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Executive Functioning in Subtypes of Attention Deficit Hyperactivity Disorder

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ABSTRACT

Introduction: This study aims to evaluate executive functions (EF), such as inhibition, planning, working memory, and set shifting, in children with attention deficit hyperactivity disorder (ADHD) by comparing three ADHD subtype groups (ADHD-Inattentive, ADHD-Combined, and ADHD-Comorbid) and a normal control group.

Methods: Participants included 147 children. In total, 111 children were assigned to the ADHD groups of the study. Each child was matched according to the WISC-R Full-Scale IQ-score, sex, and age and was grouped as follows: ADHD-Inattentive group (ADHD-I; n=37), ADHD-Combined (ADHD-C; n=37), ADHD-Comorbid group (ADHD-Comorbid with oppositional defiant disorder and/or conduct disorder; n=37), and control group (n=36). The tests used to assess the children were Conners' Parent and Teacher Rating Scales; Wechsler Intelligence Scale-Revised; Tower of London test; Wisconsin Card Sorting Test; Stroop Color-Word Test, and verbal fluency test. The data were analyzed by one-way ANOVA between subjects for all dependent variables.

Results: Children in the ADHD-I group had significantly better performances in verbal working memory and verbal category shifting than children in the ADHD-C group. There was no significant difference between the ADHD-I and ADHD-C groups in terms of inhibition, set shifting, verbal fluency, cognitive flexibility, and planning. The ADHD-Comorbid group displayed more severe impairments in EF measures than the ADHD-C group; however, the severity was not statistically significant. EF performances of children in the control group were similar to children in the ADHD-I group but better than children in the ADHD-C and ADHD-Comorbid groups.

Conclusion: The outcome of the study indicated that subjects in the ADHD-Comorbid and ADHD-C groups had more severe EF deficits than subjects in the ADHD-I and control groups.

Keywords: ADHD, subtypes, comorbidity, neuropsychology, executive functions

INTRODUCTION

Attention deficit hyperactivity disorder (ADHD), a common, early onset neuropsychiatric/developmental, behavioral disorder, is one of the most prevalent, well-studied childhood psychopathological conditions. It is estimated that 3%–5% of children have this disorder and half of them display the problems associated with ADHD in adulthood; the male/female ratio is 3–5:1 (1,2). According to the Diagnostic and statistical manual of mental disorders (3), the diagnostic criteria of ADHD include three patterns of persistent behavior that are "inattention," "hyperactivity," and "impulsivity." These behaviors are differentially expressed in three subtypes: primarily inattentive (ADHD-I), primarily hyperactive/impulsive (ADHD-H), and combined (ADHD-C) type. Children with ADHD-C display both inattentive and hyperactive–impulsive symptoms (3).

According to neuropsychological theories, ADHD is postulated to arise from a deficit in executive functioning because it is the main characteristic of the disorder (4,5). The term executive function (EF) refers to the higher cognitive processes that controls conscious and voluntary self-regulation and goal-directed behavior, such as response inhibition, planning, abstract thinking, working memory, attention shifting, verbal fluency, and problem solving (6,7,8,9). EFs are considered to be related with the prefrontal/frontal lobes (1,10). According to Frank (11), children with frontal lobe lesions have a tendency to abnormalities of impulse control as well as abnormalities in motor activity and attention span. As Barkley (5) states that children with ADHD-C are characterized as having poor behavioral inhibition, they have problems with inhibition of proponent responses that limits the control of behavior, poor planning and anticipation, reduced sensitivity to errors, and poor self-regulation. Barkley postulated that children only with ADHD-C and ADHD-H display executive function deficits but not ADHD-I (5,12). In contrast, children with ADHD-I may represent a separate disorder, displaying more problems with selective attention, sluggish tempo, difficulties in reading, mathematics and language, and poor memory retrieval (5).

