**Title:** Assessment of Executive Functions in Children and Adolescents with acquired brain injury (ABI) using a novel complex multi-tasking computerized task – the Jansari assessment of Executive Functions for Children (JEF-C©)

 **Running Head:** a novel computerized assessment of EF

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# Abstract

**Objectives**: The Jansari assessment of Executive Functions for Children (JEF-C[©]) is a new non-immersive computerized assessment of executive functions. The objectives of the study were to test the feasibility and validity of JEF-C[©] in children and adolescents with acquired brain injury (ABI).

**Methods:** Twenty-nine patients with ABI aged 10-18 years and 30 age-and gender-matched controls were tested. Participants performed JEF-C[©], Wechsler Abbreviated Scale of Intelligence (WASI) and the Behavioral Assessment of the Dysexecutive Syndrome for Children (BADS-C), while parents completed the Behavior Rating Inventory of Executive Function (BRIEF) questionnaire.

**Results:** JEF-C[©] task proved feasible in patients with ABI. The internal consistency was medium (Cronbach's alpha =0.62 and significant inter-correlations between individual JEF-C[©] constructs). Patients performed significantly worse than controls on most of the JEF-C[©] subscales and total score, with 41.4 % of participants with ABI classified as having severe executive dysfunction. No significant correlations were found between JEF-C[©] total score, the BRIEF indices and the BADS-C. Significant correlations were found between JEF-C© and demographic characteristics of the sample and intellectual ability, but not with severity/medical variables.

**Conclusion:** JEF-C[©] is a playful complex task that appears to be a sensitive and ecologically valid assessment tool, especially for relatively high-functioning individuals.

**Introduction**

Acquired Brain Injury (ABI) is defined as post-neonatal brain injury. It can result from various

endogenous causes, such as stroke, brain tumor, infection, as well as from external factors such

as traumatic brain injury (TBI), near drowning, substance abuse, or poisoning (Chevignard,

Toure, Brugel, Poirier, & Laurent-Vannier, 2010). More than half a million children up to 14

years old in the United States experience a TBI annually (Faul, Xu, Wald, & Coronado, 2010).

Children who sustain ABI are likely to exhibit physical, neurological, cognitive, emotional,

psychosocial and behavioral impairments (Greenham, Anderson, & Mackay, 2017), such as

epilepsy, impaired cognition (Chevignard, Câmara-Costa, Doz, & Dellatolas, 2016) or

communication (Doser, Poulsen, & Norup, 2015), post-traumatic stress disorder (PTSD) (Von

Steinbuechel et al., 2016), or depression (Letkiewicz et al., 2014). They are also likely to be

bullied, to bully others, and to display violent as well as non-violent conduct behaviors (Ilie et

al., 2014). Long-term psychosocial limitations include low academic achievement,

unemployment, and poor community integration with social isolation (Chevignard et al., 2016).

Executive Functions (EFs) encompass higher-order cognitive processes responsible for the

control and regulation of cognitive processes to effectively perform complex, goal-oriented tasks

(Alvarez & Emory, 2006). EFs facilitate the ability to mentally play with ideas, taking the time

to think before acting, meeting novel unanticipated challenges resisting temptations and staying

focused. Core EFs are inhibition, working memory and cognitive flexibility (Diamond, 2013).

Inhibition includes response inhibition (the ability to demonstrate self-control by resisting

temptations and resisting the urge to act impulsively) and interference control (engaging in

selective attention and cognitive inhibition); cognitive flexibility includes being able to

creatively think 'outside the box', see something from different perspectives and being able to

quickly and flexibly adapt to changing circumstances. During childhood, considerable cognitive progression in the realm of EFs is made within a relatively short time period (Spiess, Meier, & Roebers, 2016). EF deficits can interfere with the ability to complete Instrumental Activities of Daily Living (IADL) (Vaughan & Giovanello, 2010) and can also lead to social, vocational and educational difficulties (MacDonald, 2016; Wheeler, 2014).

ABI during childhood can be associated with enduring difficulties related to impairments in EFs (Tonks et al., 2011). Roughly 20-40% of children experiencing TBI between 5-15 years of age show significant executive dysfunction within the first year of injury (Sesma, Slomine, Ding, & McCarthy, 2008). In studies of EFs following childhood ABI, impairments have been found across the entire range of executive constructs (Beauchamp et al., 2011; Chevignard et al., 2016; Chevignard et al., 2017; Greenham et al., 2017; Krasny-Pacini et al., 2016). Specifically, EFs consisting of self-generative behavior, flexibility, set shifting, mental control, attention, and self-monitoring are commonly impaired in pediatric populations following TBI (Baron, 2004; Chevignard et al., 2017; Gioia, Isquith, & Guy, 2001; Krasny-Pacini et al., 2016; Shultz et al., 2016) with persistent difficulties documented up to 10 years post-injury (Beauchamp et al., 2011).

Given the importance of EFs for everyday interactions and academic achievement, the assessment of its various components constitutes one of the cornerstones of neuropsychological assessment (Lalonde, Henry, Drouin-Germain, Nolin, & Beauchamp, 2013). Three ecologically-valid approaches to assessing EF in children were recently summarized (Chevignard, Soo, Galvin, Catroppa, & Eren, 2012). They include performance in naturalistic contexts like the Children's Cooking Task (Chevignard et al., 2009), paper-and-pencil assessments developed with ecological validity in mind like the Behavioral Assessment of the Dysexecutive Syndrome

for Children (BADS-C) (Emslie, Wilson, Burden, Nimmo-Smith, & Wilson, 2003) , and

questionnaires asking parents, teachers or caregivers to rate the child's everyday behavior, in

various contexts like the Behavior Rating Inventory of Executive Function (BRIEF) (Gioia,

Isquith, Guy, & Kenworthy, 2000). However, there seems to be a disparity between these

assessments' abilities to recognize EF deficits. A review that assessed 20 studies examining the

association between performance-based and questionnaire-based measures of EF concluded that

those measures probably assess different underlying mental constructs (Toplak, West, &

Stanovich, 2013). In addition, inconsistencies have been reported between normal performance

on cognitive tests contrasting with profound deficits in EFs in daily life activities (Câmara-Costa

et al., 2017; Chevignard, Catroppa, Galvin, & Anderson, 2010). Data from proxy-reports have

advantages but also carry their limitations. First, parents need to be fluent in the language of the

country, which is not always the case. Second, parent reports can be influenced by a number of

factors, including characteristics of the parents themselves. Therefore, parent bias can produce

distortions in the perceptions of their children's behaviors (Coutinho, Kemlin, et al., 2016;

Silver, 2014).

The concerns regarding the limitations of paper–pencil and questionnaire-based tests (Silver,

2014) have encouraged the development of new forms of assessment that may come closer to

reproducing real-life contexts and demands than traditional cognitive tests (Lalonde et al., 2013).

Alternatively, computerized or virtual reality (VR) testing can immerse a user within a dynamic,

ecologically-valid environment to assess EFs  under conditions more similar to the challenges of

the 'real' world (Parsons, Silva, Pair, & Rizzo, 2008). As such, VR is a potentially powerful tool

for the assessment of cognitive functioning, and studies using VR technology are beginning to

show evidence of the utility of virtually enriched environments as a novel and effective way to

ecologically test cognitive functions in children, adolescents, adults, and various clinical

populations (Adams, Finn, Moes, Flannery, & Rizzo, 2009; Gilboa et al., 2015; Gilboa,

Rosenblum, Fattal-Valevski, Toledano-Alhadef, & Josman, 2011; Lalonde et al., 2013; Parsons,

Bowerly, Buckwalter, & Rizzo, 2007). One study so far aimed to determine the usability of a

virtual reality environment for children with TBI by assessing the performance of a simple

virtual shopping task and comparing their results to typically developing peers. The authors

concluded that the use of a short test within a functional virtual environment enabled detection of

poorer performance of children with TBI that may be due to EF deficits (Erez, Weiss, Kizony, &

Rand, 2013).

