Journal of Clinical Psychology Studies
ATU PRESS
Vol 15, Issue 54 , March 2024
ISSN (Print): 2322-3189 - ISSN (Online): 2476-6410

Research Paper

Computer-Based Stroop Animal Size Test in Children: Construction, Validation and Psychometric Properties

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Article Info:
Received: 2023/12/05
Accepted: 2024/03/20
PP: 12

Use your device to scan and read the article online:

DOI:10.22054/JCPS.2024.77074.3003

Keywords:
Attention deficit/hyperactivity disorder, Computer-Based, Inhibition, Stroop test, Validity.

Abstract

Objective: An important cognitive control process is the ability to inhibit, that mature at different rates during childhood to adolescence. The aim of our research was to construct and validate computer-based Stroop animal size test in children for measuring selective attention and response inhibition.

Research Methodology: In this survey study, we prepared the test, after the approval of experts and software development, at first test-retest reliability with a two week was evaluated in a separate sample (N=50, 5-12 years old children), then data was collected from 92 children 5-12 years old (46 girls and 46 boys) included 22 children with attention deficit/hyperactivity disorder (ADHD) studied in the academic year 2022-2023 in Alborz province. Participants decided the real size of animals by pressing response keys on computer. ANOVA, Multivariate analysis, Pearson correlation coefficients and Cronbach α were used to assess reliability and validity ($p<0.05$).

Findings: The findings showed test-retest reliability in significant range ($p<0.01$). The correlation was high for Stroopnum, ($r=0.83$), Inconsistent answers, ($r=0.72$), Wrong answers, ($r=0.89$) but lower for Consistent answers, ($r=0.28$) and Reaction time, ($r=0.41$). To assess the internal consistency, Cronbach Alpha 0.91 computed. ANOVA analysis for comparing children's function in different age groups was ($p<0.000$).

Conclusion: Multivariate analysis was used in comparing children with ADHD to the control group, results showed significant difference between groups in Stroop components, ($p<0.007$). This computerized Stroop animal size test had satisfactory reliability and validity, that can measure cognitive functions such as selective attention and inhibition in children.

Citation: Esmaili Alamuti, S., Borjali, A., Eskandari, H., Mohammadi, M. R., & Asgari, M. (2024). Computer based Stroop Animal Size Test in Children: Construction, Validation and Psychometric Properties. *Clinical Psychology Studies*, *15*(54), 33-44. https://doi.org/10.22054/jcps.2024.77074.3003

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Introduction

Executive functions refer to a set of high-level processes that are critical for goal-directed behavior regulation and implementation (Roy et al., 2018; Beattie et al., 2018 & Li et al., 2018). Attention (Shahbazi et al., 2017) and inhibition (Roy et al., 2018; Portugal et al., 2018) are each cognitive processes that are involved in executive functions (Beattie et al., 2018). Attention is a key factor in successful interaction with the environment and allows the individual to screen for environmental events. The ability to maintain attention is a prominent feature of intellectual development that is impaired due to the underdevelopment of the nervous system (Shahbazi et al., 2017). Inhibitory control is the first executive function that appears in children (Rafi'Khah et al., 2015) and entails important subcomponents, including attention control and response inhibition. Attention control, also known as selective attention, is the capacity to choose what to pay attention to and what to ignore (Li et al., 2018).

Inhibition involves the ability that allows us to control our ongoing behavior, inhibit an action, or subdue an immediate interest to achieve a goal (Beattie et al., 2018; Grange et al., 2019). An important aspect of our daily lives is our ability to abort an action after it has been initiated (Chowdhury et al., 2019) on the other hand that's the ability to stop, change, or delay a behavioral response (Jones et al., 2016) that plays an important role in a variety of high-order processes, such as planning, making decisions and suppressing inadequate behaviors or conflict from different sources (Portugal et al., 2018). Without efficient cognitive control, our behavior would be driven by bottom-up stimulus-evoked actions (Grange et al., 2019). Research by Beattie et al. (2018) indicates that inhibition is an early-developing executive function.

