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Research Paper: Investigating Executive Functions in Persian Typically-Developing Children Aged 4 to 6 Years

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ABSTRACT

Introduction: Executive functions develop, particularly in the first 5 years of life. This study aimed to investigate the executive functions in Persian typically-developing (TD) children aged 4 to 6 years.

Materials and Methods: In this cross-sectional study, 50 children (21 girls and 29 boys) participated. Executive functions (planning/problem solving, inhibition, shifting, and working memory) were measured by various performance-based tests (the Tower of London, Go/No-Go, Dimensional Change Card Sorting task (DCCS), forward Digit Span (FDS), Backward Digit Span (BDS) and Non-Word Repetition (NWR) and Behavior Rating Inventory Of Executive Function (BRIEF) questionnaire). After collecting the data, they were entered into SPSS version 16.0, and data analysis was done by Mann-Whitney U test and two-tailed Spearman test. The significant level was set at 0.05.

Results: Regarding the age groups, 5-year-old children were significantly better than 4-year-old children in FDS and BDS, and regarding gender groups, performance-based tests were not significantly different between girls and boys but in the BRIEF questionnaire as parents reported, boys were significantly had better performance in daily life. BRIEF questionnaires in the boy's group were correlated with FDS, BDS, the Tower of London, Go/No-Go, and DCCS. In the girl's group, the BRIEF questionnaire was correlated with NWR and DCCS. In 4-year-old children, the BRIEF questionnaire was correlated with FDS, BDS, Go/No-Go, and DCCS. In 5-year-old children, the BRIEF questionnaire was correlated with BDS, the Tower of London, Go/No-Go, and DCCS.

Conclusion: It seems that TD children between the ages of 4-6 years can have different working memories but does not differ in skills such as problem-solving, shifting, and inhibition.

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1. Introduction

Targeted behavior regulation is supported by several mental processes, including monitoring and updating working memory content, damping or overcoming initial responses, and changing flexible behavior depending on context demand [1, 2]. These abilities are collectively referred to by several names in the literature, including (but not limited to) Executive Function (EF). Research indicates that the most important function of the prefrontal cortex is regulating perception, thought, and behavior through the activation and inhibition of other brain areas. In humans, the prefrontal cortex is operative as early as the first year of life. The neural circuitry serving EF is slow to develop, with prefrontal regions fully maturing only during early adulthood [3-5]. This foundational work encouraged other researchers to investigate the early development of EF [6]. EF first probably emerges around the end of the first year of life [7]. The first 5 years of life play a critical role in the development of executive functions [8-11].

Although the development of executive functions in children has become an active topic of discussion and research over the past 2 decades, less attention has been devoted to the structure, organization, and development of executive functions in infants and preschool-age children [12]. Assessing executive functions in all age groups is complex and challenging because of their dynamic nature and the relationship of these central processes to domain-specific processes such as language, motor function, and attention [13].

Performance-based tests alone are not enough to create a comprehensive picture of a child's performance. Thus, we considered the preschool executive performance rating scale in the everyday context and added a performance appraisal model with controlled performance tasks that target specific aspects of executive functions and adjust parents/teachers ratings that target more global aspects of self-regulation in the everyday context [14]. The Behavior Rating Inventory Of Executive Function (BRIEF), developed by Gioia et al. and translated to Persian by Abdolahpour et al. [15] to evaluate behavioral manifestations of a range of executive functions [16]. We explored the application of the BRIEF for assessing executive functions in preschoolers.

This criterion and its approach to evaluating executive function should not be seen as a substitute for performance-based appraisal but as an auxiliary. These two methods should be combined for a more comprehensive view of the child's executive function [13]. For this reason, in this study, besides using a questionnaire, we used a performance-based assessment to evaluate each of the executive functions. In this study, 4 executive functions (problem-solving and planning, inhibition, shifting, working memory) were evaluated separately in 4-6 years old Persian children. Working memory is assessed by using the Forward and Backward Digit Span (FDS, BDS) and Non-Word Repetition (NWR) task [17].

Problem solving and planning were evaluated using the Tower of London [18]. Shifting was assessed using the Dimensional Change Card Sorting task (DCCS) [19] and inhibition was evaluated using Go/No-Go task [20]. Therefore, to find the ability of executive function skills in 4- to 6-year-old, we examined executive functions by using a parental reporting questionnaire and various performance-based tests. Also, one of the goals of the study was to determine the degree of correlation between each test and the BRIEF questionnaire.

2. Materials and Methods

Study participants

A cross-sectional study was conducted on 50 typically-developing (TD) children (29 boys and 21 girls), (min age =48 months, max age =71 months, SD=6.01 months) aged 4-6 years (4-year-old children) (n=28) and 5-year-old children (n=22). Children were randomly selected from the daycare centers in 4 geographical directions of Tehran City, Iran.

