Validation of a Persian Version of an English Language Ecologically-Valid Assessment of Executive Functions Through Childhood and Adolescence

Elham Eskandari [1*], Ashok S. Jansari [2], Mahdi Bagheri [3,4]

[1] Department of Clinical Child and Adolescent Psychology, Faculty of Education and Psychology, Shahid Beheshti University, Tehran, Iran

[2] Department of Psychology, Goldsmiths, University of London, Lewisham Way, New Cross, London SE14 6NW, United Kingdom

[3] Department of Clinical Psychology, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran

[4] Mental Health Research and Treatment Center, Faculty of Psychology, Ruhr University Bochum, Bochum, Germany

Author Note

Abstract word count: 200; Manuscript word count (main text): 5212

[*]Corresponding Author:
Address: Department of Clinical Child and Adolescent Psychology, Faculty of Education and Psychology, Shahid Beheshti University, Tehran, Iran
Tel: +49 (157) 34834238
e-mail: elhamskandari67@gmail.com
ORCID iD: 0000-0003-1484-8291

Abstract

Childhood and adolescence are pivotal periods for cognitive development. Executive functions are crucial for efficient cognitive functioning, so accurate assessment is important. One ecologically-valid virtual reality test is the Jansari assessment of Executive Functions for Children (JEF-C©; Jansari et al., 2012). In a cross-sectional study, we aimed at translating, adapting and validating JEF-C© into Persian, and at investigating whether this Persian version (JEF-C©(P)) can identify stages of development of executive functions in children aged from 8 to 16. Children and adolescents (N = 146) falling into three age groups participated: 8-10, 11-13 and 14-16 years old. They completed JEF-C©(P) and the Wisconsin Card Sorting Test (WCST). There were acceptable Cronbach's alpha coefficients for JEF-C©(P) total score (α = .72) and all constructs had a positive impact on total internal consistency, except action-based prospective memory that did not affect it. There was an effect of age group on overall JEF-C©(P) performance and of age on four constructs. There was also a correlation between the number of categories on WCST and the prioritization construct of JEF-C©(P). It seems that JEF-C©(P) is an ecologically valid executive function assessment sensitive to age and could be useful for both researchers and clinicians working with children.

Keywords: executive functions, assessment, children and adolescents, ecological validity, cultural adaptation, memory

Introduction

Within the brain's frontal lobes, the prefrontal cortex is assumed to mediate the so-called executive functions (EFs) (e.g., Grattan & Eslinger, 1991). These EFs involve the ability to acquire knowledge along with problem solving across nine areas encompassing attention, emotion regulation, cognitive flexibility, inhibitory control, initiation, organization, planning, self-monitoring, and working memory (Goldstein & Naglieri, 2013). Without doubt EFs play a key role in higher cognitive processes which assist one's behaviour especially, when it comes to unfamiliar situations (Gilbert et al., 2008) and goal-directed behavior.

Executive deficits result not only in cognitive, but also academic and everyday behavioral difficulties. For example, Marini et al (2020) suggested that there is a significant association between performance in children with developmental language disorders on EFs and linguistic and narrative skills in comparison to their typically developing peers (Marini et al., 2020). Given the importance of EFs and their longitudinal development from early childhood to adolescence, their assessment in this stage of life is of great importance (Anderson & Reidy, 2012).

To date, there have been a variety of methodologies applied to assess EFs in children. Some of the traditional tools used are the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948), the Tower of London (Shallice, 1982), and the Controlled Oral Word Association Test (COWAT; Benton et al., 1989). Despite their widespread and global use, a plethora of studies (e.g., Bennett et al., 2005; Wilson et al., 1996) have reported that these traditional tools suffer from several limitations.

First of all, since most assessments of EFs in children have been driven from adult versions and designed for a structured setting (Anderson & Reidy 2012), there have been fewer efforts regarding some factors, such as engagement-level of the environments which should be taken into consideration when an assessment is developed for children. Secondly, as mentioned earlier, EFs consist of many different areas such as memory, attention and problem solving. However, traditional assessments focus on just a few components of EFs. For example, the WCST mostly assesses mental flexibility and the Tower of London mostly assesses planning ability. Further, one of the main obstacles facing traditional assessments of EFs is the issue of ecological validity which refers to the level to which test results represent real world and everyday behavior (for a recent review, see Parsons et al., 2017). Research has demonstrated that the ecological validity of a range of traditional executive assessments is questionable, because in many cases there is incongruent performance between traditional tools and real life behavior (Jansari et al., 2014; Parsons, 2015). A classic example of this (from the adult literature) is Eslinger & Damasio's (1985) famous patient EVR who, following surgical resection of an orbitofrontal tumour was severely impaired in a range of aspects of everyday behavior including decision-making, and yet performed normally on the WCST (Eslinger & Damasio, 1985).

Over the last two decades, the issue of ecological validity has received much attention and has been addressed by some researchers (e.g., Parsons et al., 2017; Sbordone, 2000). For example, Sbordone (2000) has said that there is an urgent need to evaluate more ecologically-valid assessments in order for clinicians to provide more useful support for children with executive dysfunction. This has resulted in the development of more assessments for children including the second version of the Behavioral Rating Inventory of Executive Function (BRIEF-2; Gioia et al., 2015), the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001) and the Behavioral Assessment of Dysexecutive Syndrome Test Battery for children (BADS-C: Emslie, Burden, Nimmo-Smith, Wilson, & Wilson, 2003).

One way of addressing the lack of ecological validity has been the use of Virtual Reality (VR). VR assessments are function-led computer-based environments (Gregg & Tarrier, 2007) where the participant can respond to events, manipulate objects and complete tasks in a context which is simulating reality. VR has emerged as a powerful ecologically-valid method in assessing cognitive functions. Since VR-based tools have proven very useful (Campbell et al., 2009; Parsey & Schmitter-Edgecombe, 2013), the last two decades have witnessed a huge growth in developing these tools such as the Virtual Apartment/Home tasks (Sweeney, Kersel, Morris, Manly, & Evans, 2010), the Virtual Park (Buxbaum, Dawson, & Linsley, 2012) and the Virtual office, the Jansari assessment of Executive Functions (JEF©: Jansari et al., 2004; Jansari et al., 2014).

Considering the fact that there have been few VR tools designed for assessing children, and the successful findings of the adult JEF© paradigm, Jansari, Edmonds, Gordon, Nwosu & Leadbetter (2012) addressed this by developing the Jansari assessment of Executive Functions for Children (JEF-C©); this is a child-friendly non-immersive VR-based assessment in which children are presented with a computer 'game' which involves them hosting their own birthday party in the absence of their parents (see Methods for further information). Previous research using JEF-C© has revealed that it is an ecologically-valid assessment to evaluate the development of EFs through childhood (Jansari, Edmonds, Gordon, Nwosu, & Leadbetter, 2012). Moreover, the result of a study using a French translation of JEF-C© has shown that it can differentiate performance between children with acquired brain injury (ABI) and healthy children (Gilboa et al., 2017). These are promising results that lend credibility to JEF-C© as a tool to assess ABI. Further, a recent review by Corti and colleagues revealed that more than half of the traditional tools used to assess ABI in children lack applicability and are irrelevant to patients' everyday activities (Corti et al., 2021).