Throughout childhood, children's executive functions become more sophisticated (Beattie et al., 2018; Bull & Scerif, 2001). Literature shows that children's performance is impaired relative to adults' performance (Schuch & Konrad, 2017; Tricoche et al., 2023) when different tasks can occur (Yanaoka et al., 2024). It is possible that stimulus encoding and motor processes are slower in children than in adults, consistent with the idea of less mature sensorimotor processes (Schuch & Konrad, 2017). Cognitive function that develops from early childhood through adolescence or adulthood (Ikeda et al., 2014; Quiñones-Camacho et al., 2019; Schuch & Konrad, 2017), along with maturation primarily of the prefrontal cortex (PFC) (Ikeda et al., 2014; Quiñones-Camacho et al., 2019; Beattie et al., 2018). Specifically, the structural and functional changes that the PFC undergoes during the preschool years, allow for the substantial increases in cognitive development observed relatively late during childhood (Quiñones-Camacho et al.,2019; Schuch & Konrad, 2017). Previous reports have described that interference has a nonlinear pattern with age across the lifespan. It increases as 3- to 7-years-old learn to read, then decreases until young adulthood to middle adulthood, thereby demonstrating that prepotential response inhibition develops from at least age 7 and that it continues to develop through young adulthood to middle adulthood (Ikeda et al., 2014). Moreover, PFC regions like superior frontal areas including the supplemental motor area and subcortical regions play a role in response inhibition (Chmielewski & Beste, 2019). The anterior cingulate cortex is critical for both stress and inhibitory control processes (Yip et al., 2019). Inhibitory control is a key cognitive function of typical and atypical child development (Ikeda et al., 2014). Low inhibitory control is related to behavior problems in adolescents (Vasin & Lobaskova, 2016). Deficits in inhibitory control are reported in numerous developmental and acquired neuropsychological disorders of young children (Catale & Meulemans, 2009) such as attention deficit/hyperactivity disorder (ADHD), Tourette syndrome, and autism (Barkley,1997; Roy et al., 2018; Ikeda et al., 2014) traumatic brain injury, epilepsy (Roy et al., 2018). Indeed, ADHD was found to be the most prevalent disorder in childhood (Mohammadi et al., 2021), and an early-onset childhood disorder that is introduced by attention deficiency, hyperactivity and impulsivity (Alamuti et al., 2016). Poor inhibitory control has been implicated as a core deficit in ADHD and resulted in the observed hyperactivity-impulsivity symptoms (Shen et al., 2014). Beattie et al. (2018) have reported that individuals with ADHD display deficits in executive functioning skills including inhibition and special working memory, in addition to deficits in attention.

Assessment of executive functions in children has become a critical clinical issue in neuropsychology over the past few years (Roy et al., 2018). Throughout the years, researchers of attention and cognitive control have employed various experimental tasks (Henik et al., 2018). Examples of tasks that engage both attentional control and response inhibition include the Stroop task (Hawkins et al., 2015) the go/no-go task, the Simon task and the flanker (Henik et al., 2018) all of which have been examined in functional activation tasks (Li et al., 2018). The Stroop task stands out as a paradigmatic task for the failure of selective attention (Henik et al., 2018) and it evaluates a construction of executive function that is named "inhibition control" that has made this test a highly utilized instrument in diagnostic and research aspects of executive functions (Roy et al., 2018; Malek et al., 2013).