The inclusion criteria were being 4 to 6 years old and having no history of seizure, recurrent otitis media, motor or a visual impairment, cerebral palsy, genetic syndromes, metabolic disease, and social-emotional disorders. Also, the participants were monolingual (Persian). The exclusion criteria were lack of cooperation of the child or his family during sampling and occurrence of any seizures or neurological problems during sampling.

Study procedure

The children were tested individually in a quiet room. The examiner was sitting facing the child at a low table and necessary explanations were given to them. A parent (usually the mother) was present in the room, completing questionnaires while the examiner and the child were doing the tests. The order of the tests was rotational. The assessments took 45-60 minutes for each child.

Study measures

Tower of London

The Tower of London task was designed based on the Tower of Hanoi, which uses colored balls that must be moved on three pegs of graduated sizes. Children are presented with an initial arrangement of balls and with a target Tower and they are asked to describe how they would alter their initial arrangement so that it corresponds to the target tower. The task has been used with preschoolers and school-age children. There are 12 problems in this test and the child has 3 opportunities to solve the problem. If he solves the problem at the first opportunity, he gets 3 points. In the same way, in the second and third opportunities, he gets 2 and 1 points, respectively. If the child cannot solve 2 problems in a row, the test stops. In this test, the child can score between 0 and 36 [18, 21, 22].

Go/No-Go

Children are required to display a simple motor response to one cue, the Go stimulus while refraining from responding to another stimulus, the No-Go stimulus. Scoring is based on reaction time, errors of commission (i.e., incorrectly responding to a No-Go stimulus), and errors of omission (not responding to a Go stimulus). In this test, the child can score between 0 and 40 [20].

Dimensional change card sort (DCCS)

Children are presented with cards depicting colored shapes that can be sorted differently, depending on whether one sorts them by color or by shape. Children are first told to sort the cards by one dimension (e.g., color), and then told to sort by the other dimension (e.g., shape). The key-dependent measure is the correct number on the post-switch phase. The DCCS has been used on 3- to 5-year-old children, although versions have also been used with school-age children and adults. The score of this test is between 0 and 12 [19].

Non-word repetition

There are 25 words with 1 to 4 syllables in this task. First, the examiner introduced the participants to how to do the task, using 4 non-word training. The participants were explained that "you will hear a few meaningless words." After making sure that the participants were familiar with how to do the NWR task, they were asked to do the main task. About scoring, one point was assigned for the correct repetition of each syllable. As a result, each child received a score from 0 to 53 [17].

Forward digit span (FDS)

This test consisted of 7 sets, each set with two exercises. The number of items in the sets started from 3 digits in the first set, and the seventh set contained 9 digits. Work began with the first set for all participants, and if unsuccessful, both exercises on each set were stopped. To complete the task, the trial was read to the participants, who were asked to listen carefully and then repeat in the same order. Numbers were read to participants at 1-s intervals. If the participants repeated each exercise correctly, they were given a score. There were 7 sets in this task and the maximum score in the FDS task was 14. FDS task was done before the BDS task [23].

Backward digit span (BDS)

This task consists of 7 sets and each set has 2 exercises. This task starts with the first set and if the participants failed in both exercises, the test would stop. To complete the task, the numbers of each exercise are read and the participant must repeat in reverse order. Scoring is the same as the FDS task [23].

Behavior rating inventory of executive function (BRIEF)

BRIEF is a rating scale for 2 to 5 years old children that have 63-item and completed by parent/teacher. Items comprise 5 executive domains: inhibition (16 items), shifting (10 items), emotional control (10 items), working memory (17 items), and planning/organizing (10 items). The scales are summarized in three indicators: inhibitory self-control (inhibit and emotional control), flexibility (shift and emotional control), and emergent metacognition (working memory and plan/organize). The BRIEF-P requires an approximately fifth-grade reading level and takes 10–15 minutes to complete [16]. The validity coefficient of the Persian version of this questionnaire (0.89) was determined by Abdollahipour et al. [15].

Statistical methods

After collecting data, we entered them into SPSS, version 16.0. Given that the variables are discrete, the Mann-Whitney test was used to compare test scores in age and gender groups. A two-tailed Spearman nonparametric test was used to determine the correlation between test scores and the questionnaire. The significant level was set at 0.05.

3. Results

According to descriptive statistics data for the age groups, 5-year-old children scored higher than 4-year-old children in NWR, FDS, and BDS. In the Tower of London, Go/No-Go, DCCS, and BRIEF questionnaire, 4-year-old children scored higher than 5-year-old children. And regarding the gender groups, the results show that boys scored higher than girls in the Tower of London, Go/No-Go, DCCS, NWR, FDS, and BDS. Also, girls scored higher in the BRIEF questionnaire.