A new approach using non-immersive VR has been taken by Jansari et al. who created an

ecologically-valid measure for adults (Jansari et al., 2014). They first developed a task in the real

world which involved participants playing the role of someone working in an office for an

afternoon and having to perform various tasks on their own because the manager was not

available to help them. They tested adults with ABI and compared them to age and IQ matched

healthy controls. They found that while the patients were in the unimpaired range on three

standard clinical tests, the Brixton, Hayling and BADS, compared to the matched controls, they

were significantly impaired on the role-playing task (Jansari et al., 2014). Jansari et al. then

recreated the task in non-immersive VR and found that this task, which looks like a computer

game, also differentiated patients with ABI from healthy controls (Jansari et al., 2014); further,

for the individuals that did both the real-life and VR versions, there was no significant difference

between the two conditions justifying the use of the VR version in future studies. This new task,

known as the Jansari assessment of Executive Functions (JEF$^{©}$) has been shown to be sensitive

enough to detect significant EF impairments in patients with circumscribed frontal lobe lesions

when standard clinical tests fail to do so (Denmark et al., 2017). Further JEF[©] has been used to detect the impact on EFs of recreational ecstasy/MDMA (Methylenedioxymethamphetamine) (Montgomery, Hatton, Fisk, Ogden, & Jansari, 2010), alcohol (Montgomery, Ashmore, & Jansari, 2011), cannabis (Montgomery, Seddon, Fisk, Murphy, & Jansari, 2012), nicotine (Jansari, Froggatt, Edginton, & Dawkins, 2013) and caffeine (Soar, Chapman, Lavan, Jansari, & Turner, 2016).

Given growing interest from clinicians for the adult version of the task, a children's task JEF-C[©] has been been developed by Jansari, Edmonds, Gordon, Nwosu and Leadbetter (2012). This task is set in a family house where the child has to get the house ready and run a birthday party in the absence of their parents (see Method section for more information). Jansari et al (2012) found that JEF-C[©] was able to differentiate healthy typically developing children of different ages ranging in age from 7 to 18 in a way that mirrored the subjective ratings given by teachers in the BRIEF. Given the apparent ability of the JEF-C[©] to detect developmental improvements of EF with age, it has potential for use in paediatric ABI (Jansari, Edmonds, Gordon, Nwosu, & Leadbetter, 2012).

To summarize, ABI during childhood can be associated with enduring difficulties related to EF impairments that may detrimentally affect outcome (Tonks et al., 2011).  EFs are the most challenging area to assess in neuropsychological testing conditions (Chevignard et al., 2012). Overall, to assess EFs in a comprehensive and ecologically-valid way to better reflect everyday difficulties, it has been recommended that a combination of standardized tests and questionnaires should be used (Chevignard et al., 2012; Longaud-Vales et al., 2015). The objectives of the study were to test the feasibility of the use of a French translation of JEF-C[©] in a sample of children and adolescents with ABI, compared to a group of matched typically developing controls.

Overall, we aimed to study the task's internal consistency, discriminant validity and concurrent validity, as well as demographic and clinical factors influencing task performance.

## Methods

## Participants

A convenience sample of twenty-nine children with ABI and 30 age-and gender-matched controls, aged 10-18 years, were assessed.

*Inclusion criteria*

The children all needed to be aged 10–18 years, have adequate proficiency in French allowing them to understand and perform the task and finally, parental consent to participate in the study was needed. In addition, for the patient group, children had to have sustained significant ABI after birth and before the age of 18 years and to require medical and neuropsychological follow-up in a rehabilitation center devoted to childhood ABI, either as in- or out-patients.

*Exclusion criteria (valid for both groups)*

Children were excluded if they had a pre-injury diagnosed learning disability, ADHD or psychiatric condition, intellectual disability (estimated IQ<70) or significant motor, comprehension, memory, hearing, visual or reading deficits, precluding task performance (see below). Indeed, JEF-C$^{©}$ is a complex task that has been designed to detect subtle EF deficits when they are not adequately diagnosed by traditional paper-and-pencil tests and is thus most suited to medium to relatively high functioning individuals.

## Materials

*Demographic and medical data*

The demographic and medical information was gathered from a background demographic questionnaire given to the parents, and from the medical files. The following demographic information was collected: gender, age, age at injury/diagnosis, parental education level used as a proxy for socio-economic status (SES) and type of ongoing education.

SES was rated based on the maximal education level achieved by either of the two parents (the highest of the two parents was used) in 4 categories: attended primary school; attended 'primary high school'; attended 'superior high school' and superior studies after graduation from high school. The child's type of ongoing education was rated based on academic success and the level of help needed in 4 categories: mainstream school without help, without repeating a year; mainstream school, repeated at least one year; mainstream school, with personalized help and/or adaptations; and special classroom or special education. Regarding medical information, type of injury was noted, along with severity of TBI (Glasgow Coma Scale (GCS) score, length of coma) and treatments received for brain tumors (use of cranial radiation therapy and dose).

*Assessment of executive function and overall cognitive functioning*

**JEF-C$^{©}$: The Jansari assessment of Executive Functions for Children (Jansari et al., 2012)**
The JEF-C$^{©}$ computerized assessment parallels the adult JEF$^{©}$ assessment (Denmark et al., 2017) regarding the constructs assessed (see below). The context for the children's version is a birthday party and was designed to assess children between 8 and 18 years of age. Within this context, the participant is told that it is their birthday and that their parents are trusting them to run their own party. They are asked to plan, set up and run this party through the completion of tasks. The party takes place in a virtual home with three rooms, the kitchen, the living room and the DVD/games room. There is a front door, which participants can open, and a back garden with a

gate leading to the neighbor's garden. The participant can move freely around the three rooms, hallway and garden, using the computer mouse, and all the required tasks are performed within these areas of the VR environment. Figure 1 shows a screenshot of the living room.

Insert Figure 1 – about here

Similar to the adult JEF$^©$ (Jansari et al., 2014) there are eight constructs in JEF-C$^©$, each of which has an operational definition. The eight constructs are planning (PL), prioritisation (PR), selective-thinking (ST), creative-thinking (CT), adaptive-thinking (AT), action-based prospective memory (ABPM), event-based prospective memory (EBPM) and time-based prospective memory (TBPM). For each of these constructs, realistic tasks that could happen in a child's birthday party have been created in order to tax them as ecologically as possible (see Table 1 for operational definitions of each construct and an example of a task for each construct). Tasks have been designed to have (or at least appear to have) ambiguous and multiple solutions as is the case in real-life situations so that solutions are not always immediately obvious.

Insert Table 1- about here

To start the assessment, the participant is allowed to explore the ground floor rooms of the family house and garden. The assessor reads from a script which explains the task to the participant. After the reading of the script and clarification of any unclear points, the participant is given an instruction card, lists for use during the party and a guest biography sheet telling them about the friends who are going to attend the party along with their likes and food preferences. The participant is then shown and allowed time to navigate around the house and to pick up

objects to practice interacting with the environment as needed during the assessment. The participant is finally given a letter from their parents outlining what they need to do and asked, after reading it, to create their 'To do list' board which is presented in hard copy. As soon as the participant finishes reading the letter from their parents the VR program is started, indicating the formal start of the assessment. As the participant completes each task, their performance is recorded and scored on a clearly delineated scoresheet that is broken down by cognitive construct. All tasks are scored on a 3 point scale for success; 0 for failure, 1 for a partial or non-optimal completion and 2 for satisfactory completion. The scores for the two tasks for any particular construct are summed (maximum of 4 possible) and this score is converted to a percentage of achievement for this construct. In addition to the eight individual construct scores, an average total percentage is computed for the whole assessment.

To run the assessment, a standard laptop running a Windows operating system is required as well as some desk space for hard copy paperwork that is required during the administration; this is because while the majority of the tasks are completed in the virtual environment, for ease, some of the tasks (such as selection and planning tasks) are done in the 'real world' on hard copy. Once instructions have been explained to the participant, the assessment takes between 30 and 35 minutes to complete; however, since with the exception of certain pre-programmed events, the participant decides when their birthday party is finished, some participants can take longer.

