.6)	11.1 (1.7)	z=-4.7; p=0.000*
Cocktail	2.4 (0.9)	2.9 (0.4)	z=-2.8; p=0.006*
Rubbish in the bin	2.2 (1.1)	2.7 (0.6)	z=-2.0; p=0.039*
Dirty dishes in the sink	2.2 (1.1)	2.77 (0.6)	z=-2.4; p=0.016*
Say "I finished"	1.8 (1.5)	2.8 (0.75)	z=-3.4; p=0.001*
Total number of errors in the CCT	75.4 (52)	28 (36.6)	z=5.6; p=0.000*
Qualitative analysis of CCT			
Task duration [min]	47 (17.3)	31.9 (9.5)	z= 4.5 ; p= 0.000*
Goal achievement [no]	55%	9 %	V = 0.46† p=0.000*
Dangerous behaviours [yes]	63%	9 %	V = 0.3† ; p=0.003*
Spontaneous initiation of both recipes [no]	33 %	8%	V= 0.28†; p=0.013*
Intervention of an adult necessary [yes]	60%	11%	V = 0.45†; p=0.000*
RMBT PM subtest Standard score (0-2)			

Appointment	1.22 (0.6)	
Hidden belonging	1.41 (0.6)	
Wechsler Standard scores# **(WISC III n= 18, WISC IV n= 27, WAIS IV n=8)**		
Processing Speed Index	80.7 (18.3)	–
Working Memory Index	82.8 (19.9)	–
Perceptual Organization/Reasoning Index#	84.0 (13.4)	-
Verbal Comprehension Index	89.2 (18.3)	-

Table 1: Comparison of demographic characteristics and of test scores in children with acquired brain injury and typically developing controls.

*Note: apart from qualitative data denoted by † which is reported by Cramer's V from Fisher's exact test, the statistics reported are standardized Z statistic obtained by Mann-Whitney U test for independent samples; * denotes significant results (p<0.05); # Perceptual Organization index from WISC III and WAIS III and Perceptual Reasoning Index from WISC IV were pooled to obtain a unique mean score of perceptual abilities; ABI: Acquired brain injury; CCT: Children's Cooking Task; RMBT: Rivermead Behavioural Memory Test; PM: Prospective Memory.*

As expected, the total number of errors in the CCT, which is a measure of ecological global executive functioning, was correlated with the CCT PM score (r=-.336, p=0.039) in the control group; i.e. as children made more errors, they had a lower PM score. This is consistent with literature showing that in typically-developing children aged 6-12, performance on EF tasks such as planning and switching [7], working memory [8], and inhibition [9] is correlated with PM. In children with ABI however, the CCT PM score and the total number of errors were not correlated, similar to Ward et al. study, who found that most EF tests were not predictive of PM [12].

Prospective Memory: PM scores for typically developing controls were significantly higher (Mean rank=59.77) than those of children with ABI (Mean Rank= 34.36; p<0.001; see table 1 The performance of older children (14-20) with ABI did not differ significantly from the performance of young (8-10) controls, while 89% of their typically developing peers aged 14-18 obtained the maximum possible PM score (see figure 1). The difference was still significant (p<0.001) when subjects with impaired working memory index (<65) were excluded from analysis, suggesting that poor PM was not due to poor short-term or working memory. Examples of behaviour of children with ABI in relation to PM tasks and before the task ended included: leaving the kitchen after having prepared the cake to go play in the next room, licking various utensils and objects on the table instead of picking up the utensils and rubbish on the table, drinking the fruit cocktail, beginning to play with a smartphone halfway through tidying and leaving the cake burn in the oven. Children with ABI were not helped by non-specific cues: 44% of them did not manage the PM tasks even after non-specific cues were given (PM score<8), versus only 6% of the controls, all of whom were in the youngest age group (8-10). In the two PM sub-tests of the Rivermead Behavioural Memory Test (RBMT), only 11% of children with ABI obtained the maximum score on the two sub-tests used, whereas according to the normative data, 80% of children aged 8 to 14 are expected to do so.