Regarding age groups, the Mann-Whitney test demonstrated significant difference in FDS (z= -2.07, P=0.03) and BDS (z= -1.95, P=0.05) but in the Tower of London (z=-0.32, P=0.74, effect size=0.05, power=0.24), NWR (z=-0.06, P=0.95, effect size=0.07, power=0.26), DCCS (z=-0.57, P=0.56, effect size=0.14, power=0.24), and Go/No-Go (z=-0.37, P=0.7, effect size=1.36, power=0.96) significant differences were not seen.

Regarding gender groups, the Mann-Whitney test demonstrated significant difference in BRIEF questionnaire (z=-1.97, P=0.04) but in the Tower of London (z=-1.57, P=0.11, effect size=0.38, power of test=0.43), Go/No-Go (z=-1.30, P=0.19, effect size=0.50, power of test=0.54), DCCS (z=-1.28, P=0.19, effect size=0.31, power of test=0.36), FDS (z=-1.11, P=0.26, effect size=0.33, power of test=0.39), BDS (z=-0.41, P=0.67, effect size=0.33, power of test=0.39)

Table 1. Descriptive statistics, comparison, and correlation in age groups

Variables	4 Years Old (n=28)	5 Years Old (n=22)	Comparison	Correlation
	Mean±SD/ Min / Max / Median		P (z)	4 Years Old - 5 Years Old P (r)
The Tower of London	21.79±7.51 / 5 / 32.5 / 23	21.36±8.68 / 4 / 35 / 21	0.74(-0.32)	0.8(0.04)-0.006(0.56)
Go/No-Go	34.18±7.36 / 15 / 40 / 37	33.36±8.44 / 12 / 40 / 37	0.70(-0.37)	0.01(0.47)-0.005(0.57)
DCCS	10±2.5 / 5 / 12 / 10	9.64±2.57 / 5 / 12 / 11	0.56(-0.57)	0.001(0.59)-0.002(0.61)
NWR	49.86±4.92 / 29 / 53 / 51.5	50.18±4.23 / 34 / 53 / 52	0.95(-0.06)	0.61(0.26)-0.07(0.39)
FDS	3.71±1.24 / 2 / 6 / 4	4.45±1.05 / 2 / 6 / 4	0.03(-2.07)	0.000(0.7)-0.17(0.29)
BDS	1.39±1.19 / 0 / 4 / 2	2.27±1.66 / 0 / 6 / 2	0.05(-1.95)	0.001(0.58)-0.01(0.53)
BRIEF	32.04±8.97 / 17 / 45 / 34	27.95±6.97 / 14 / 42 / 28	0.07(-1.76)	_____

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DCCS: Dimensional Change Card Sorting; NWR: Non-Word Repetition; FDS: Forward Digit Span; BDS: Backward Digit Span

Table 2. Descriptive statistics, comparison, and correlation in gender groups

Variables	Girls (n=21)	Boys (n=29)	Comparison	Correlation
	Mean±SD/ Min / Max / Median		P(z)	Girls-Boys P Value(r)
The Tower of London	19.86±6.82 / 6 / 31 / 20	22.86±8.60 / 4 / 35 / 25	0.11(-1.57)	0.28(0.2)-0.01(0.43)
Go/No-Go	31.52±9.47 / 12 / 40 / 35	35.48±5.93 / 15 / 40 / 37	0.19(-1.30)	0.07(0.39)-0.01(0.59)
DCCS	9.38±2.59 / 5 / 12 / 11	10.17±2.45 / 5 / 12 / 12	0.198(-1.28)	0.02(0.48)-0.000(0.62)
NWR	49.38±5.33 / 29 / 53 / 51	50.45±4.01 / 34 / 53 / 52	0.36(-0.91)	0.05(0.42)-0.27(0.21)
FDS	3.81±1.07 / 2 / 6 / 4	4.21±1.29 / 2 / 6 / 4	0.26(-1.11)	0.09(0.37)-0.000(0.67)
BDS	1.62±1.20 / 0 / 4 / 2	1.9±1.65 / 0 / 6 / 2	0.67(-0.41)	0.01(0.51)-0.000(0.63)
BRIEF	33±6.9 / 14 / 42 / 33	28.24±8.81 / 17 / 45 / 28	0.04(-1.97)	----------

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DCCS: Dimensional Change Card Sorting; NWR: Non-Word Repetition; FDS: Forward Digit Span; BDS: Backward Digit Span

and NWR (z=-0.91, P=0.36, effect size=0.22, power of test=0.29) significant differences were not seen.