About cognitive inhibition, the Stroop is one of the most commonly used tests in clinical neuropsychology, both in adults and children (Roy et al., 2018). The original task was published by John Ridley Stroop in 1935 to examine the potential interference of word reading on color naming and vice versa (Henik et al., 2018) requires individuals to identify, as quickly and accurately as possible, the font color written characters without reading them (Augustinova et al., 2018). Several studies have shown significant sensitivity of the Stroop effect to neurodevelopmental or acquired brain disorders in children, including for instance ADHD, phenylketonuria, autistic spectrum disorder, epilepsy or head trauma (Barkley, 1997, Levin and Hanten, 2005, Roy et al., 2018). Stroop observed that responding «red» to the word «blue» displayed in red letters is slower than responding «red» to a red patch of color. This phenomenon is known as the Stroop effect or interference effect (Filipiak, 2017). The Stroop effect refers to the lengthening of response time and more proneness to committing errors when faced with conflicting data (Roy et al., 2018). Stroop interference (Stroop, 1935) is commonly considered to be among the most familiar, most cited, and most investigated phenomena in all of cognitive psychology (Protopapas et al., 2018). Disorders that are marked by problems with poor interference control (e.g. ADHD) could be better explained by understanding the development of interference control (Filipiak, 2017). Interference paradigms have been widely used to investigate the development of cognitive control processes, for instance, the Simon task, the Flanker task and Stroop-like tasks. In these studies, the size of the interference effect is usually found to decrease with increasing age across childhood, a finding that is sometimes interpreted as increased inhibitory ability when children grow older (Schuch & Konrad, 2017).

The name Stroop has become part of titles such as the Suicide Stroop (Wilson et al., 2019) Pet Store Stroop (Quiñones-Camacho et al., 2019) emotional Stroop, numerical Stroop, spatial Stroop, picture Stroop, etc. This attests to the use of the task or its variations in numerous areas of psychology (Henik et al., 2018). It is well established that it takes longer to name the color in which a word is printed when the word means a different color (e.g. the word ‘‘red” printed in green ink). In contrast, the color a word is printed in makes no difference in reading the word (Protopapas et al., 2017) because the Stroop color-word test requires well-developed reading skills, its effectiveness is limited when used with children younger than around 7 years old, who have little or no reading ability (Ikeda et al., 2014). Since the Stroop effect and interference control gained popularity in psychological research in a wide range of populations, special attention has been focused on pre-reading children (Filipiak, 2017). In addressing that important limitation of the classic Stroop color-word test, attempts have been made to develop new measures based in principle on Stroop interference) i.e., two-dimensional stimuli associated with two different and competing responses that do not require reading skills). Such methods are the fruit Stroop task (Archibald & Kerns, 1999), the color–object Stroop task, the animal Stroop task, the real animal size test (Catale & Meulemans, 2009) and the Pictorial Animal Size Test (Ikeda et al., 2014; Filipiak, 2017). It was also demonstrated that as soon as we see a pictured object, we also automatically activate information about how big or small the object typically is in the world. Some evidence for this automatic activation comes from a size-stroop paradigm (Long & Konkle, 2017). Children sat at a child-sized desk where they were asked to complete the pet store Stroop task as part of a battery of cognitive tasks. This task is based on the traditional Stroop (Stroop, 1935), but was modified to be engaging for the preschool age group. Children were told that all the animals in the pet shop had escaped from their cages and were asked to put each animal back in the correct cage. Children were told that they would see an animal and hear a sound (either a dog, a bird or a frog; the sound lasted for 2s) (Quiñones-Camacho et al., 2019). It is considered in this task children must inhibit two issues at the same time. Catale & Meulemans (2009) pointed out that in many Stroop-like measures such as day/night Stroop or fruit Stroop, the task is difficult for young children (≤7 years old) because they had to keep rules in working memory that is, both inhibition of prepotential response and generation of a conflicting response from working memory. Furthermore, in the real animal size test, images are presented in black mode and it seems the animal images aren’t objective for children. Since the existing stroop tests in Iran required reading skills, they were not suitable for evaluating pre-primary children. It was also necessary to make a computerized test, because we need a high accuracy assessment for children's tests. Therefore, the purpose of this study was to construct and validate the computerized Stroop animal size test. Hypothesis of this research included: Computer-based Stroop animal size test has sufficient reliability for measuring cognitive inhibition, Reaction time (RT) in the congruent/incongruent conditions would be different across age groups and Inhibition response in children with ADHD is different from the control group.