A literature review indicates that neuropsychological tests presuming to assess EFs have found differences between children with ADHD and control groups (4,13). Tests for assessing different aspects of EFs, such as response inhibition, planning, working memory, set-shifting, or cognitive flexibility, indicated that subjects with ADHD performed more poorly than controls (14). In the meta-analysis of Pennington

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and Ozonoff (15), 18 published studies of EFs in ADHD are reviewed; 15 of them indicated a significant difference between ADHD subjects and controls in one or more EF measures. A total 40 out of the 60 EF scores were significantly worse in the ADHD group (67%). In addition, the most consistently impaired domains of EF is inhibition; on the contrary, set shifting and working memory were less impaired in children with ADHD (16).

Geurts et al. (17) investigated the EF hypothesis of Barkley (5), proposing that children with ADHD-C would display pervasive EF deficits. They compared three groups (ADHD-I, ADHD-C, and normal controls); each group comprised 16 subjects matched by age; IQ; and presence of oppositional defiant disorder (ODD), or conduct disorder (CD). Groups were compared in five major domains of EF: response inhibition, visual working memory, planning, cognitive flexibility, and verbal fluency. The study outcome did not support Barkley's EF model of ADHD; EF measurements did not demonstrate significant differences between the ADHD-C and ADHD-I groups. In addition, no significant difference was observed between ADHD-C and normal controls for general executive dysfunction, on working memory, planning, and verbal fluency except one of the cognitive flexibility measures.

It has been estimated that more than half of the children with ADHD exhibit comorbidities with at least one other psychiatric condition, such as depression, anxiety, ODD, CD, and substance use disorders (18,19,20,21,22). For ADHD-C, the comorbidity rate of ODD and CD was reported to be as high as 40%–65% (23). Majority of the literature concerning ADHD-Comorbidity is on ODD and CD (24,25,26); therefore, it was considered that these disorders should be closely studied. Crawford et al. (27) concluded in their study that the presence of comorbid disorders, such as ODD, CD, or reading disorder, would worsen cognitive and behavioral functioning in ADHD. Therefore, in the present study, children with ADHD-C and with comorbid ODD and/or CD were recruited in a third group.

In light of the literature review, this study aims to test Barkley's EF hypothesis by evaluating the specificity of EF measures, such as inhibition, planning, working memory, and set shifting in children with ADHD by comparing groups of ADHD subtypes (ADHD-I and ADHD-C) and ADHD-Comorbid group (ADHD-C comorbid with ODD and/or CD) with a normal control group.

METHODS

Participants

In this study, 147 children aged between 7 and 12 years were included. Thirty-seven children (five girls, 32 boys) were assigned in the ADHD-Inattentive group, thirty-seven children (six girls, 31 boys) were assigned in the ADHD-Combined group, and thirty-seven children (four girls, 33 boys) were classified as ADHD-Comorbid group (ADHD-C with ODD included four girls and 31 boys and ADHD-C with CD included two boys). Thirty-six children (six girls, 30 boys) were assigned to the control group by matching with the ADHD groups according to the WISC-R Full Scale IQ-score, sex, and age. The children in the ADHD groups were referred from the Child and Adolescent Mental Health Department of Bakırköy Sadi Konuk Training and Research Hospital, The children in the control group were recruited from local public elementary schools. All children in the ADHD group fulfilled the criteria for ADHD-I, ADHD-C, and ADHD-Comorbid subgroups, according to DSM IV-TR.

An assessment sheet was prepared by the researcher to record the demographic characteristics of the children and was completed with parents during the clinical interview. One-way ANOVA was performed to analyze the continuous demographic variables. There was no significant difference between the groups regarding family income or the parents' age groupings. However, a significant difference was observed between ADHD-Comorbid and control groups concerning the mother's education [F (3,143)=3.33, p=.021], indicating that the education level of the control groups' mothers was higher than the ADHD-Comorbid (p=.025) group. For the father's education level, the ADHD-Comorbid group revealed significantly lower levels than the control (p=.007) and ADHD-I (p=.037) groups [F (3,143)=4.26, p=.007] (Table 1).