Correlation of tests and tasks with BRIEF questionnaire

To test the relations between each test or task and BRIEF questionnaire, we carried out a correlation analysis in age and gender groups. The result showed that BRIEF questionnaire in boys' group were correlated with FDS (P=0.000, r=0.67), BDS (P=0.000, r=0.63), the Tower of London (P=0.01, r=0.43), Go/No-Go (P=0.01, r=0.59), and DCCS (P=0.000, r=0.62) but were not correlated with NWR (P=0.27, r=0.21, effect size=0.21, power of test=0.38). In girls' group, BRIEF questionnaire results were correlated with BDS (P=0.01, r=0.51), NWR (P=0.05, r=0.42), and DCCS (P=0.02, r=0.48) but were not correlated with FDS (P=0.09, r=0.37, effect size=0.37, power of test=0.56), the Tower of London (P=0.28, r=0.24, effect size=0.23, power of test=0.36) and Go/No-Go (P=0.07, r=0.39, effect size=0.39, power of test=0.59).

Regarding 4-year-old children, BRIEF questionnaire results were correlated with FDS (P=0.000, r=0.70), BDS (P=0.001, r=0.58), Go/No-Go (P=0.01, r=0.47), and DCCS (P=0.001, r=0.59) but were not correlated with NWR (P=0.16, r=0.26, effect size=0.26, power of test=0.46) and the Tower of London (P=0.8, r=0.04, effect size=0.04, power of test=0.21). Regarding 5-year-old children, the BRIEF questionnaire results were correlated with BDS (P=0.01, r=0.53), the Tower of London (P=0.006, r=0.56), Go/No-Go (P=0.005, r=0.57), and DCCS (P=0.002, r=0.61) but were not correlated with FDS (P=0.17, r=0.29, effect size=0.29, power of test=0.46) and NWR (P=0.07, r=0.38, effect size=0.38, power of test=0.60) (Tables 1 and 2).

4. Discussion

This study examined executive functions and their components in TD children. As Garon et al. stated, the first 5 years of life play a critical role in the development of executive functions [8]. Therefore, children aged 4 to 6 years were the target group. The study compared different aspects of executive function in different age and gender groups. Additionally, the study provided an important bridge toward understanding the impact of the deficits on the child's everyday executive functions using BRIEF and comparing its score in age and gender groups. One of the goals of the study is to determine the degree of correlation between each test and a questionnaire.

In line with previous studies [24-26], significant differences were not found between the gender groups in terms of the scores of the 6 measures but there was a significant difference between age groups in BDS and FDS. Although age groups were not significantly different in the BRIEF questionnaire, gender groups were significantly different and the girls reportedly performed better in their daily context, according to their parents. There is no significant difference in the daily performance of children in the age groups studied. This finding may be because children aged 4-6 years are usually in a similar situation in terms of daily tasks according to significant differences between girls and boys in BRIEF questionnaire score. We supposed that in different cultures, the level of expectation for girls to be more successful in performing daily tasks is higher than boys [24-26].

As a previous study [8] has proposed, the components of executive function emerge in sequence across the preschool years, and working memory coming online first. The prefrontal cortex is one of the slowest developing brain areas and also executive functions have been strongly associated with the prefrontal cortex [6]. Therefore, the absence of significant differences in other components of executive functions in the age range of 4 to 6 years can be justified.

Results also showed that FDS, BDS, DCCS, Go/No-Go and NWR was significantly correlated with the BRIEF questionnaire. But there was no significant correlation between the Tower of London and the BRIEF questionnaire. According to the results, the correlation between the tests and the questionnaire was moderate. The lack of significant correlation between the Tower of London and BRIEF questionnaire and also a moderate correlation between other tests and questionnaire could be due to some features of the translated version of the questionnaire as well as the scoring method of the questionnaire. Some parents did not understand some of the sections of the questionnaire or did not know the meaning of some words.

Also, sometimes the parents' answers to some sections were not included in the scoring of the questionnaire and they had to give more or fewer points. According to what was said and the study done [13], this executive function evaluation criterion should not be used as a substitute for performance-based tests, because performance-based tests evaluate the various components of executive functions at a more specific level, while the BRIEF questionnaire is more general and only in the context of daily activities monitors executive functions [26].

One of the limitations of the present study was that selection of other executive assessment tasks or the use of multiple tests to evaluate each aspect of executive function might have culminated in different results.

5. Conclusion

It seems that TD children of 4-6 years old can have different working memories but do not differ in skills such as problem-solving, shifting, and inhibition. The BRIEF questionnaire, along with performance-based assessments, can provide valuable information about the child's executive function status to the therapist.

Ethical Considerations

Compliance with ethical guidelines

This study has been approved by the Ethics Committee of Tehran University of Medical Sciences (Code: IR.TUMS.FNM.REC.1399.043). All participant's parents were signed the written informed consent.

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Authors contributions

All authors contributed in preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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