Methodology

Procedure

for making a computer-based animal size Stroop test, the features of the original version of Stroop (1935) and common versions of the Stroop test were checked out. The main framework of this test is taken from a real animal size test (Catale & Meulemans, 2009). Due to the greater communication of children with animals, as mentioned in the Children's Apperception Test (Bellak, 1954) for designing this test we used animal photos. After confirming the structure of the test professors of psychology at Allameh Tabataba'i University and University of Tehran, a preliminary version of the test was prepared. The experts evaluated the aspects of the test so the stages of it were determined. Finally, the task was given to a computer engineer to prepare a software version that has been computerized. At first, 50 children 5 to 12 years old in two weeks completed the primitive form of the test. Because one of the participants left the test halfway through and the second stage wasn't completed, the results of 49 children were investigated. In this version of the Stroop task, no reading skills are required and we could test preschool children as same as children in primary school. In this survey study, participants were 92 (46 girls and 46 boys), including 22 children with ADHD were chosen by diagnosis by a psychiatrist and interviewing of psychologist. Initially, to control the effects of intelligence, children were tested by Raven colored progressive matrices test. Entrance criteria were being in the age range of 5 to 12 years old, being in the normal range of intelligence (IQ>70), No hearing or visual impairments, no sensorimotor problems in hands and fingers, not suffering from acute psychological disorders. Participants were asked to compare two animal images and decide which one was bigger in the real-world size ignoring the visual size on the screen as quickly as possible because the test is time-dependent and reaction time (based on thousandths of a second) is measured. The first condition required making quick decisions and presenting 20 pictures of animals in congruent sizes. This condition indicated participants were faster to make visual size judgments on the congruent trials and could automatically process the animal's real size. The second and third conditions presented 48 photos of animals, 24 expressing congruent and 24 incongruent sizes. It's important that the consistent and inconsistent stimulants be equal in number and presented randomly and mixed. This work helps to divide the attention between the dimensions of the stimuli and increase the level of interference (Macleod, 1991). The test results table at the end prepared and showed the time and correct answers in consistent and inconsistent conditions, wrong answers, omission ones and reaction time. Stroop interference (Stroopnum & Strooptime) is given in the results table, that is commonly considered to be among the most familiar, most cited, and most investigated phenomena in all of cognitive psychology (Protopapas et al., 2018) and in addition to other scores we analyzed these two main components in our study. Construct validity was carried out by comparing average scores of the test among age groups. To evaluate the reliability of the test used two weeks' test-retest. A two-week gap is considered long enough for participants to have forgotten their responses and short enough not to have attained additional knowledge (Alkaed et al., 2018). For comparing the function of children in the Stroop test and the various age groups of children, One-way Analysis of Variance (ANOVA) was used. Ultimately, Multivariate analysis was used to compare the performance of children with ADHD and the control group in different components of this test.

Measures

Raven colored progressive matrices Test: The children's version of Raven's Colored Progressive Matrices was administered to measure general fluid intelligence (Raven, 1951). This test is a nonverbal one that is described as the best rating of general intelligence (Anum, 2022) and measures abstraction and conceptual reasoning ability (Catale & Meulemans, 2009). Children aged 5–11. 11 years received 36 images in three steps of 12; the first two were colorful and the third was in black and white, so children had to choose the correct image to answer and complete a pattern. The external validity of this test has been investigated simultaneously with general intelligence tests. The correlation of Raven with Binet and Wechsler's intelligence scale for English-speaking children and adults has been obtained from 0.54 to 0.86 (Shehne Yailagh et.al, 2006).