Performance in neuropsychological tests may be affected by culture across both childhood and adolescence. Ellefson et al. (2017) compared performance of children and adolescents from Hong Kong and the UK in four different tasks measuring inhibition, working memory, cognitive flexibility, and planning. Children from Hong Kong had a better performance in all four tasks (Ellefson et al., 2017). Similar findings capitalizing on differences in the performance of children from Western and East Asian countries have been found in other studies (e.g., Wang et al., 2016). Are the developmental changes in executive functions in Western children universal or culturally-specific. To address this question it is necessary to adapt and then validate tools developed in Western countries to individuals in non-western countries; if such validations are successful, it will then allow cross-cultural comparisons to be investigated in the future Recently, Simon, Jansari & Gilboa (2020) have demonstrated that it is possible to translate, culturally-adapt and validate JEF-C© into Hebrew for use in an Israeli context (Simon et al., 2020). In this study, we wanted to investigate applicability of JEF-C© in a Middle Eastern country, Iran.

The purposes of the current study were therefore threefold. First, since English and French are both European cultures, it is important to establish whether JEF-C© is suitable in a non-European culture, this time a Middle Eastern one. To echo the work by Simon et al (2020), our first aim was to see whether a translated version could work in the Persian language. Since during childhood and adolescence executive abilities increasingly develop (Davidson et al., 2006), one feature that a newly developed neuropsychological test should have is the ability to show this development. The next aim was to evaluate the concurrent validity of the new assessment against a version of the WCST that has been validated for use in the Persian context. The final aim was to provide a comprehensive view of children's and adolescents' performance, through a larger sample than used in previous JEF-C© studies.

Method

Design

The study used a mixed design with age group as the independent variable and scores on the executive function assessments (WCST and JEF-C©(P)) as the dependent variables.

Since this was an exploratory study, with the assumption from the English-language and Hebrew-versions that there would be an improvement in executive functions through adolescence, participants were split into three age groups (see below).

Participants

Participants for this study were 146 children (49.3% girls) recruited from six public schools in Tehran. All participants were Persian in origin aged between eight and sixteen years old with a mean age of 12.05 (*SD* = 2.52) and were assigned to three age groups: 8-10 (*n* = 45); 11-13 (*n* = 52) and 14-16 (*n* = 49) years old. Based on school psychologist reports, the 146 children who participated in this study had no known developmental disorders (language, learning, or attention disorders) or any neurological disorders (e.g., epilepsy) and were therefore recognized as typically developing children. Participants were also monitored whether they knew how to work with laptop keyboards. All participants could follow the instructions and provided proper responses before testing, e.g. keeping the forward arrow key to move forward within the JEF-C©(P) environment. The process of the participant recruitment was approved by the local ethics committee as well as the ethics committee of each of the six schools that provided participants for the study. The process complied with the Helsinki Declaration.

Materials

Wisconsin Card Sorting Test

The computerized version of the Wisconsin Card Sorting Test (WCST: Grant & Berg, 1948; Milner, 1963) (Heaton, Chelune, Talley, Kay, & Curtiss, 1993) has been increasingly used in research (e.g., Chen & Shu, 2018). In the current study, the Persian version of the computer-based WCST (Shahgholian, Azadfallah, Fathi-Ashtiani, & Khodadadi, 2011), which had acceptable reliability in the number of categories (α = .73) and perseverative responses (α = .74), was administered. During the assessment, participants have to classify cards based on different criteria. There are four different ways to sort out each card, and the feedback is whether the classification is correct. Performance of children was assessed by using the number of categories completed and perseverative errors.

The Jansari Assessment of Executive Function for Children (JEF-C©): Persian Version

JEF-C© is a non-immersive assessment which requires participants to arrange and run a birthday party without parental supervision within the virtual reality environment of a house. The party occurs in three rooms: the kitchen; the living room; and the TV/games room. There is also a front door, which participants can open, and a back garden with a gate next to the neighbour's garden. Participants can move freely across the three rooms, hallway and garden. Figure 1 shows a screenshot of the hallway in the house. Along with the VR program, there are a set of laminated materials in order for participants to use to complete certain tasks in the 'real world'. This type of 'mixed-reality' testing that involves a merging of real and digital worlds has recently received an increased interest; it is an important development, since it allows for progressively more natural interaction with both real physical and digital content in a way that resembles everyday life (Coolen et al., 2020). Using this blended methodology maximizes the advantages of both approaches while minimizing their weaknesses. Integrating familiar objects into virtual worlds reduces cognitive stress and the risk of behavioral and psychological symptoms (Clay et al., 2020).

Assessment begins with the assessor explaining the task to the participant by reading from a script. Following this, participants can explore the virtual house and see if they have any questions before the assessment formally commences. Next, they are given laminated lists to use during the assessment, such as an instruction card, the first planning task card which requires the participant to make a To-Do list, and a sheet containing each guest's biography. Moreover, the assessor provides participants with a piece of paper to record some events such as phone calls. Throughout the assessment, participants are asked to complete a number of tasks and respond to a series of events such as phone calls, guests arriving and objects breaking which are programmed to occur at fixed times.

INSERT FIGURE 1 HERE

Each task within the assessment is designed to investigate a specific area of eight executive behaviours which are considered to be important for overall executive functioning, namely Planning (PL), Prioritization (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). These eight constructs are driven by Jansari et al. (2012) from the adult version of the assessment (Jansari et al., 2014). For further details, see the list of constructs, definitions and an example of each JEF-C© task in Table 1.

INSERT TABLE 1 HERE

There are two sub-tasks for each construct with a score being given for each task separately. An objective scoring system allows an assessor to rate performance on each task on a three-point scale; a score of 2 is given for ideal performance, 1 for acceptable performance, and 0 for an incorrect response or failing to tackle the task. The total raw score for each construct is converted into a percentage score resulting in eight separate scores and an average of these eight scores for a total Average JEF-C© score. Previous research has demonstrated very high inter-rater reliability for the English version of the task ($r = .999$, $p < .001$) (Cracknell, 2013).

Procedure

The instructor manual and participant materials for JEF-C© were translated into Persian and also back-translated by a university research team (including psychologists and linguists) fluent in both English and Persian using the guidelines for translating and adapting psychological instruments (Gudmundsson, 2009). In addition to linguistic translation, given that JEF-C© involves a birthday party where guests come to the participant's family home and at one point are given party food, a small number of cultural adjustments were made to the VR program to make it appropriate in the Persian culture. These adjustments included changing the names of party guests and changing yoghurt into cake as a dessert as Iranians do not eat yoghurt as dessert. Furthermore, we changed the English sounds within the programme into Persian sounds. We also altered English instructions within the programme into Persian. The whole process of translating and programme adjustments took roughly six months. Attempts were made to make the Persian version as close as possible to the original English version of JEF-C©.