The inter-rater reliability for the scoring system has been established in previous research (Cracknell, 2013). Two raters simultaneously and independently scored the performance of nine healthy children (ranging in age between 11 and 18) while performing JEF-C[©]. The scores for each construct were correlated using Pearson's Correlation; this showed very high inter-rater

reliability with correlation coefficients ranging between r=0.96 (p<0.001) and 1.0 (p<0.001) for the eight constructs separately and for the overall average JEF-C score (r = 0.999, p < 0.001). For the current study, the English version of JEF-C$^{©}$ was translated into French.

**The Behavior Rating Scale Inventory (BRIEF) Parents Form (Gioia et al., 2000).**

The BRIEF comprises 86 questions, assessing eight domains of EFs in the real world: three behavioral domains (inhibit, shift, and emotional control), which lead to a Behavioral Regulation Index (BRI), and five cognitive domains (initiate, working memory, plan/organize, organization of materials, and monitor), which lead to a Metacognitive Index (MI). These two composite scores lead to a Global Executive Composite (GEC). Parents rate their child's behavior for each question on a three-point Likert scale (never, sometimes, and often). T-scores are calculated with a mean score of 50 (SD = 10) and the level of clinical significance is defined at 1.5 SD (i.e., a T-score ≥ 65). A higher score indicates poorer EFs.

Mean internal consistency ratings reported for clinical populations using the BRIEF Parent Form range from .82–.98. Three-week test–retest correlations for clinical populations on the Parent Form range from .72–.84 (Gioia et al., 2000).

**The Behavioral Assessment of the Dysexecutive Syndrome for Children (BADS-C) (Emslie et al., 2003)**

The BADS-C is a battery of EF assessments for children aged 7–16. The BADS-C, which includes six subtests of higher order EFs which involve skills such as planning, novel problem solving, flexibility, and perseveration. In the current research 4 sub-tests were used:

The Water Test has been designed to assess problem solving. It requires the development of an action plan in order to solve a problem. The children are presented with a rectangular stand

with a large transparent beaker two-thirds full of water on one end, with a removable lid that has a central hole. Next to the beaker is a tall, thin, transparent tube with a small cork at the bottom. A metal rod and a small, opaque, screw-top container are placed next to the stand. The children are asked to get the cork out of the tube using any of the objects placed on the table, but without touching the beaker or the tube.

Zoo map Tests 1 and 2 assess planning. In zoo map 1, the children are asked to imagine they are going to a zoo, and to plan a walk in order to visit designated animals and places. In zoo map 2, the children are asked to plan a walk in order to visit animals and places in a pre-defined sequence.

The Six Part Test is a test of planning, task scheduling, and performance monitoring. The children are given three different color-coded tasks: a green task (arithmetic), a blue task (picture naming), and a red task (sorting). Each of these tasks has two parts. The children must organise their time in order to attempt at least something from each part, in five minutes.

The BADS-C scoring sheet allows the clinician to record all responses and calculate raw test scores. The manual provides comprehensive norms (age-scaled scores and percentile ranks) for eight age groups and three IQ groups.

Raw scores for each of the component subtests can be converted to age-scaled standard scores, which are adjusted for the child's age and estimated IQ. Age-scaled standard scores were used as outcome measures; they range from 1 to 19 and are designed for approximately normal distribution, with a mean of 10 and a standard deviation of 3. In order to reduce the number of comparisons, we summed up the 4 subtests to create a total BADS-C score. The construct validity of the BADS-C was demonstrated among typically developing children (Engel-Yeger, Josman, & Rosenblum, 2009; Roy, Allain, Roulin, Fournet, & Le Gall, 2015).

**Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler, 1999).**

The general intellectual ability of each subject (mean=100; SD=15) was estimated with two sub-tests: the Matrix Reasoning and Vocabulary of the WASI (Wechsler, 1999). These subtest scores (mean = 10, SD = 3) are generated by the examiner administering the test following the formula specified in the WASI Administrator's Manual. The WASI is a quick estimate of an individual's level of intellectual functioning, with higher scores indicating greater intellectual ability.

**Procedure**

The study took place between April 2014 and January 2017. Participants in the patient group were recruited from the Rehabilitation Department for Children with Acquired Neurological Injury, Saint Maurice Hospitals, Saint Maurice, France. A convenience sample of controls was recruited either in the Rehabilitation Department for Children with Orthopaedic Injuries in the Saint Maurice Hospitals, or via local schools using snowball sampling.

The study was approved by the local Ethics Committee (CPP IDF6). Following the signing of an informed consent form by a parent and oral and written consent by the child, participants were taken to the testing room. The patients underwent the WASI sub-tests, JEF-C[©] and the BADS-C assessments, and parents answered a demographic questionnaire and the BRIEF questionnaire while their child was being tested. In order to reduce the assessment-related burden for the control children, the controls did not perform the BADS-C. Assessment was performed over one two-hour session.

**Data analysis**

All analyses were performed with SPSS version 21. Descriptive statistics were computed for

demographic, medical and severity information and test parameters' results, using means and

standard deviations (SD) for continuous data and percentage for categorical data.

Cronbach's alpha was used for evaluating internal consistency. T-tests, Chi-square tests, one-way

analysis of covariance (ANCOVA) and multivariate analysis of variance/ multivariate analysis of

covariance (MANOVA/MANCOVA)  were used to examine group differences across the

demographic variables and the dependent variables of the JEF-C[©] and BRIEF. In addition a one-

sample t-test was used to compare the BADS-C performance between the ABI group and

published norms (the calculated total score was compared with the expected mean of 40). Effect

size values were computed using the Eta squared η2. Interpretations of the effect sizes: small

(η2 = 0.01), medium (η2 = 0.06), and large (η2 = 0.14) effects (Cohen, 1988). Pearson

correlations were calculated to check for associations between JEF-C[©], the BADS-C the BRIEF

scores, and the demographic and injury /medical variables. Spearman Rank correlation test was

applied for analyzing ordinal data. To determine a predicted value of the relationship between

the demographic and injury /medical variables and EF, a multiple regression analysis using

stepwise method was performed for the JEF-C[©] total score. Given the exploratory nature of the

study, multiple testing corrections were not performed in the statistical analyses.

**Results**

*Participants' characteristics*

Fifty-nine subjects participated in the study, 29 patients who had sustained ABI and 30 matched

controls. Descriptive statistics of demographic variables and medical characteristics of the two

groups are described in Table 2. There were no significant differences between groups in the distribution or frequency of age, gender and SES. As expected, the IQ scores of the ABI group were lower than those of the control group.

Insert table 2- about here

Overall, JEF-C© was feasible in a French speaking group of healthy controls and in a group of children and adolescents who had sustained significant ABI. All participants were able to complete the task. Overall, irrespective of whether or not they had performed well, the examiners' impression from the participants' responses was that they found the assessment fun and motivating.

*Interrelationships between JEF-C$^©$ subscales*

Overall, internal reliability using Cronbach's alpha was .62 (medium) for the whole sample. Significant inter-correlations were found between some of the JEF-C$^©$ subscales (Table 3).

Insert table 3- about here

**Discriminant validity**

In order to establish the discriminant validity of JEF-C$^©$ and the standard measures used, comparisons of the EF measures between patients with ABI and healthy controls (HC) were performed. An ANCOVA controlling for estimated IQ and SES, on the overall average JEF-C$^©$

score comparing the ABI and HC groups revealed a significant difference between groups

(F(57)=5.28, p=0.02, η2=0.105) with the ABI (44.93±12.78) group performing significantly

worse than the control group (59.06±11.38). The results of JEF-C$^©$ did not demonstrate ceiling

or floor effects (Terwee et al., 2007). Moreover, none of the participants in the control and the

ABI groups achieved either the minimal or the maximal score.