Computer-Based Stroop Animal Size Test: Children were presented with pictures of animals on the computer screen. With the approval of experts and certified professors, images were selected. Large animals such as an elephant, a bear, a giraffe and a horse vs. small animals such as an ant, a mouse, a frog and a pigeon were selected. These real animal pictures are displayed either in big or small sizes. The big size of the animal picture was 8 cm ×10 cm and the small one was 2 cm ×3 cm. The visual size of two animals could either be congruent with their real-world size (e.g. the big elephant in 8 cm ×10 cm picture and the small ant in 2 cm ×3 cm), or incongruent (e.g. the big ant in 8 cm ×10 cm picture and the small elephant in 2 cm ×3 cm). It was required to judge which animal shown on the screen was bigger in the real world. Each time they have to decide the real size of an animal by pressing the response keys. In response to the presented picture of the big animal in the real world on the left direction of the monitor screen 'A' key needed to be pressed and for the answer on the right one 'P' key needed to be pressed. Answering the test takes 10 minutes and the Stroopnum **(**the result of the difference in the correct number of consistent and inconsistent answers), Strooptime (the result of reaction time difference in consistent and inconsistent answers), consistent answers, inconsistent answers, wrong answers, omission and reaction time are measured. The cut-off point in a test is the score that divides test takers into different classes. Perie and Zieky (2006) emphasized that the cut-off point should be determined after be validated and needed to measure by experts in multiple stages of the judgment process through several steps (Kareshki et al., 2021). Therefore, it should be reviewed in a separate article**.** Reliability of Stroop test has been reported in the range of 0.80 to 0.91 through test-retesting (MacLeod, 1991, Mashhadhi et al., 2011)**.**

Results

All analysis was conducted using SPSS, version 20.0. Descriptive data has been reported in figure 1.

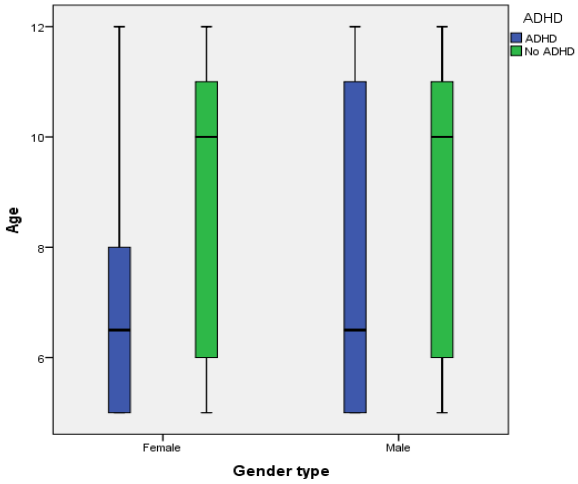

Figure1. Age group, ADHD and gender type of participants.

As figure 1. shows, the mean age of children in ADHD group was 7 years with 2.55 Std. Deviation and included 10 girls and 12 boys. The group without ADHD was 36 girls and 34 boys with an average age of 8 years and 2.64 Std. Deviation.

Test-retest reliability has calculated by Pierson correlation. The correlation of test for Stroopnum was (r=0.83) and for Stroop time calculated (r=0.14). Also, correlation of consistent, inconsistent and wrong answers, omission ones and reaction time (r=0.28), (r=0.72), (r=0.89), (r=0.18) and (r=0.41) was reported in table1.

Table1. Pearson correlation coefficients of Stroopnum, wrong answers, Strooptime and reaction time in test-retest reliability

	Pearson Correlation	Sig. (2-tailed)	N
Stroopnum	0.836**	0.000	
Strooptime	0.140	0.336	
Consistent answers	0.285*	0.048	49
Inconsistent answers	0.726**	0.000	
Wrong answers	0.898**	0.000	
omission	0.186	0.202	
Reaction time	0.415**	0.003	

**. Correlation is significant at the 0.01 level (2-tailed).

Cronbach's alpha Stroopnum based on standardized items computed 0.91. As in table2 mentioned, reaction time of children in consistent condition was shorter than inconsistent condition. Moreover, old children decided faster than young children and ANOVA confirmed this difference between age groups.

Table 2. Mean of responses reaction time (RT) in the Consistent and Inconsistent conditions across age groups

	Age groups								
	5 years old	**6 years old**	**7 years old**	**8 years old**	**9 years old**	**10 years old**	**11 years old**	**12 years old**	**Total RT**
Consistent RT	1018.33	988.27	1079.60	997.86	878.33	870.00	744.33	653.88	881.32
Inconsistent RT	1106.05	1090.27	1092.80	1014.29	1020.33	879.00	770.33	739.81	940.68

We used the ANOVA analysis for comparing children's function in different age groups. Results are brought in table 3, post hoc tests showed the performance of 10-, 11- and 12-years old children in this component of Stroop test had significant difference from other ages.