In the youngest age group only, we found a significant correlation between age at injury and PM score (r= 0.7; p=0.025): the earlier the injury, the lower the PM score was. There was no overall effect of age at injury in the whole ABI group.

No significant correlation was found between the PM score on CCT and sum of PM raw scores of RMBT in the ABI group.

Developmental changes in PM scores: PM scores of the youngest typically developing controls (8-10) and of children with ABI of all ages showed important variability (see figure 1), whereas older controls (11-13 and especially 14-20) showed very homogeneous high scores, suggesting important PM development from age 8 to 11 in typically developing children, with mature PM by the age of 14 on the CCT PM tasks. In typically developing controls only, PM showed a developmental trend: as children grew older, they had higher (better) PM scores (Jonckheere test J=2.701; p = 0.07), with differences between age groups that were statistically significant (Kruskal Wallis test, H(2)= 6.99; p=0.03) and a significant correlation (r=0.373, p=0.032) between age and the CCT PM scores. Difference between age groups and trend in children with ABI were not significant, but there was a correlation between PM score and age in this group (r=0.275, p=0.044), suggesting improvement of PM with age. Given the variability in patient's CCT PM scores in the 11-13 and to a lesser extent the 14-20 group, we expect that a larger sample size would have enabled us to find an age effect with the statistical tests used. An alternative explanation could be that children with ABI precisely do not improve their PM at the critical time of PM improvement found in typically developing controls of our sample, potentially due to lack of normal EF maturation found in typically developing children. However, ABI severity could not be considered in multivariate analyses along with age and age at injury given the heterogeneous sample. One cannot exclude that effects of age at injury or severity also contributed to this finding.
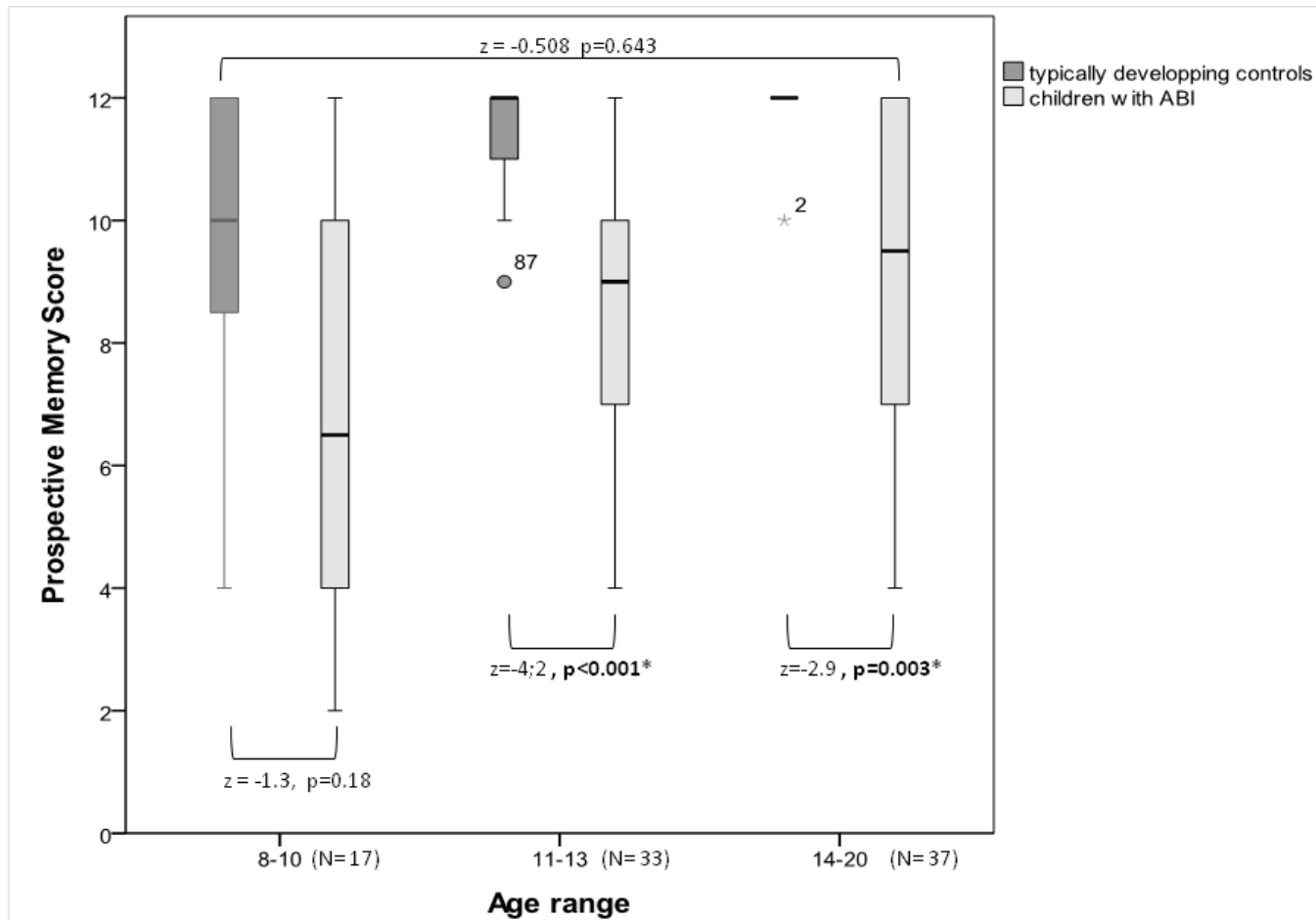
Figure 1: Boxplot of Prospective Memory Scores according to age group and injury status
Note: The tinted box represents the interquartile range (i.e. the middle 50% of scores), the thick horizontal line represents the median, the whiskers represent the range of the top 25% and 25% bottom, excluding outliers (represented by a circle) and extreme cases (represented by a star).