To explore this overall difference between the two groups, a one-way MANOVA using

all eight JEF-C© measures was conducted. This revealed a main effect of group [F(8,50)=4.67,

p<.001, Wilks λ= 0.572, ή2 of 0.428 with the power to detect the effect high (0.99)]. Given the

significance of the overall test, the univariate main effects were analysed. The univariate analysis

confirmed that this main effect of group was due to significant differences in performance

between the ABI and HC groups on the subscales of planning [F(1,57) = 8.69, p < 0.005; partial

η2 = 0.132], Selective-thinking  [F(1,57) = 6.69, p = 0.006; partial η2  = 0.105], ABPM [F(1,57)

= 11.67, p < 0.001; partial η2 = 0.170], EBPM [F(1,57) = 19.48, p < 0.001; partial η2 = 0.255]

and TBPM [F(1,57) = 3.69, p = 0.03; partial η2 = 0.061]. However, differences in Selective-

thinking, ABPM and TBPM were no longer statistically significant when estimated IQ and SES

were added as covariates. As can be seen in Figure 2, on all of these constructs, the ABI group

performed worse than the matched controls.

Insert figure 2- about here

Based on the overall average JEF-C$^©$, 41.4 % of the children with ABI were classified

with moderate to severe executive dysfunction (defined as at least 1.5 SD below the mean of the

control group). Additionally, significant differences or trends towards significance were revealed

between the ABI and control groups in most of the BRIEF subscales and indices. Based on the

results from the BRIEF, the percentage of participants classified with executive dysfunctions (<1.5 SD) was 30.8% in the ABI group and 6.9% in the control group (as expected from the manual)(Gioia et al., 2000).

For the BADS-C, the total score was significantly lower in the ABI group than expected (published norms). However, the only individual subtest that differentiated between children with ABI and the expected scores was the Six Part Test. In the ABI group, 14.3-22.2% of children performed more than 1.5 SD below the mean of the general population norms. A summary of BRIEF and BADS-C results is provided in Table 4.

Insert table 4- about here

*Correlational analysis between JEF-C$^©$ and the standard EFs tests*

Pearson correlations between the JEF-C$^©$ total score and the BRIEF indices and total score were low and non-significant (ranging from r =-.15 to -.23). Correlation of the JEF-C$^©$ total score with the BADS-C total score was somewhat higher, but also non-significant (r=.31; p=.11). In both cases correlations were in the expected direction (higher – better performance in JEF-C$^©$, higher – better scores in the BADS-C and lower – better scores on the BRIEF).

*Demographic and medical /severity variables influencing JEF-C$^©$ task performance*

*Age at testing effect*: Among the control group, as expected, we found a significant medium correlation between the JEF-C$^©$ total score and age (r=.48, p<.008; figure 3a). However, among the ABI group no correlation between the JEF-C$^©$ total score and age was found (figure 3b).

Insert figure 3- about here

Figure 4 presents the performance of the ABI and control groups separated into two age groups. As can be seen, across both participant groups, there is an improvement with age but with the ABI group lagging behind.


Insert figure 4- about here

*Effect of IQ*: For the ABI and the control groups together (N=58), the JEF-C$^{©}$ total score correlated significantly with the IQ subtests (Matrix Reasoning, r=.50, p< .01; vocabulary, r=.36, p<.009) and with the estimated FSIQ (r=.51, p< .001). In addition, for the ABI group (N=28) the JEF-C$^{©}$ total score correlated significantly with the Matrix Reasoning subtest (r=.46, p< .05) and with the estimated FSIQ (r=.41, p< .05). For the HC group (N=30) the JEF-C$^{©}$ total score correlated significantly with the vocabulary subtest (r=.40, p< .05) and with the estimated FSIQ (r=.44, p< .05).

 *Effect of injury variables*: No correlations were found between the JEF-C$^{©}$ total score and the injury variables: age at injury/diagnosis, time since injury/ diagnosis, length of coma or radiotherapy dose.

*Effect of SES and education***:** Significant Spearman correlations were found between the JEF-C$^{©}$ total score and SES (r=.44, p<.001) and type of child ongoing education (r=-.51, p<.001). A better JEF-C$^{©}$ performance was associated with higher SES and more typical education.

*Regression analysis*

The demographic and medical /severity variables in which significant correlations with the JEF-C$^{©}$ were found (see above) were included in a multiple regression analyses using stepwise method with the JEF-C total score as the dependent variable. The group attribution, age, estimated IQ and SES, as well as the interactions group X age and group X estimated IQ were

entered as predictor variables. The estimated IQ was able to predict 26.7% (p <.001) of the variance of the JEF-C$^©$ total score, age alone accounting for 12.0% (p=.004) of this variance and group X age interaction was able to predict 8.8% (p =.009) of the variance of JEF-C$^©$ total score.

**Discussion**

This study described the initial stages of the development and validation process of the JEF-C$^©$, an assessment tool designed for the evaluation of children aged 8-18 years suspected of having executive dysfunction in their natural environments. By that, this study replies to the call for the development of ecologically valid and sensitive instruments to measure cognitive outcomes in childhood ABI (Chevignard et al., 2012).

Overall in this preliminary study, results indicated that JEF-C$^©$ is a playful and easy way to assess EF. JEF-C$^©$ was feasible for both patients and controls who often enjoyed it, seeing it simply as a game to play. With JEF-C$^©$, the clinician observes how the person organizes on multi-tasking and uses the environment of a family house to get the house ready and run a birthday party. JEF-C$^©$ may be used in any clinical setting, can be administered and scored by trained personnel and emphasizes an individual's strengths and weaknesses on real-world task performance, making it a practical alternative to traditional EF tests. In addition, we found JEF-C$^©$ to be a reliable and valid assessment of EF abilities in children and adolescents with ABI. Overall, these strengths of JEF$^©$ (Denmark et al., 2017) and JEF-C$^©$ are probably consequences of the 'bottom-up' approach that went into their original development; a behavioural analysis of the types of errors that individuals with executive problems demonstrate became operationalized into the eight constructs that are tested and these were then used to create specific tasks to address each ability in an ecological manner. This is quite different to 'top-down' approaches

that have possibly been taken in the development of other tasks that have started from a theoretical perspective to construct many clinical assessments; this approach, certainly in the context of EFs, may be the reason for the discrepancy between test scores and performance in everyday life.

*Inter-relationships between JEF-C$^©$ measures*

This study found moderate internal consistency and significant small to moderate correlations between the JEF-C$^©$ individual constructs. Our results are in line with a previous study on the BADS-C, where internal consistency of the BADS-C was acceptable for the ABI group (alpha = .76) but low in controls (alpha = .41) (Longaud-Valès et al., 2016). Hence our results are not unexpected, and may accurately reflect the multidimensional nature of EF (Campbell et al., 2014). In addition, it should be noted that Cronbach's alpha may underestimate the internal consistency of ordinal scales with fewer than 5 levels of response, as is the case for the JEF-C$^©$ (Zumbo, Gadermann, & Zeisser, 2007). Additional work should be conducted to establish test-retest reliability.

*Discriminant validity*

This study indicates adequate discriminant validity of the JEF-C$^©$ which was found to be sensitive to differences between a group of (relatively high functioning) children and adolescents with ABI and a group of healthy matched controls; there were significant differences between the groups on JEF-C$^©$ total score and five out the of eight sub-scores while the differences for one additional sub-score approached significance. These findings are consistent with previous research, which have found that performance-based assessments, such as JEF-C$^©$, can discriminate between patients with ABI and controls (Chevignard, Catroppa, et al., 2010; Wolf, Dahl, Auen, & Doherty, 2015). However, in the current study as in previous studies using other

instruments, all domains of EF were not impaired homogeneously and  patients' performance in ecological tasks was very variable according to the sub-tests (Longaud-Valès et al., 2016).

In addition, on the traditional tests, the BADS-C and the BRIEF, the ABI sample was rated as having more EF problems than the healthy control children. In the BADS-C, a significant difference was found for the total score and in the Six Parts subtest, in which patients performed significantly worse than matched controls. The Six Parts subtest which assesses planning, task scheduling, and performance monitoring (Chevignard et al., 2009), has been categorized, like JEF-C©, as 'open-ended' because the participant can generate novel ways of doing the task (Rajendran et al., 2011). It has been argued that it is this 'open-ended' characteristic that, at least in part, underpins the success of these tasks in detecting many of the aspects of dysexecutive behavior that has been previously hard to quantify in the clinic (White, Burgess, & Hill, 2009). The zoo map and the water tests are categorized as constrained tasks (White et al., 2009). These results are in line with previous results that demonstrated that 'open-ended' tasks exhibited group differences (Chevignard et al., 2009), while none of the more constrained tasks did (White et al., 2009).