Parents and school principals gave written consent for the children to participate. Furthermore, children themselves verbally agreed to participate in the study and were free to stop their contribution whenever they wished. Each child was tested individually in a classroom in a quiet area of their school. Prior to commencing, an assessor provided participants with test instructions, and let them move around the VR environment and asked them if they had any questions. After that, participants were asked to play the 'game' to host their own birthday party; the VR game took approximately 30 minutes. Following this, about two thirds of the participants completed the WCST, which took roughly 15 minutes, bringing the total testing time to almost one hour. In order to investigate the inter-rater reliability, 14 children were tested in the presence of two assessors. Both of the assessors sat beside the participants so that they could score participants independently. The assessors did not consult or share their scoring sheets. They both rated children's performance based on the scoring protocol (see above). All children were thanked for their participation and given a gift encompassing a cartoon DVD and a chocolate bar.

Results

We included data of all participants in our data analyses.

Consistency & Reliability

In order to assess the internal consistency Cronbach's α was applied to the entire JEF-C©(P) dataset. The Cronbach's alpha for Average score was α = .72. It is possible to evaluate the impact on this measure if each construct is removed individually in case some are having disproportionately negative impacts. The changes in the Cronbach's *α* for the Average score following deletion of each construct individually were as follows: Planning (α = .69), Prioritization *(*α = .69), Selective-Thinking (α = .68), Creative-Thinking (α = .68), Adaptive-Thinking (α = .68), ABPM (α = .72), EBPM (α = .71), TBPM (α = .70). This shows for example that the Cronbach's alpha would have reduced from 0.72 to 0.69 if Planning had been removed. Therefore, with the exception of deletion of ABPM (which itself did not impact the value of internal consistency), the inclusion of all other constructs improved the internal consistency which therefore justifies keeping them all.

To investigate the reliability of the scoring protocol for JEF-C©(P), Intraclass Correlation Coefficients (ICC) were run for the scores given by two assessors for each of the constructs for 14 participants that were jointly assessed. The ICC estimates and their 95% confidence intervals were calculated based on a single rating, absolute-agreement, two-way random-effects model. The single measures ICC was 1 for all eight constructs except for ABPM in which the ICC was 0.97, $F\ (13,13) = 89.61$, $p < .001$, 95% CI [.93, .99]. For average JEF-C©(P), the single measures ICC was 0.99, $F\ (13,13) = 1354.23$, $p < .001$, 95% CI [.99, 1]. Overall, therefore, a very high degree of reliability was found in all of the eight constructs as well as the average JEF-C©(P) score.

Further, the correlation between two sub-tasks of each construct and between each construct with total JEF-C©(P) was run. Significant inter-item correlations between all constructs were found. There were also significant correlations between all eight constructs and total JEF-C©(P).and relationship between most constructs of JEF-C©(P) with each other were found at p level of < .01 (see Table 2).

INSERT TABLE 2 HERE

Convergent Validity

To assess the relationship between JEF-C©(P) and the WCST, the Pearson correlation was utilized. There was a significant correlation between number of categories on the WCST and Prioritization in JEF-C©(P), $r(86) = .28$, $p < .01$, but there were no correlations between the WCST and any of the remaining measures of JEF-C©(P) (in all situations, $p > .05$) (see Table 3).

INSERT TABLE 3 HERE

Development of Executive Functions

A univariate ANOVA showed that there was a significant main effect of age group on Average JEF-C©(P), $F(2, 143) = 9.68$, $p < .001$, $\eta_p^2 = .11$. A *Scheffe* post hoc analysis showed that there were significant differences between 8-10 and 11-13 years old ($MD = 2.77$, $SD = 0.98$, $p = .02$), and between the 8-10 and 14-16 years old ($MD = 4.36$, $SD = 1.00$, $p < .001$).

To investigate the effect of age on children's performance on each individual JEF-C©(P) construct, a MANOVA test was conducted. A significant main effect was found for age groups, $F(16, 272) = 2.66$, $p = .001$, *Wilks Lambda* = 0.74, $\eta_p^2 = .13$. Subsequent tests of between-subjects effects revealed that there were significant differences between the three age groups in Planning, $F(2, 143) = 6.58$, $p = .002$, $\eta_p^2 = .08$, Prioritization, $F(2, 143) = 7.18$, $p = .001$, $\eta_p^2 = .09$, Selective-Thinking, $F(2, 143) = 13.39$, $p < .001$, $\eta_p^2 = .15$, and Creative-Thinking, $F(2, 143) = 4.71$, $p = .01$, $\eta_p^2 = .06$. A *Scheffe* post hoc was run to determine pairwise differences between the three groups in these constructs. The results indicated that there were significant differences between groups as follows: for Planning between 8-10 and 14-16 years old (*MD* = 0.65, *SD* = 0.17, p = .002); for Prioritization between 8-10 and 11-13 years old (*MD* = 0.74, *SD* = 0.23, p = .008) as well as between 8-10 and 14-16 years old (*MD* = 0.83, *SD* = 0.24, p = .003); for Selective-Thinking between 8-10 and 11-13 years old (*MD* = 0.62, *SD* = 0.22, p = .02), 8-10 and 14-16 years old (*MD* = 1.16, *SD* = 0.22, $p < .001$), and11-13 and 14-16 years old (*MD* = 0.74, *SD* = 0.23, p = .008); and finally for Creative-Thinking between 8-10 and 14-16 years old (*MD* = 0.63, *SD* = 0.20, p = .01) (see Figure 2).

INSERT FIGURE 2 HERE

To investigate effects of age group on children's performance on the WCST scales, a MANOVA test was run. A significant main effect was found for age group, $F(4, 166) = 4.51$, $p = .002$, *Pillai's Trace* = 0.19, $\eta_p^2 = .09$. Subsequent tests of between-subject effects revealed that there was a significant effect of age on the number of categories correctly sorted, $F(2, 83) = 5.72$, $p = .005$, $\eta_p^2 = .12$; however, there was no effect of age group on numbers of perseverative errors, $F(2, 83) < 1$. A *Scheffe* post hoc revealed that there were significant differences between the 8-10 and 11-13 years old (*MD* = 0.73, *SD* = 0.22, p = .006) in the numbers of categories sorted. For further details, see Table 4.

INSERT TABLE 4 HERE

As an ancillary analysis, to investigate the relationship between actual age, JEF-C©(P) performance, and WCST performance, Pearson's correlation coefficients analysis was carried out using the actual age of participants. There was a significant correlation between age and JEF-C©(P) total score, $r(146) = .38$, $p < .001$, showing that performance on JEF-C©(P) improves with age. However, for the WCST, while there was a significant correlation between the actual age and number of categories, $r(86) = .30$, $p = .004$, there was no correlation between age and number of perseverative errors, $r(86) = -.10$, $p = .32$. For further details, see Table 3. Finally, we ran an ANOVA to assess effects of gender on participants' performance in JEF-C©(P). There was a limited but not significant effect of gender on participants' performance $F(2, 143) = 2.87$, $p = .09$, $\eta_p^2 = .02$ with girls performing better than boys.