Table3. Anova analysis in consistent and inconsistent reaction time across age groups

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Inconsistent reaction time	Between Groups	2127190.058	7	303884.294	18.455	0.000
	Within Groups	1383183.800	84	16466.474		
	Total	3510373.859	91			
Consistent reaction time	Between Groups	1922695.203	7	274670.743	10.548	0.000
	Within Groups	2187340.656	84	26039.770		
	Total	4110035.859	91			

For comparing the inhibition response in children with ADHD and the normal group, components of computer-based Stroop animal size test included number of errors, congruent correct and incongruent correct response and reaction time were analyzed. For checking the differentiate of groups, multivariate test was used. Components of Stroop test as dependent variable, ADHD and control groups as independent variable and the age as covariate variable were considered.

Table4. Tests of Between-Subjects Effects, Stroop components in ADHD group compared to control group

Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
ADHD	consistent correct answers	26.742	1	26.742	1.947	0.166	0.021
	inconsistent correct answers	311.948	1	311.948	15.963	0.000	0.152
	Wrong answers	353.539	1	353.539	6.155	0.015	0.065
	Stroopnum	121.216	1	121.216	6.195	0.015	0.065
	Strooptime	16117.935	1	16117.935	3.542	0.063	0.038

Multivariate test results showed significant difference between groups in Stroop components, $p<0.007$, F (5,85) =3.441, Hotelling's trace=0. .202, Partial $\eta 2$ =0.168. As table 4 shows, tests of between-subject's effects included inconsistent correct answers, wrong answers and Stroopnum, $p<0.01$ were significant and consistent correct answers and Strooptime weren't significant.

Discussion and Conclusion

Psychology must redouble its efforts to develop reliable and valid measures (Clark & Watson, 2019). The classic form of the Stroop test like many other cognitive and neuropsychological tests, is not without bugs and many participants who cannot read (such as preschoolers, students with reading disorders and illiterate adults) also can't be measured with this form. Reading comprehension has a great impact on the level of interference (Adams & Jarroled, 2009). The purpose of this research was the construction and validation of a computer-based animal size Stroop test with no reading skills required, especially to draw the attention of experts and researchers to the critical preschool period. In a review study, Salehi Fadardi and Ziaei (2010) emphasized constructing a computerized form of the Stroop test. According to the hypothesis, the computer-based Stroop animal size test had sufficient reliability for measuring cognitive inhibition. Data analysis showed that Cronbach's alpha rate was acceptable in statistics. The test-retest correlation, $r \geq 0.7$, was interpreted as acceptable, 0.3 to 0.7 as intermediate and below 0.3 as unacceptable (Piper et al., 2015). Results showed the correlation of Stroopnum, inconsistent and wrong answers were acceptable, correlation of consistent answers and reaction time were intermediate, Stroop time and omissions were unacceptable. In the analysis of test-retest reliability, the correlation coefficient showed that the test is reliable. Due to the complexity of measuring human behavior by psychological tools, it is rarely possible for the reliability to be higher than 0.4, even if tests with a coefficient of 0.3 may be suitable tools (Strauss et al., 2006). It was claimed in the next hypothesis that reaction time (RT) in the congruent/incongruent conditions would be different across age groups. As the results showed, all children in different age groups spent more time choosing inconsistent images, furthermore, the reaction time of younger children was different from older that the elders decided better in a specified time. Interference control plays a crucial role in early cognitive development (Filipiak, 2017). Since the first investigation of Stroop tasks and development, it has been shown repeatedly that the interference effect decreases with age-started from 7 years old. The typical explanation is that the inhibitory process matures progressively, becoming increasingly efficient with age (Lemercier et al., 2017). Schwartz and Verhaeghen (2008) did not find evidence for differential maturation rates for persons with ADHD and the control groups. The Stroop interference effect appears immune to age, regardless of ADHD status. In contrast, Nicosia et al. (2021) produced clear evidence supporting a disproportionate age difference in the Stroop effect above and beyond the effecting of general slowing.