Using the BRIEF, significant differences were found on all subscales and indices but one, with a high proportion of patients scoring in the clinical range. In line with previous studies the Working Memory subscale was the most impaired (Chevignard et al., 2017; Sesma et al., 2008) while the least impaired subscale was Organization of Materials (Chevignard et al., 2017; Donders, DenBraber, & Vos, 2010; Sesma et al., 2008).

Based on the JEF-C© total score about 40% of the patients with ABI were classified within the clinical range. In contrast, the Six Parts subtest results classified only 22.2% of the children with ABI within the clinical range. Using the BRIEF, approximately 30% of this sample

was rated as having executive dysfunctions based on parents' reports on the GEC. These results are consistent with previous research about children with ABI where 25-50% were reported within the clinical range (Chevignard et al., 2017; Chevignard et al., 2009; Donders et al., 2010; Longaud-Valès et al., 2016; Vriezen & Pigott, 2002).

Based on the current results it can be argued that JEF-C$^©$ is more sensitive to a mild dysfunction than the other traditional tools. These results are line with previous studies where a larger proportion of children and adults with ABI was identified in the clinical range by the ecological cooking task and the JEF$^©$ than by the cognitive tests or the questionnaires (Chevignard et al., 2009; Denmark et al., 2017). Since JEF-C$^©$ is complex, with an average of approximately 60% of correct answers in the controls, it could be found suitable for medium to high functioning adolescents with ABI for example, who have minor dysfunction when other tests fail to demonstrate difficulties reported by patients or families.

*Concurrent validity*

The data largely demonstrated non-significant correlations between JEF-C$^©$ and parental report of EFs. These results are in line with previous papers that describe a discrepancy between performance-based measures and questionnaires when assessing clinical outcomes in pediatric patients with neurological disorders (Chevignard, Catroppa, et al., 2010; Coutinho, Câmara-Costa, et al., 2016; Gross, Deling, Wozniak, & Boys, 2015). A recent systematic review (Toplak et al., 2013) of studies in adults and children is also consistent with our findings in indicating that there are, at best, modest associations between questionnaire-based ratings of EFs and results of formal office-based tests of those executive skills. This may simply reflect the fact that the BRIEF captures aspects of EFs that are not identified on performance-based tasks in a neuropsychological clinic (Donders et al., 2010), be it standard paper and pencil or much more

ecological tests like the Children's Cooking Task (Chevignard, Catroppa, et al., 2010) or the

JEF-C$^©$. Therefore, the combination of performance-based neuropsychological tests with

everyday life questionnaires is recommended in order to provide a comprehensive assessment of

various aspects of EF in brain-injured children (Chevignard et al., 2012; Longaud-Valès et al.,

2016).

In addition, the non-significant correlation between the JEF-C$^©$ and the BADS-C is also

in line with the results from previous studies that assessed children and young adults treated for

frontal lobe tumors and TBI (Chevignard, Catroppa, et al., 2010; Longaud-Valès et al., 2016):

the correlations between the BADS-C, the Trail Making Test and the Wisconsin Card Sorting

Test were not significant when Full Scale Intellectual Quotient was taken into account (Longaud-

Valès et al., 2016).

It is worth noting, however, that although JEF-C$^©$ was not significantly associated to the

traditional EF measures, the correlations were in the expected direction. Higher JEF-C$^©$ scores

were associated with lower (better) BRIEF scores and higher BADS-C scores while the

correlations are of about the same amplitude as those among the different JEF-C$^©$ subscales.

*Correlational analysis with demographic and medical variables*

The large age range in the current study allowed analyzing and understanding the different

patterns of the development of EF with age as reflected in both groups. The correlation of JEF-

C$^©$ scores with age and its' predictive value among the healthy control group reinforces the well-

established developmental pattern of EF during childhood and adolescence (Zelazo & Carlson,

2012). In contrast, non-significant correlation was found between age and JEF-C$^©$ total score in

the group of children with ABI. This can be explained by the heterogeneity of the sample in

terms of injury related variables that effect differently of the EF developmental process. Indeed

studies report that the maturation process of cognitive skills is frequently altered following childhood brain injury (Anderson, Spencer-Smith, & Wood, 2011; Gilboa et al., 2015). Further, the oldest (at assessment) age group had the lowest age at injury, and those two factors probably both influence performance (Chevignard et al., 2017), as does injury severity, which we could not characterize into one single variable given the heterogeneous sample (various etiologies of ABI). Further studies could seek to explore this with a more homogeneous sample (for example only TBI or only brain tumours receiving cranial radiation therapy).

The correlation and the predictive value between the JEF-C© and IQ is in line with previous research in which all tasks of EFs were highly correlated with intellectual functioning among children with ABI (Chevignard, Catroppa, et al., 2010; Longaud-Vales et al., 2015). For example FSIQ and its four factors were strongly correlated (r=.70-.81) with the BADS-C overall score, in children and young adults treated for frontal lobe tumours (Longaud-Valès et al., 2016). This can be explained by the fact that EFs show conceptual overlap with intelligence. EFs contribute to the performance in complex cognitive tasks, and are thought to represent the elementary cognitive basis of individual differences in general intelligence (Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014). Neuropsychological evidence suggests that intelligence and EFs depend upon shared, though not identical, neural substrates (Stautz, Pechey, Couturier, Deary, & Marteau, 2016).

The JEF-C© total score was significantly correlated with SES, measured by parental education level and with the type of school the child was attending. Our results are in agreement with previous studies that have reported that lower parental education and family resources, lower SES and poor family functioning, are linked to higher levels of executive dysfunction (Ganesalingam et al., 2011; Potter et al., 2011; Sesma et al., 2008). Furthermore, a recent study

suggests that EFs may be an important link between childhood SES and academic achievement (Longaud-Valès et al., 2016). However, other studies have different results (Chevignard et al., 2017; Donders et al., 2010) so this area warrants further research.

No correlations were found between the total score of the JEF-C$^{©}$ and the standard injury variables of age at injury/diagnosis, time since injury/diagnosis, length of coma and radiotherapy dose. Some of these results may be driven by a small sample size (e.g. only 7 patients had a brain tumor and 5 had radiotherapy). In addition, results on these topics are equivocal in the literature. For example, in a study that assessed 21 patients, aged 8–27 years, treated for a childhood benign or malignant frontal lobe tumour, age at diagnosis was not significantly associated to cognitive outcome (Longaud-Valès et al., 2016). However, in other studies younger age at diagnosis was associated with worse outcomes (Anderson et al., 2011; Gilboa et al., 2015) and worse complaints on the parental BRIEF (Chevignard et al., 2017). In yet another study, age at injury predicted progress in EF, but the relationship was not linear; children 10–12 years old at injury showed better outcome than older and younger children (Krasny-Pacini et al., 2016). Given the divergent results in the literature additional research is needed on this topic.

*Study limitations and future directions*

Feedback from clinicians, parents and patients indicated the potential of JEF-C$^{©}$ in terms of ecological and predictive validity: however, a study exploring the JEF-C$^{©}$ ability to predict real world functioning was not conducted. In addition, it will be important to establish test–retest reliability of the JEF-C$^{©}$ assessment and to provide normative data. Secondly, the sample was selected from rehabilitation referrals, which obviously biased it towards relatively more complicated cases and more severe injuries, although only the relatively high functioning individuals were included. As such, it is not representative of the general population of children

with ABI and conclusions cannot be generalized. Thirdly, the current research includes a convenience sample across a wide age range that is heterogeneous in terms of type of ABI, age at injury, injury severity and SES and a non-representative control group. In addition the heterogeneous etiologies did not allow generating one common severity score and therefore made it difficult to specifically study the impact of injury severity. Lastly, although the ratio of subjects to variables met the suggested minimum requirement for regression analysis (Austin & Steyerberg, 2015), the total number of subjects in each group was relatively small. Future studies should include larger homogeneous samples allowing studying respective influences of injury severity variables.