Discussion

The main aim of this study was to validate the Persian version of a novel, ecologically-valid, non-immersive assessment (JEF-C©) to track development of EFs through childhood and adolescence. JEF-C©(P) was found to have acceptable internal consistency and as a result, it can be concluded that it and its constructs assess aspects of the same characteristic, here EFs, and their inclusion strengthens the validity of the total JEF-C©(P). These results were convergent with the original findings in English (Jansari et al., 2012), the French (Gilboa et al., 2017), and Hebrew (Simon et al., 2020) versions of JEF-C©. In line with previous work with JEF© (Jansari et al., 2014) and JEF-C© (Cracknell, 2013), the current study found high inter-rater reliability for JEF-C©(P), demonstrating that the scoring protocol of JEF-C©(P) is of a robust quality and reliability.

In terms of convergent validity, while we found a significant correlation between the number of WCST categories and the Prioritization JEF-C©(P) construct, our results showed no other significant correlations between the number of categories or preservative errors on the WCST and any other constructs of JEF-C©(P). This result is interesting in light of the fact that it has been argued that some existing executive function assessments including the WCST have potential problems with specificity and it is not completely obvious which of the executive functions or dysfunctions this task assesses (e.g., Pennington & Ozonoff, 1996) and might not always differentiate intact from impaired performance. For example, using the WCST, Robinson et al. (2009) failed to find significant differences between the performance of participants suffering from Autism Spectrum Disorder (ASD) and typically-developing controls in perseverative and total number of errors (Robinson, Goddard, Dritschel, Wisley,

& Howlin, 2009). Similarly, using the adult version of JEF© to evaluate 27 patients with acquired brain injury, Perniske and colleagues found that only one out of five of the WCST variables tested (categories completed) differentiated their performance from matched healthy controls while the other four variables (trials administered, total correct, perseverative errors age-matched Z score and percent perseverative errors age-matched Z score) failed to do so (Perniske et al., under review).

Both the correlational analysis and the categorical group analysis demonstrated that JEF-C©(P) performance is sensitive to increasing age during childhood and adolescence. This echoes previous JEF-C© findings (Jansari et al., 2012; Simon et al., 2020) but in a larger sample and is in line with previous research which has argued that EF performance develops during childhood and adolescence (Taylor, Barker, Heavey, & McHale, 2013). Previous research (e.g., Anderson, 2002; Brocki & Bohlin, 2004) has also found, albeit using more traditional measures, that two of the fundamental dimensions of executive functions, inhibition and working memory, develop from early childhood to early adolescence. Improvement in tasks related to executive functions, like working memory tasks, has been seen across adolescence (e.g., Best & Miller, 2010; Conklin, Luciana, Hooper, & Yarger, 2007). Importantly the JEF-C© findings extend this literature by using a more integrated ecologically-valid approach.

Given the eight distinct constructs, JEF-C©(P) has the potential to be a more sensitive assessment tool than the WCST to assess executive functions. Based on the literature, JEF-C© is a useful tool to detect executive problems. For instance, Gilboa et al. (2017) used JEF-C© amongst children and adolescents suffering from acquired brain injury and compared their performance with a healthy control group. Their results showed that the former had significantly weaker performance than the latter for overall average JEF-C© and five out of eight constructs (Gilboa et al., 2019). Similar results have been found by using JEF©, the adult version. Patients with focal frontal lobe lesion in overall average JEF© and in five out of eight constructs were worse than the healthy control group (Denmark et al., 2019).

In the current study, there was no significant effect of age, both actual age and age groups, on the three prospective memory constructs. Jansari et al (2012) found no correlation between age and Action-Based Prospective Memory but did find a correlation for Event-Based and Time-Based Prospective Memory. This discrepancy may be due to the sample sizes or particular characteristics of the samples. Due to the paucity of research available on prospective memory in JEF-C© and generally during development, in order to have a better understanding of interactions of these constructs and age, further investigations are needed.

While the difference between boys and girls did not reach statistical significance, there was a trend with girls performing better than boys. This echoes findings from a new version of JEF© for adolescents (JEF-A©) which found that female teenagers were better than male teenagers (Jansari, Lepak & Wickham, *in prep*). There are complex gender differences in the development of the brain during adolescence (e.g. Jung et al, 2019) and so further investigation of how executive functions may have different trajectories in boys and girls is merited.

This study translated and validated the Jansari assessment of Executive Functions for Children in an Asian country. It provides a valid tool for assessing development of EFs in typically developing children and to evaluate executive dysfunction amongst children and adolescents in Persian speaking areas.

Study Limitations and Future Directions

While our findings are very promising and the first for a non-European version of JEF-C©, we acknowledge that there are some limitations. Since at the time of the data collection, there were no Persian versions of the BRIEF or BADS-C, it was not possible to compare objective performance on JEF-C©(P) with subjective reports from the participants, their parents or their teachers. Therefore, the inconsistency between JEF-C©(P) and WCST might underscore the efficiency of the gold standard. A problem in testing (concurrent in our case) criterion validity is that the (available) gold standard itself might probably not be an accurate representative of the phenomenon (Bellamy, 2015).

Iran has different ethnic groups and our sample was from Tehran in which the majority speaks Persian. A recent meta-analysis showed that in the United States there is a significant difference in performance of majority and minority groups in executive functions (Rea-Sandin et al., 2021). JEF-C©(P) should apply amongst minorities, e.g. Kurdish children, with the caveat that children from different ethnic groups may perform differently. Therefore, future studies can address this by doing cross-cultural studies on different ethnic groups in Iran.

One potential limitation is the format of assessment that is used. As stated in the Methods, we recruited children living in a big city in Iran where use of laptops is not uncommon in schools and family homes. However, most children, especially in small cities of Iran, have less access to technology. In addition to access to technology, poorer socioeconomic status itself has been found to be related to poorer cognitive performance (Hackman & Farah, 2009). Future research should take this element into consideration, for example with gathering information about the socioeconomic status of a child's family to see if that covaries with performance. At a general level, this is always going to be a tension both at the research and clinical level if ecological validity is desired since at the moment, virtual reality helps in this pursuit but in itself can be a limitation.