ADHD is associated with deficits in inhibitory functions including interference control, inhibition of prepotent/automatic responses and suppression of already initiated responses (Junior et al., 2023). Response inhibition is one of the indicators that distinguish ADHD subjects from normal control groups. Stroop is one of the best tests that measure response inhibition (Castellanos and Tannock, 2002). Inhibition also has a central role in impulse control (Portugal et al., 2018). Working memory and inhibitory control are two fundamental and supportive components of executive function that are critical for school-age children. Executive function is highly related to academic performance (Liu et al., 2023). For assessing the validity of the Stroop test, different methods have been used among which the most common one is differential validity focusing more on ADHD (Malek et al., 2013). Multivariate analysis showed components included inconsistent correct answers, wrong answers and Stroopnum, which were significantly different in the ADHD group but consistent correct answers and Strooptime weren't significant. Also, Catale and Meulemans (2009) have found statistical differences between ADHD and control groups in the incongruent condition and suggest the Real Animal Test is a good measure of inhibitory control in 5-9-year-old children. Lufi et al. (1990) and Lavoie and Charlebois (1994) similarly reported that children with ADHD had poorer performance in the Stroop test indices compared with normal children. The differential validity in this study showed that the Stroop test may differentiate ADHD children from normal ones. Examining the Stroop test in participants with impaired executive functions such as patients with schizophrenia, Alzheimer's, Parkinson and ADHD has shown an increasing effect of interference in these groups (Strauss et al., 2006). Tehranidoost et al. (2005) research showed that children in normal children and children with Phenylketonuria without autism or ADHD hadn't significant differences in doing the Stroop test. Mashhadi et al. (2011) reported performance of children with autism spectrum compared to normal children was lower in numbers of congruent and incongruent correct answers, congruent reaction time and wrong answers, but their differences in reaction time incongruent stimulants and Stroopnum weren't significant. Contemporary research documents explicitly that naming the colors is a less automatic reaction than reading words of colors printed in black (Filipiak, 2017). Among its most important applications is the creation of valid psychological tests based on the Stroop effect to measure a person's selective attention capacity and skills, as well as processing ability (Arghavani et al., 2017). However, making tests available for Iranian society is an inevitable necessity. The first limitation of this study was related to the statistical sample limited to Alborz province. We suggest to use larger samples in future studies. The presence of other coexisting disorders can also affect children's performance (Adams & Jarrold, 2009), in our study this issue was not controlled, and we only relied on the reports of school officials. The next objective would be using this version of Stroop and comparing the results in other psychological disorders.

The results have shown appropriate validity and reliability in research and clinical environments. The findings showed test-retest reliability in significant range ($p<0.01$). Cronbach Alpha 0.91 was computed. The correlation was high for Stroopnum, ($r=0.83$), inconsistent answers, ($r=0.72$), wrong answers, ($r=0.89$) but lower for consistent answers, (r=0.28) and reaction time, (r=0.41). Although some scores of correlations weren't acceptable, use of a larger sample would provide better results in the future.

Construct, validate and use the computer-based test as it has been emphasized in the computerized construction of the Stroop test (Verhaeghen & Meersman, 1998) because of their saving time, more control on variables, reducing human errors in calculating results and increasing accuracy of data (especially when dealing with children) instead of using classic paper-pencil forms in measuring neuropsychological processors is taken into consideration.

It is often implicitly assumed that the neural basis of inhibitory control is universally similar across cultures (Pornpattananangkul et al., 2016). This test was constructed to be free from the influence of cultural bias and with feature independence of linguistic elements.

Ethical Considerations

All ethical principles have been considered in this article.

Financial Support

This study conducted as the Ph.D thesis with supportive grant No. P/3696 from Allameh Tabataba'i University. The funders hadn't any role in designing and preparing of this study.

Conflict of Interest

The authors of this article declare that they have no conflict of interest. This research approved by research ethics committees of Allameh Tabataba'i university; Approval ID: IR.ATU.REC.1400.056.

Acknowledgments

I would like to appreciate headmasters of schools and the participants in the study.

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