Future research needs to validate the JEF-C using other, more widely administered, measures of EFs. In addition, the positive findings from JEF-C© both with healthy children and with children with ABI as demonstrated in the current study have suggested the possibility of an assessment specifically for older children, i.e. adolescents given that this is an age group for whom there are very few specific assessments. Therefore, the development of a JEF-A$^{©}$ environment is currently underway. With the rise of advanced computer platforms such as VIVE and Project Tango which incorporate immersive VR there is the possibility of creating more complex versions of JEF$^{©}$ and JEF-C$^{©}$ so that the environments can be even more realistic, avatars can be incorporated for the participant to interact with and more information can be collected during an assessment. These possibilities are being explored but with caution due to the possible extra cost involved in using advanced technologies; while more advanced systems can yield rich research data, from a pragmatic perspective, if hardware and software costs are kept to a minimum, the easier it will be for clinicians from different economic backgrounds to access.

*Conclusions*

The availability of psychometrically robust and simple to administer measures designed for specific populations is essential, enabling health professionals to tailor and improve intervention. Our findings in this preliminary study contribute to the growing pool of psychometric evidence for the validity of EF tests for children and adolescents with ABI. Overall, our results support the evidence of significant executive difficulties in children and adolescents with ABI, with consequences on their everyday life, as evidenced by the BRIEF. Our study supports the use of the JEF-C$^{©}$ in this population, especially in adolescents who have moderate to minor dysfunction with difficulties in everyday life that are not evidenced by the classical tests. The JEF-C$^{©}$ results enable an understanding of the unique EF profile of each individual patient. This could be used (and has been used for the patients in this study) for more precise goal-setting for rehabilitation. In addition, there are more differences than similarities between performance-based and inventory ratings of EF among children and adolescents with ABI. Therefore the combination of neuropsychological tests with everyday life questionnaires should be recommended in order to provide a comprehensive assessment of various aspects of EF in brain-injured children.

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Figure 1: Screenshot of living room within JEF-C© environment

Figure 2: Performance on JEF-C$^{©}$ as a function of group and cognitive construct.
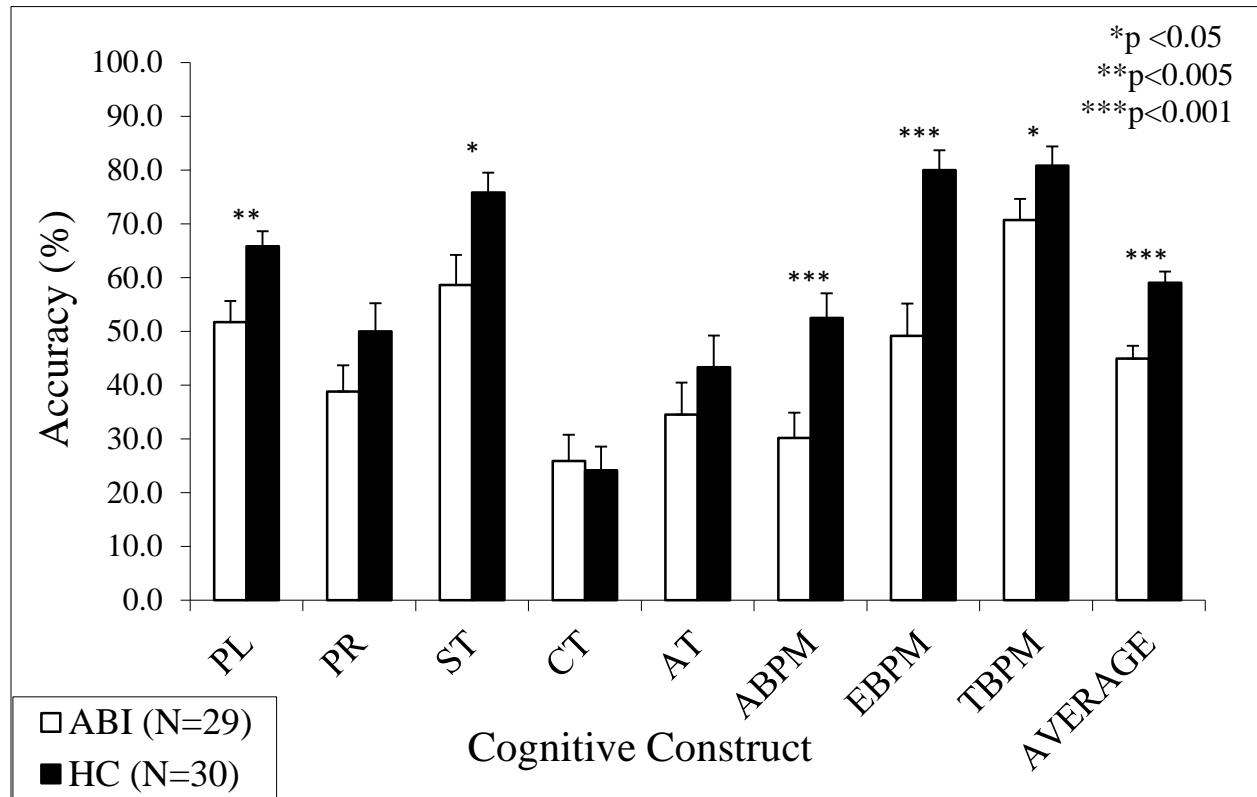


PL=Planning, PR=Prioritisation, ST=Selective-Thinking, CT=Creative-Thinking, AT=Adaptive-Thinking, ABPM=Action-Based Prospective Memory, TBPM=Time-based Prospective Memory, EBPM=Event-based Prospective Memory, Average=Average score across all constructs. Error bars represent one standard error.