In terms of future research, given the age sensitivity of JEF-C©(P) it could be used to create a profile for typical EFs development throughout childhood and adolescence. This typically developing profile could be useful for detecting signs of EFs impairments during development in a way that it is not currently possible, and conversely, also to ensure that fluctuations in typical EFs developments are not mistaken for executive dysfunction. Moreover, JEF-C© has potential to be used in children with ABI to predict difficulties in real life settings and to help in development of rehabilitation programs. For example, Figure 3a shows the individualized profiles for two children in which the performance is now standardized to z-scores; in such a representation, a score of 0 would mean that the participant scores at the exact average of age-matched healthy controls, a positive score that they score better than average and a negative one that they are impaired relative to controls. Using this sort of individualized profile will help educational psychologists or clinicians work out areas of specific difficulty for that person; this demonstrates a particular strength of JEF-C© in that in addition to knowing that the individual is impaired overall on the assessment, it can reveal which specific areas rehabilitation or psychoeducation for parents and the child's teacher can be targeted to limit the impact of specific difficulties in their everyday life. The child in Figure 3a shows the performance of one of the 8-10 year old children in the current study and shows that that they have an Average z-score of nearly 0 showing that their overall performance is close to the mean of all the children tested in their age group. However, Figure 3a shows that this Average score is made up of some areas of strengths with z-scores that are at least one standard deviation above the group average (Planning, Prioritisation, Action-Based Prospective Memory and Time-Based Prospective Memory) and at least one area of weakness where their score is approaching two standard deviations below the mean (Event-Based Prospective Memory). To demonstrate potential future utility of such a depiction Figure 3b shows the performance of a child with brain-damage (not in the current study) relative to age-matched controls from a central database of English-speaking children. This shows that while the child is very impaired relative to healthy controls (with an Average score four standard deviations from the mean), they are performing above the mean for Action-Based Prospective Memory and close to the mean for Prioritisation. However, against these relatively unimpaired abilities, the child has specific difficulties in Selective-Thinking, Adaptive-Thinking and Event-Based Prospective Memory which would be where efforts for rehabilitation or psychoeducation could be targeted. A further strength of JEF-C© and the individualized profiles shown in Figure 3 is that a standard assessment might show that the child in Figure 3a from the present study falls in the 'average' range which on its own would suggest that the child is unimpaired; this would of course be inaccurate since it seems that the child has some weaknesses on very specific abilities which many standard tests might fail to detect. Using this methodology, JEF-C© could also contribute to building profiles of EF performance for any developmental groups who may have unique profiles, such as those with attention deficit hyperactivity disorder (ADHD) or ASD.

INSERT FIGURE 3 HERE

Conclusions

In conclusion, JEF-C©(P) is a non-immersive computer-based ecologically valid assessment that is sensitive to development of EFs from late childhood to early and middle adolescence. Its design allows the measurement of a number of different executive functions simultaneously and by demonstrating concurrent validity with existing measures, shows potential for being used alongside the traditional tests.

Acknowledgements

We would like to thank Dr. Hamidreza Pouretamd for his help as the supervisor of the first author.

Conflict of Interests

The authors have nothing to disclose.

Funding

There was no funding for this study.

References

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology*, *8*(2), 71–82.

Anderson, P. J., & Reidy, N. (2012). Assessing executive function in preschoolers. *Neuropsychol Rev*, *22*(4), 345–360. https://doi.org/10.1007/s11065-012-9220-3

Bellamy, N. (2015). 2—Principles of clinical outcome assessment. In M. C. Hochberg, A. J. Silman, J. S. Smolen, M. E. Weinblatt, & M. H. Weisman (Eds.), *Rheumatology (Sixth Edition)* (pp. 9–19). Mosby. https://doi.org/10.1016/B978-0-323-09138-1.00002-4

Bennett, P. C., Ong, B., & Ponsford, J. (2005). Assessment of executive dysfunction following traumatic brain injury: Comparison of the BADS with other clinical neuropsychological measures. *J Int Neuropsychol Soc*, *11*(5), 606–613. https://doi.org/10.1017/S1355617705050721

Benton, A. L., Hamsher, K. d, & Sivan, A. (1989). *Multilingual Aphasia Examination. Iowa City, IA: AJA Associates*.

Brocki, K. C., & Bohlin, G. (2004). Executive functions in children aged 6 to 13: A dimensional and developmental study. *Developmental Neuropsychology*, *26*(2), 571–593.

Clay, F., Howett, D., FitzGerald, J., Fletcher, P., Chan, D., & Price, A. (2020). Use of Immersive Virtual Reality in the Assessment and Treatment of Alzheimer's Disease: A Systematic Review. *Journal of Alzheimer's Disease*, *75*(1), 23–43. https://doi.org/10.3233/JAD-191218

Coolen, B., Beek, P. J., Geerse, D. J., & Roerdink, M. (2020). Avoiding 3D Obstacles in Mixed Reality: Does It Differ from Negotiating Real Obstacles? *Sensors*, *20*(4), Article 4. https://doi.org/10.3390/s20041095

Corti, C., Oprandi, M. C., Chevignard, M., Jansari, A., Oldrati, V., Ferrari, E., Martignoni, M., Romaniello, R., Strazzer, S., & Bardoni, A. (2021). Virtual-Reality Performance-Based Assessment of Cognitive Functions in Adult Patients With Acquired Brain Injury: A Scoping Review. *Neuropsychology Review*. Scopus. https://doi.org/10.1007/s11065-021-09498-0

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*(11), 2037–2078. https://doi.org/10.1016/j.neuropsychologia.2006.02.006

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan Executive Function System*. /doiLanding?doi=10.1037%2Ft15082-000

Denmark, T., Fish, J., Jansari, A., Tailor, J., Ashkan, K., & Morris, R. (2019). Using Virtual Reality to investigate multitasking ability in individuals with frontal lobe lesions. *Neuropsychological Rehabilitation*, *29*(5), 767–788. https://doi.org/10.1080/09602011.2017.1330695

Ellefson, M. R., Ng, F. F.-Y., Wang, Q., & Hughes, C. (2017). Efficiency of Executive Function: A Two-Generation Cross-Cultural Comparison of Samples From Hong Kong and the United Kingdom. *Psychological Science*, *28*(5), 555–566. https://doi.org/10.1177/0956797616687812

Eslinger, P. J., & Damasio, A. R. (1985). Severe disturbance of higher cognition after bilateral frontal lobe ablation: Patient EVR. *Neurology*, *35*(12), 1731–1741.

Gilbert, S. J., Bird, G., Brindley, R., Frith, C. D., & Burgess, P. W. (2008). Atypical recruitment of medial prefrontal cortex in autism spectrum disorders: An fMRI study of two executive function tasks. *Neuropsychologia*, *46*(9), 2281–2291. https://doi.org/10.1016/j.neuropsychologia.2008.03.025

Gilboa, Y., Jansari, A., Kerrouche, B., Uçak, E., Tiberghien, A., Benkhaled, O., Aligon, D., Mariller, A., Verdier, V., Mintegui, A., Abada, G., Canizares, C., Goldstein, A., & Chevignard, M. (2017). Assessment of executive functions in children and adolescents with acquired brain injury (ABI) using a novel complex multi-tasking computerised task: The Jansari assessment of Executive Functions for Children (JEF-C©). *Neuropsychological Rehabilitation*, *29*(9), 1359–1382. https://doi.org/10.1080/09602011.2017.1411819

Gilboa, Y., Jansari, A., Kerrouche, B., Uçak, E., Tiberghien, A., Benkhaled, O., Aligon, D., Mariller, A., Verdier, V., Mintegui, A., Abada, G., Canizares, C., Goldstein, A., & Chevignard, M. (2019). Assessment of executive functions in children and adolescents with acquired brain injury (ABI) using a novel complex multi-tasking computerised task: The Jansari assessment of Executive Functions for Children (JEF-C©). *Neuropsychological Rehabilitation*, *29*(9), 1359–1382. https://doi.org/10.1080/09602011.2017.1411819

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2015). *BRIEF-2: Behavior rating inventory of executive function*. Lutz, FL: Psychological Assessment Resources, Inc.