Our study adds objective data to the parental reports[15] and to the previous studies [11,12,13,14] reporting that PM is impaired after brain injury in children. In this study, however we used an ecological assessment consisting of simple and natural PM tasks, very close to what is expected of a child (e.g.: put the rubbish in the bin after finishing an activity, follow instructions at school, similarly to the CCT where two recipes need to be prepared). Results showed severe impairment on these simple PM tasks after childhood ABI. Similarly to McCauley et al. study [13], children with ABI were not helped by non-specific cues.

It might be argued that the success or failure on these tasks was not related to PM ability only but that it may have been influenced by other factors and especially, social cognition (children are expected to clean after finishing an activity) and theory of mind (deducing that

"I have finished" is to be said if examiner is not reacting at the end of the test). If, however, implicit, socially-driven cues were the reason children with ABI performed poorer on PM tasks, performance should have been corrected after being given non-specific cues explicitly, which was not the case. The lack of correlation between the two assessments of PM (RBMT subscores and CCT MP score) speaks to the problem we face in studying PM in non-natural settings: do the ecologically valid tests really measure the same thing as the laboratory tests in children? Although meant to be "ecological", the RBMT is still a paper-and-pencil task that comprises only two PM items and is therefore probably insufficient to adequately screen for PM difficulties. The same discrepancies have been found in other ecological assessments of executive functioning and remain an important issue that needs further research[33,21]. The main limitation of this study is the absence of retrospective memory data that could account for PM failure. Also, mechanisms of injury may have influenced PM but the small numbers of children in each condition did not allow a differential analysis in each diagnostic group. Another drawback is that PM sub tests from the RMBT were administered only to children with ABI, impeding a direct comparison of performance with typically developing peers on these subtests. As suggested previously[14,12], future research should include an evaluation of both retrospective and prospective memory, as well as an assessment of EF, in order to better understand memory functional impairment in children with ABI. Another limitation of the study is the small sample size in the typically developing healthy controls. To examine age effects and typical development of PM skills, a much larger sample size would be needed. This study does, however, support previous literature on typical PM development but future research should examine the age-effects in a much larger sample.

Our study shows that PM is significantly impaired in children with ABI performing an ecological, close to real life cooking task including four simple PM tasks. Unfortunately, usual neuropsychological assessments of memory often do not explore PM, and focus mostly

on episodic memory. Ecologically valid and sensitive tests of PM should be included in assessments of children with ABI, in order to better reflect actual impairment in everyday life and at school.

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