Figure 3: Figure 3- Correlation between the JEF-C$^{©}$ total score and age for the ABI (3a) and control groups (3b)
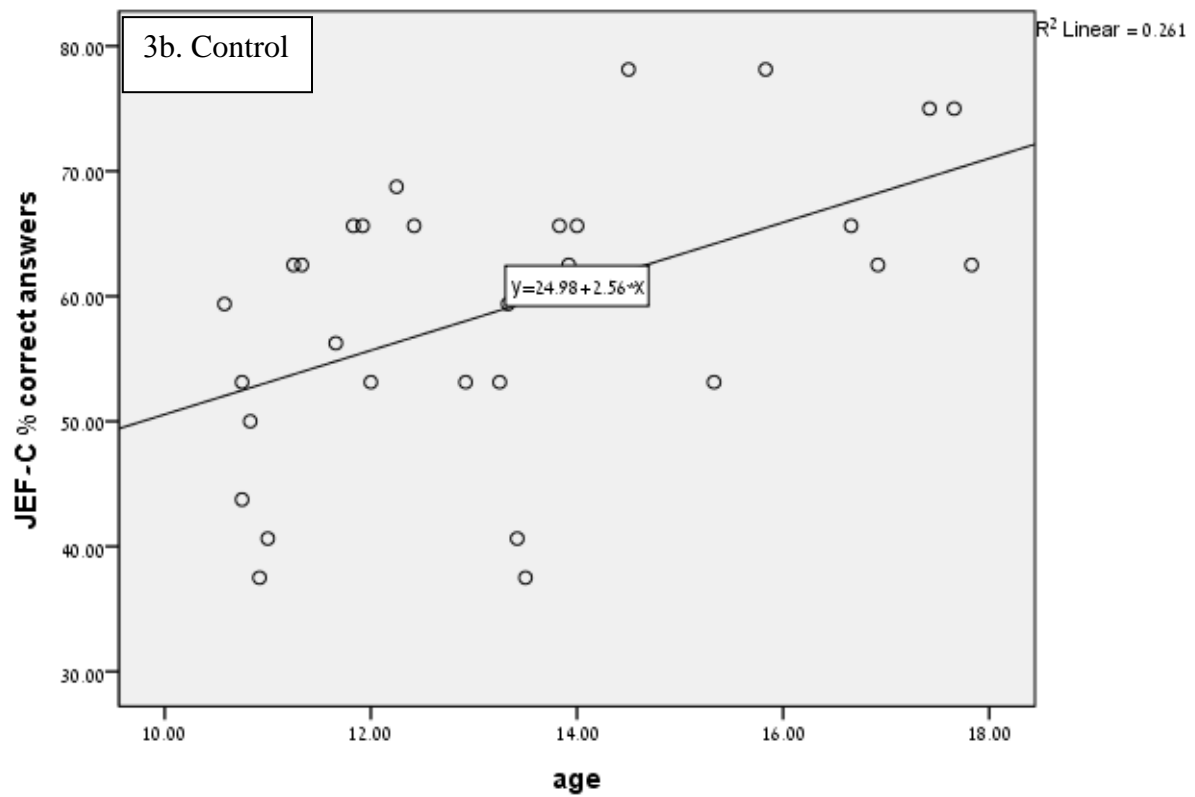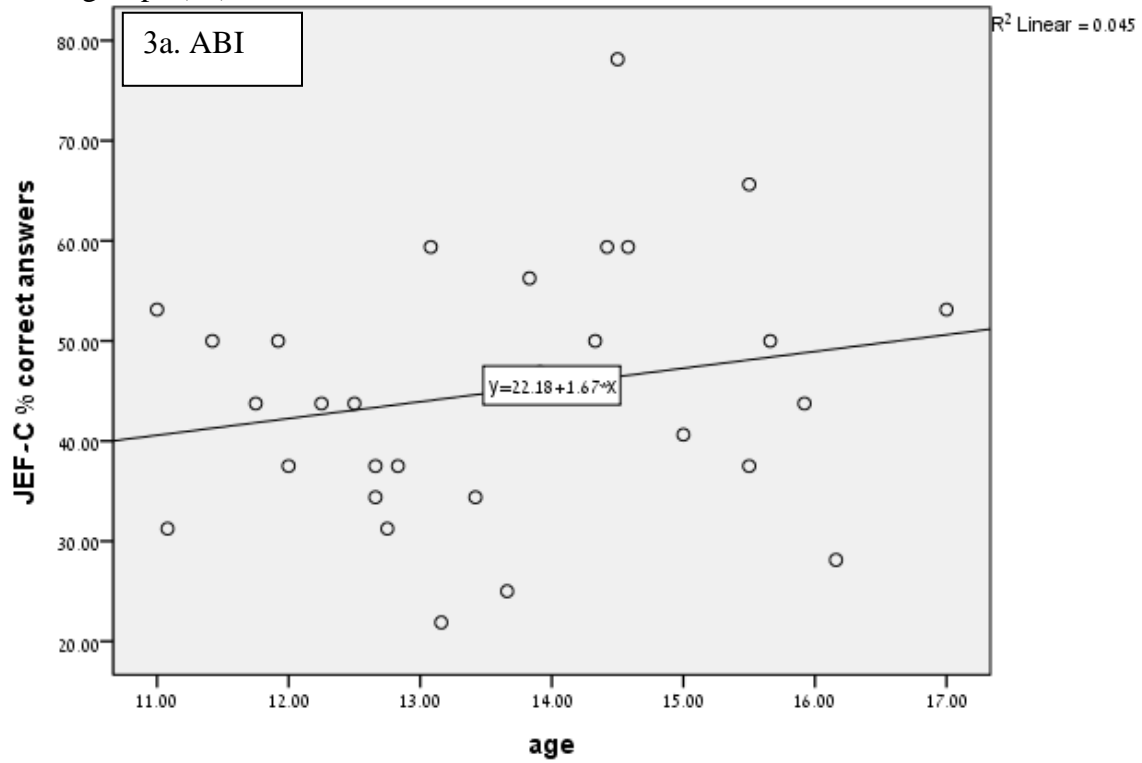
Figure 4: Performance on JEF-C$^{©}$ as a function of group, age and cognitive construct.
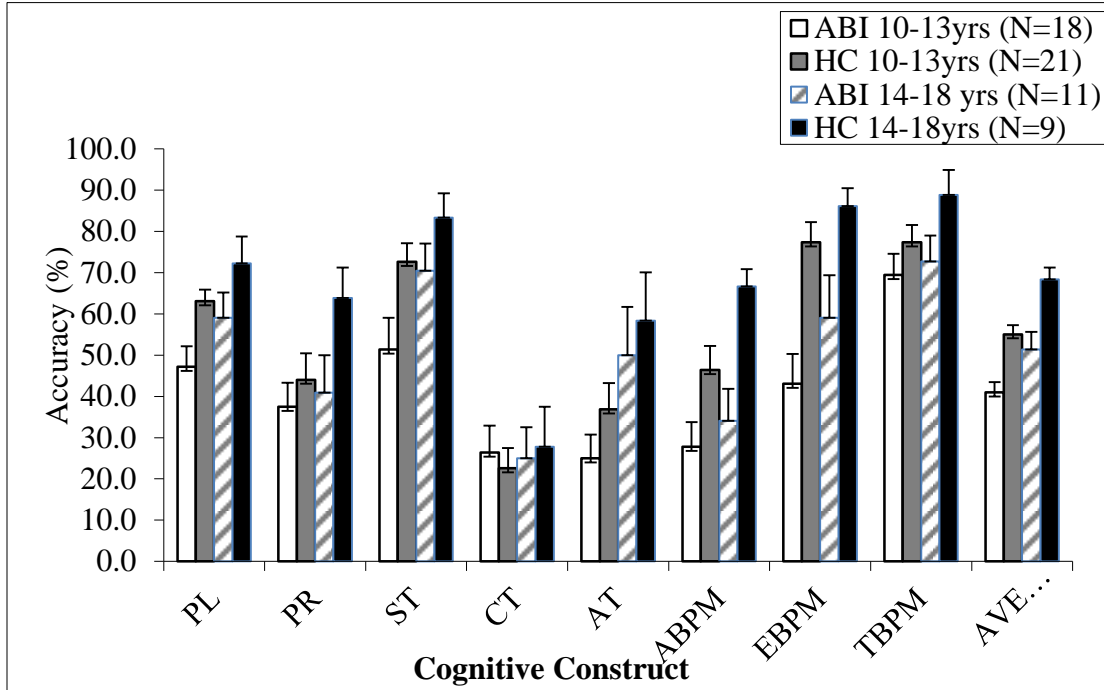


ABI 10-13 yrs = ABI children aged 10-13 years; HC 10-13yrs = Healthy Control children aged 10-13 years; ABI 14-18 yrs = ABI children aged 14-18 years; HC 14-18yrs = Healthy Control children aged 14-18 years PL=Planning, PR=Prioritisation, ST=Selective-Thinking, CT=Creative-Thinking, AT=Adaptive-Thinking, ABPM=Action-Based Prospective Memory, EBPM=Event-based Prospective Memory, TBPM=Time-based Prospective Memory, Average=Average score across all constructs. Error bars represent one standard error.

1    Table 1

2    List of constructs, operational definitions and an example of each task in JEF-C<sup>©</sup>

| Construct | Definition | Example of task |
| --- | --- | --- |
| **Planning (PL)** | Ordering events/objects due to logic (not importance) | Rearrange parent's list of tasks that need to be carried out either in preparation for the party, during the party or after it has ended |
| **Prioritisation (PR)** | Ordering events due to perceived importance | Arrange 5 cleaning tasks into a sensible order for completion at the end of the party |
| **Selective-thinking (ST)** | Choosing between two or more alternatives by drawing on acquired knowledge | Choose which food to give to different party guests based on their preferences or allergies |
| **Creative-thinking (CT)** | Looking for solutions to problems using unobvious and/or unspecified methods | Finding a method to cover the drawing of a spider that is drawn on a whiteboard in the hallway (because one of the guests is frightened of spiders) but which cannot be |

| | | |
|---|---|---|
| | | erased because it has been drawn in permanent ink |
| **Adaptive-thinking (AT)** | Re-achieving goals in the face of changing conditions of success | Find an alternative seating solution when one of the chairs breaks when the children sit down to eat |
| **Time-Based Prospective Memory (TBPM)** | Remembering to execute a task at a pre-determined future point in time | Take the dog to the neighbour's house by a set time before they have to go out |
| **Event-Based Prospective Memory (EBPM)** | Remembering to execute a task cued by an external stimulus/event | Write down any messages from phone calls that arrive during the party |
| **Action-Based Prospective Memory (ABPM)** | Remembering to execute a task cued by a stimulus related to an action the individual is already engaged in | Make a note for the parents of anything that gets broken during the party |