Goldstein, S., & Naglieri, J. A. (2013). *Handbook of executive functioning*. Springer Science & Business Media.

Grattan, L. M., & Eslinger, P. J. (1991). Frontal lobe damage in children and adults: A comparative review. *Developmental Neuropsychology*, *7*(3), 283–326.

Gregg, L., & Tarrier, N. (2007). Virtual reality in mental health. *Social Psychiatry and Psychiatric Epidemiology*, *42*(5), 343–354. https://doi.org/10.1007/s00127-007-0173-4

Hackman, D. A., & Farah, M. J. (2009). Socioeconomic status and the developing brain. *Trends in Cognitive Sciences*, *13*(2), 65–73. https://doi.org/10.1016/j.tics.2008.11.003

Jansari, A., Agnew, R., Akesson, K., & Murphy, L. (2004). The use of virtual reality to assess and predict real-world executive dysfunction: Can VR help for work-placement rehabilitation? *Brain Impairment*, *5*(1), 110.

Jansari, A., Edmonds, C., Gordon, R., Nwosu, U., & Leadbetter, T. (2012). Towards a novel ecologically-valid assessment of executive functions in children and adolescents: Could virtual reality be the answer? *Brain Impairment*, *13*(146).

Jansari, A. S., Devlin, A., Agnew, R., Akesson, K., Murphy, L., & Leadbetter, T. (2014). Ecological Assessment of Executive Functions: A New Virtual Reality Paradigm. *Brain Impairment*, *15*(2), 71–87. https://doi.org/10.1017/BrImp.2014.14

Marini, A., Piccolo, B., Taverna, L., Berginc, M., & Ozbič, M. (2020). The Complex Relation between Executive Functions and Language in Preschoolers with Developmental Language Disorders. *International Journal of Environmental Research and Public Health*, *17*(5). https://doi.org/10.3390/ijerph17051772

Orkin Simon, N., Jansari, A., & Gilboa, Y. (2020). Hebrew version of the Jansari assessment of Executive Functions for Children (JEF-C©): Translation, adaptation and validation. *Neuropsychological Rehabilitation*, 1–19. https://doi.org/10.1080/09602011.2020.1821718

Parsons, T. D. (2015). Virtual Reality for Enhanced Ecological Validity and Experimental Control in the Clinical, Affective and Social Neurosciences. *Front Hum Neurosci*, *9*, 660. https://doi.org/10.3389/fnhum.2015.00660

Parsons, T. D., Carlew, A. R., Magtoto, J., & Stonecipher, K. (2017). The potential of function-led virtual environments for ecologically valid measures of executive function in experimental and clinical neuropsychology. *Neuropsychol Rehabil*, *27*(5), 777–807. https://doi.org/10.1080/09602011.2015.1109524

Perniske, Ward, Dalrymple, Pickering, & Jansari. (under review). *Cognitive correlates of everyday function after acute brain Injury: The Jansari Assessment of Executive Functions (JEF©) has greater ecological validity than standardized executive function tests*.

Rea-Sandin, G., Korous, K. M., & Causadias, J. M. (2021). A systematic review and meta-analysis of racial/ethnic differences and similarities in executive function performance in the United States. *Neuropsychology*, *35*(2), 141–156. https://doi.org/10.1037/neu0000715

Shallice, T. (1982). Specific impairments of planning. *Philos Trans R Soc Lond B Biol Sci*, *298*(1089), 199–209.

Wang, Z., Devine, R. T., Wong, K. K., & Hughes, C. (2016). Theory of mind and executive function during middle childhood across cultures. *Journal of Experimental Child Psychology*, *149*, 6–22. https://doi.org/10.1016/j.jecp.2015.09.028

Wilson, B. A., Alderman, N., Burgess, P. W., Emslie, H., & Evans, J. (1996). *Behavioural assessment of the dysexecutive syndrome*. Thames Valley Test Company.

Table 1

The Eight Constructs of JEF-C© With Their Definitions and an Example of a Task for Each Construct.

Construct	Definition	Example of task
Planning	Ordering events/objects due to logic (not importance)	Set up the TV room ready to watch a DVD with their friends during the party
Prioritisation	Ordering party activities due to perceived importance	Order the four party activities based on given information
Selective-Thinking	Choosing between two or more alternatives by drawing on acquired knowledge	Choose presents to give to each guest based on biographical information of each guest
Creative-Thinking	Looking for solutions to problems using non-obvious and/or unspecified methods	Finding a solution to keep the garden gate close so the dog cannot leave the garden
Adaptive-Thinking	Re-achieving goals in the face of changing conditions of success	Provide a suitable alternative for to birthday cake as a dessert when one of the guests say they are trying to eat more healthily
Action-Based prospective memory	Remembering to execute a task cued by a stimulus related to an action the individual is already engaged in	Put candles on the cake when they take it out of the fridge
Event-Based prospective memory	Remembering to execute a task cued by an external stimulus/event	Write down the name of any guest who come to the party
Time-Based prospective memory	Remembering to execute a task at a pre-determined future point in time	Take the cake out of the fridge at the set time

Table 2

Correlations Between individual constructs JEF-C©(P) and between the constructs and Average JEF-C©(P).

	Planning	Prioritization	Selective-Thinking	Creative-Thinking	Adaptive-Thinking	ABPM	EBPM	TBPM	Average JEF-C©(P)
Planning	-								
Prioritization	.39**	-							
Selective-Thinking	.41**	.30**	-						
Creative-Thinking	.33**	.34**	.41**	-					
Adaptive-Thinking	.31**	.29**	.39**	.40**	-				
ABPM	.01	.18*	.13	.13	.12	-			
EBPM	.17*	.14	.10	.21**	.24**	.41**	-		
TBPM	.30**	.19*	.26**	.25**	.21*	.25**	.17**	-	
Average JEF-C©(P)	.60**	.61**	.64**	.64**	.64**	.48**	.55**	.51**	-

Note. ABPM: Action-Based Prospective Memory. EBPM: Event-Based Prospective Memory. TBPM: Time-Based Prospective memory.
*p < .05, **p < .01.

Table 3

Correlations Between Age, Wisconsin Card Sorting Test and JEF-C©(P).

	Age	Planning	Prioritization	Selective-Thinking	Creative-Thinking	Adaptive-Thinking	ABPM	EBPM	TBPM	JEF-C©(P)
Age	-	0.31**	0.30**	0.41 **	0.26**	0.20*	0.12	0.10	0.08	0.38**
WCST										
Clusters Numbers	0.30**	0.16	0.28**	. 18	0.05	-0.01	-0.00	0.06	0.07	0.19
preservation numbers	-0.10	0.01	-0.18	0.01	-0.01	-0.04	-0.04	-0.12	0.06	-0.09

Note. WCST: Wisconsin Card Sorting Test. ABPM: Action-Based Prospective Memory. EBPM: Event-Based Prospective Memory. TBPM: Time-Based Prospective Memory.
*p < .05, **p < .01.

Table 4

Mean and Standard Deviations for Wisconsin Card Sorting Test performance as a Function of Age Group.

	Age groups		
	8-10	11-13	14-16
	M (*SD*)	*M* (*SD*)	*M* (*SD*)
Number of categories	2.63 (.96)	3.36 (.88)	3.22 (.87)
Number of preservative errors	17.16 (6.44)	16.94 (6.63)	15.16 (5.33)

Figure 1.

Screen Capture of the Hallway of the Virtual House (Taken From Front Door)

Figure 1 Alt Text. A hallway of a house with five doors and some pictures on the wall and a whiteboard on the right side of the corridor as you enter.

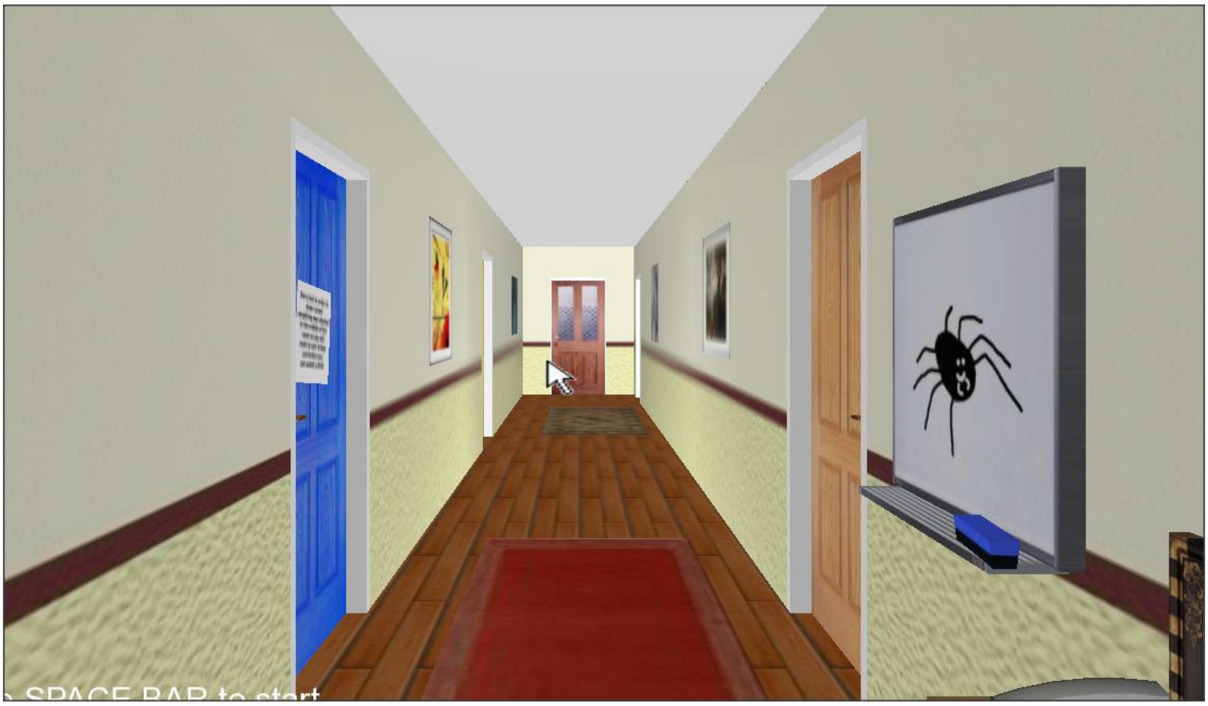
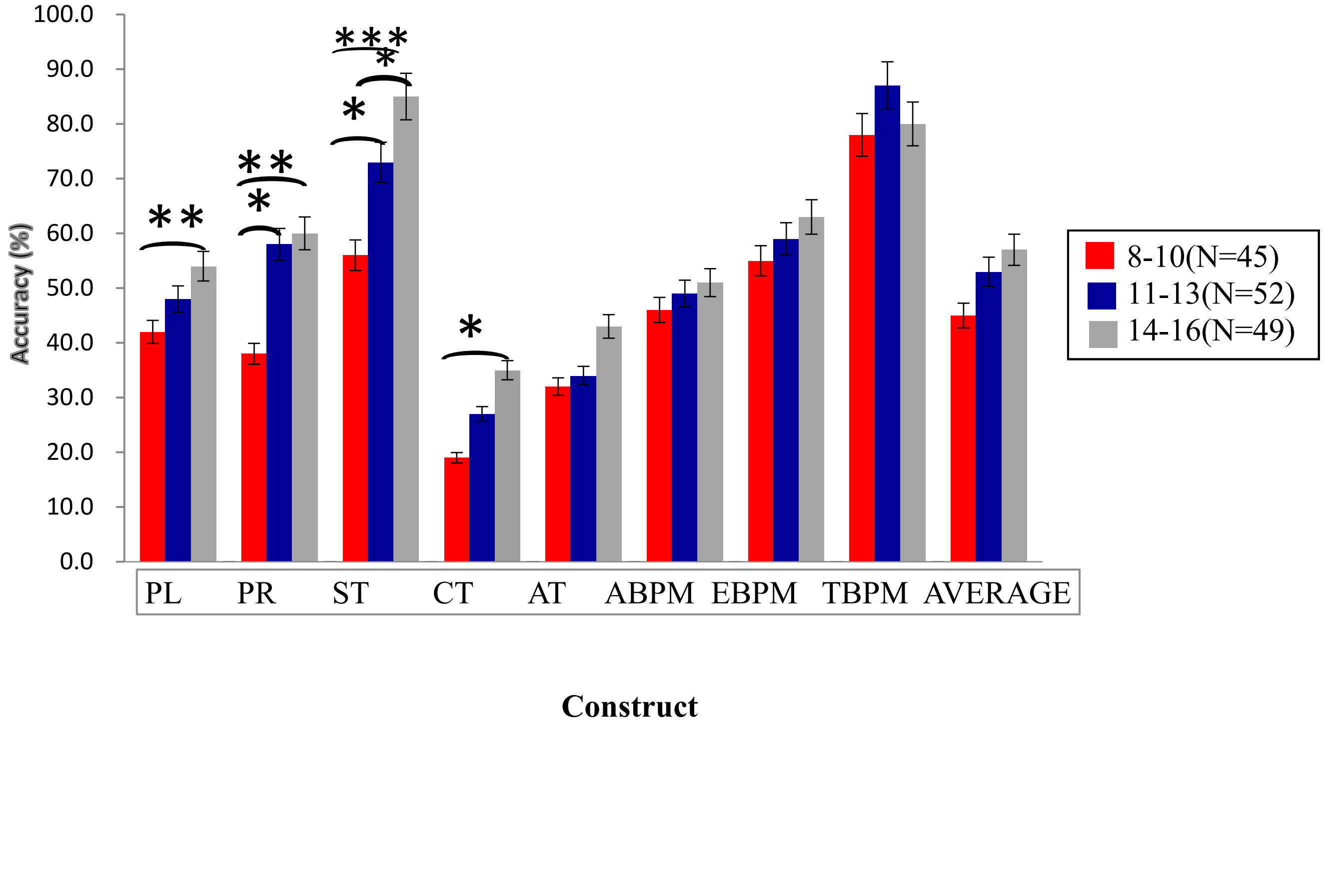


Figure 2.