1

1    Table 2

2    Demographic and medical characteristics of the ABI and control groups.

|  | ABI (N=29) | Control (N=30) |  |
|---|---|---|---|
| Demographic information |  |  |  |
| Age at assessment, years; mean (SD), range | 13.60 (1.62) 11.0-17.0 | 13.32 (2.27) 10.58-17.83 | $t_{(1,57)}=.53$ (p=.59) |
| Males; N (%) | 14 (48%) | 14 (46.7%) | $\chi^2=.015$ (p=.90) |
| Frequency distribution by gender and age groups, years; n (% males) |  |  |  |
| 10-13 | 18 (50%) | 21 (38%) |  |
| 14-18 | 11 (45%) | 9 (66%) |  |
| *Ongoing type of education [n (%)] |  |  |  |
| 1. Mainstream school without help, without repeating year | 1. 3 (10.3%) | 1. 30 (100%) | $\chi^2=47.12$ (p<.001) |
| 2. Mainstream school, repeated at least one year | 2. 3 (10.3%) |  |  |
| 3. Mainstream school, with personalized help and/or adaptations | 3. 14 (48.3%) |  |  |
| 4. Special classroom or special education | 4. 9 (31%) |  |  |

| | | | |
|---|---|---|---|
| SES- parental education: the highest maximal education level achieved by either of the two parents [n (%)] | | | $\chi^2=7.00$ (p=.072) |
| 1: primary school | 1. 3 (14.3%) | 1. 1 (3.6%) | |
| 2: attended the "primary high school" | 2. 3 (14.3%) | 2. 0 (0%) | |
| 3: attended superior high school | 3. 6 (28.65) | 3. 8 (28.6%) | |
| 4: superior studies after graduation from high school | 4. 9 (42.9%) | 4. 19 (67.9%) | |
| | ABI (N=28) | Control (N=30) | |
| *IQ- vocabulary; mean (SD), range | 10.14 (3.88) | 12.70 (2.46) | t(1,56)=3.04 (p=.004) |
| *IQ- matrix; mean (SD), range | 9.64 (2.31) | 11.63 (2.38) | t(1,56)=3.22 (p=.002) |
| *Estimated FSIQ | 98.92 (13.24) | 111.34 (11.31) | t(1,56)=3.84 (p<.001) |
| Characteristics of the brain injury | | | |
| Age at injury/diagnosis, years, mean (SD), range | 8.3 (4.0) | – | |

| | | | |
|---|---|---|---|
| | 1.8–13.8 | | |
| Time since injury/diagnosis, years, mean (SD), range | 5.47 (4.45) 0.58-13.67 | – | |
| Cause of injury/diagnosis; n (%) | | | |
| TBI | 18 (62.1%) | | |
| Brain tumors | 7 (24.1%) | | |
| Childhood stroke | 3 (10.3%) | | |
| Anoxic Brain Injury | 1 (3.4%) | – | |
| Frequency distribution by cause of injury/diagnosis and age groups, years; n (%) | | | |
| 10-13 years (n=18) | | | |
| TBI ;n(%) | 10 (55.6%) | | |
| Brain tumors | 5 (27.7%) | | |
| Childhood stroke | 3 (16.7%) | | |
| Anoxic Brain Injury | 0 (0%) | | |
| Age at injury/diagnosis, years, mean (SD) | 9.57 (3.38) | | |

| 14-18 (n=11) | | | |
|---|---|---|---|
| TBI | 8 (72.7%) | | |
| Brain tumors | 2 (18.2%) | | |
| Childhood stroke | 0 (0%) | | |
| Anoxic Brain Injury | 1 (9.1%) | | |
| Age at injury/diagnosis, years, mean (SD) | 8.03 (4.26) | | |
| Injury severity **for TBI** (N=18)**:** | | – | |
| GCS Score, mean (SD) | 6.17 (2.17) | | |
| Length of coma [days; mean (SD)] | 8.11 (4.58) | | |
| For brain tumors | | – | |
| Treatment (N=7) | | | |
| Cranial radiation therapy, n (%) | 5 (71%) | | |
| Number of Grays, mean (SD) | 49.92 (9.29) | | |

1

2 *Significant differences between the patient and control groups.

3 SD, standard deviation; ABI, acquired brain injury; TBI, traumatic brain injury; IQ, intelligence

4 quotient; FSIQ: Full-Scale Intelligence Quotient; GCS: Glasgow Coma Scale.

5

1 Table 3

2 Inter-correlations of the JEF-C$^©$ sub-scales (N=59)

|  | PR | ST | CT | AT | ABPM | TBPM | EBPM |
|---|---|---|---|---|---|---|---|
| PL | .15 | .03 | -.02 | **.26*** | .24 | .24 | -.04 |
| PR | - | .10 | .09 | **.34**** | **.26*** | .23 | .06 |
| ST |  | - | .19 | .10 | .19 | **.32*** | .20 |
| CT |  |  | - | .07 | .02 | -.09 | .02 |
| AT |  |  |  | - | **.31*** | **.36**** | .09 |
| ABPM |  |  |  |  | - | **.28*** | **.32*** |
| TBPM |  |  |  |  |  | - | .23 |

3

4 PL=Planning, PR=Prioritisation, ST=Selective-Thinking, CT=Creative-Thinking, AT=Adaptive-

5 Thinking, ABPM=Action-Based Prospective Memory, TBPM=Time-based Prospective

6 Memory, EBPM=Event-based Prospective Memory

7 *<0.05, **p<0.01

1 Table 4

2 Comparison of the EF measures results between patients with ABI and healthy controls or norms.

| BRIEF subscales | ABI (N=26) M±SD | CONTROLS (N=29) M±SD | F | Effect size (d) | % of ABI group>65 (>1.5 SD) |
|---|---|---|---|---|---|
| Inhibition | 60.23±14.79 | 48.58±9.60 | 12.23** | .93 | 30.8 |
| Flexibility | 59.76±14.14 | 50.37±9.87 | 8.46** | .77 | 30.8 |
| Emotional control | 60.23±16.23 | 50.96±11.37 | 6.12* | .66 | 30.8 |
| Behavioral Regulation Scales | 61.84 ±17.20 | 50.03±10.24 | 9.80** | .83 | 26.9 |
| Initiation | 60.11±10.76 | 48.46±12.61 | 12.52** | 1.41 | 19.2 |
| Working memory | 61.00±13.45 | 48.79±9.04 | 15.88** | 1.06 | 23.1 |
| Planning and organization | 58.96±12.55 | 51.24±9.81 | 6.52* | .68 | 19.2 |
| Organization of Materials | 51.42±11.55 | 53.10±10.43 | .33 | 0.15 | 7.7 |
| Monitor | 57.84±11.35 | 48.65±10.05 | 10.21** | .86 | 19.2 |
| Metacognition Scales | 59.80±13.30 | 50.00±10.46 | 9.33** | .82 | 30.8 |
| Global Executive Composite | 61.61±14.90 | 50.24±10.52 | 10.85** | .88 | 30.8 |
| BADS-C subtests | ABI (N=28) | norms | T | p | % of ABI group <1.5 |

| | M±SD | | | | SD below mean | |
|---|---|---|---|---|---|---|
| Water test | 9.39 ±3.25 | 10±3 | -.98 | .33 | 17.9 | |
| Zoo 1 | 8.89 ±3.31 | 10±3 | -1.76 | .08 | 14.3 | |
| Zoo 2 | 9.46 ±3.37 | 10±3 | -.84 | .41 | 21.4 | |
| Six Part | 7.51±2.29 | 10±3 | -5.62** | .001 | 22.2 | |
| Total score | 35.00±7.40 | 40 | -3.57 | .001 | | |

SD, standard deviation; ABI, acquired brain injury; BADS-C, The Behavioral Assessment of the Dysexecutive Syndrome for Children; BRIEF, The Behavior Rating Scale Inventory

*<0.05, **p<0.01