Performance on JEF-C©(P) as a Function of Age Group and Cognitive Construct

Figure 2 Alt Text. Performance on eight subtasks and overall Average JEF-C©(P) as a function of age group.



Note. 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.

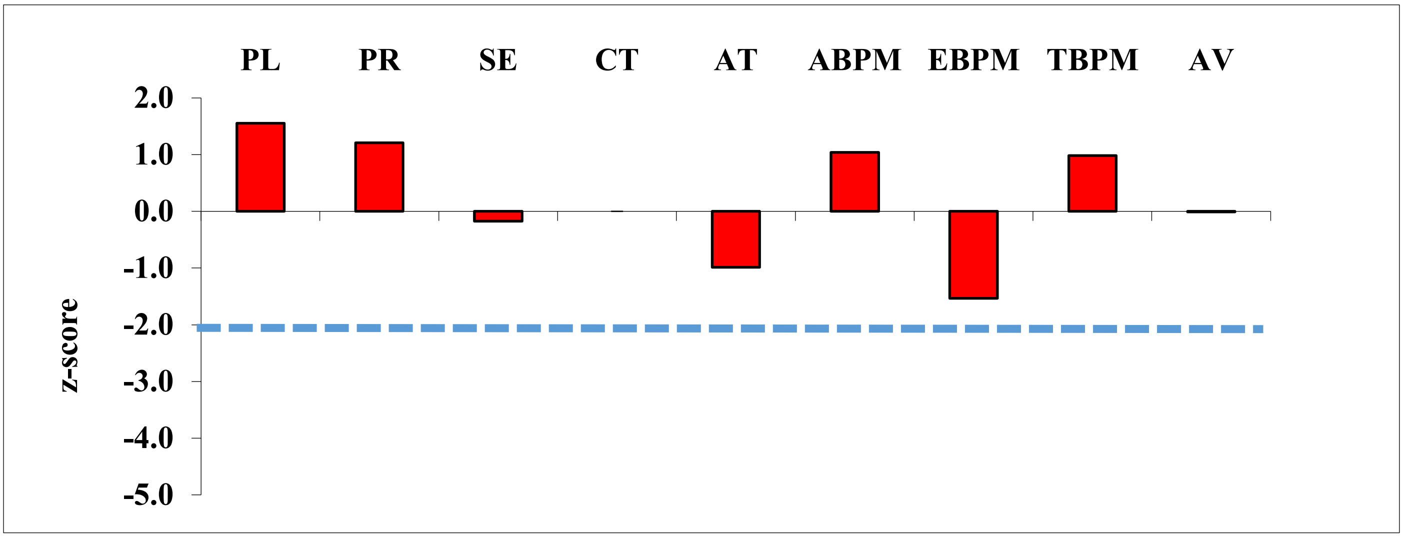
*p <.05, **p < .01, ***p < .001.

Figure 3.

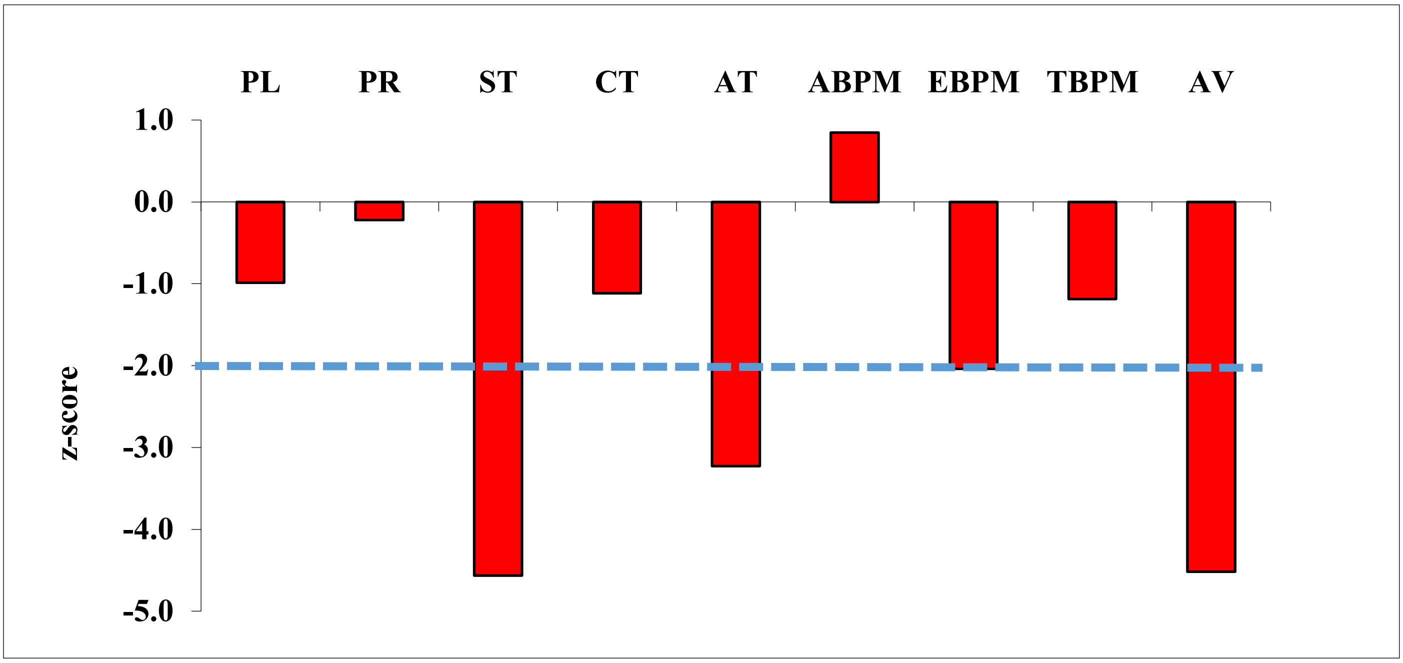
Individualised Performance of Two Participants With Brain Damage From the Central JEF-C© Database.

Figure 3 Alt Text. Individualized JEF-C© profiles for a) a child from the current study in the 8-10 age group and b) a child (not from this study) with brain damage, showing their standardized performance across the eight constructs and the overall average of JEF-C©. In this depiction, a z-score of 0 (on the horizontal axis) represents performance in the middle of a normal distribution, a positive one, performance that is better than average and a negative score, weaker performance; a score past the -2 line would denote performance that is statistically impaired relative to the mean and could be targeted for either rehabilitation or psychoeducation. (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). Note. The performance is shown as z-score relative to that of children of the same age group; for a) the performance is determined relative to the whole group of 8-10 year-old Persian children in the current study; and for b) the performance is relative to healthy English-speaking controls in our central database.

a)



b)



PL
PR
ST
CT
AT
ABPM
EBPM
TBPM
AV
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
z-score