Measures

Phase I: Scales for Screening of Children

Wechsler Intelligence Scale-Revised (WISC-R)

WISC-R is the most widely used intelligence test for assessing children's/adolescents' intelligence level and for identifying specific areas of deficit. The Turkish adaptation of WISC-R has been composed by Savaşır and Şahin (28) with 1639 children whose age range was 6–16 years. Split half reliability of Verbal tests, performance tests, and Full Scale tests were .97, .93, and .97, respectively. Correlations of subtests varied between .51 and .86.

Conners' Parent and Teacher Rating Scale

Conners' Rating Scales aim to measure ADHD in children and adolescents through parents' and teachers' ratings of their behavioral problems as well as ODD and CD. The scales correspond with symptoms used in the DSM-IV criteria for ADHD. In the present study, the short versions of the scales were used. The parent version short form comprising 48 items and teacher version-short form comprising 28 items measured inattentiveness, hyperactivity/impulsivity, ODD, and CD.

A Turkish adaptation and validity of CPRS-48 and CTRS-28 has been composed by Dereboy et al. (29). The Turkish versions of CPRS-48 and CTRS-28 indicated good internal consistency with Cronbach's alpha coefficients of .95 and .90, respectively. Cronbach's alpha scores of subscales are as follows: CPR-I .67, CPR-H .82, CTR-I .83, and CPR-H .72.

Phase II: Assessment of EF of Children Tower of London-Drexel University (ToLDX)

ToLDX was developed by Culbertson et al. (30), with the aim of measuring higher order problem solving and ability of executive planning. The information it provides is not only useful when assessing frontal lobe damage but also when evaluating attention disorders and EF difficulties in children and adults. In this study, differences in planning ability between the groups were compared using the total move score, initiation time- in other words planning time (the latent time between instruction completion and the first move, which is lifting a bead from a peg)-, and the number of correct responses. The Turkish standardization of ToLDX has not been conducted for children.

Wisconsin Card Sorting Test (WCST)

WCST provides a measure of ability to identify abstract reasoning and cognitive flexibility in problem solving as well as set shifting (2,31,32). In this study, the number of categories completed and perseverative errors were used as the main scores of WCST for assessing set shifting. The Turkish standardization of WCST has been conducted by Aközel et al. (33) for primary school children.

Verbal Fluency and Category Fluency Task

Verbal fluency measures the ability to generate a novel strategy under time constraints for guiding an organized search of the internal semantic network (34). Cognitive processes involved in verbal and category flu-

Table 1. Distribution of subject's age, parents' age, education, and family income

	ADHD-I (n=37)		ADHD-C (n=37)		ADHD-Comorbid (n=37)		Control (n=36)		
	M	(SD)	M	(SD)	M	(SD)	M	(SD)	F
Subject's age	9.89	(1.70)	8.95	(1.60)	9.14	(1.81)	9.33	(1.67)	2.15
Mother's age	35.95	(4.39)	34.32	(4.82)	33.97	(5.52)	36.97	(5.63)	2.75
Father's age	39.21	(4.52)	38.45	(6.07)	38.83	(5.67)	41.33	(5.83)	1.94
Mother's education	8.70[a]	(3.54)	7.43[a]	(3.43)	7.02[a]	(3.29)	9.19[b]	(3.32)	3.33*
Father's education	9.46[a]	(3.46)	8.46[a,b]	(3.62)	7.27[b]	(3.09)	9.94[a]	(3.70)	4.25**
Family income (in thousand)	1.61	(1.22)	1.45	(1.22)	1.25	(.84)	1.51	(1.26)	.69

SD: standard deviation. *p<.05, **p<.01. Means with differing subscripts with rows are significantly different at the p<.05 based on Tukey's AD post hoc pairwise comparison.

ency measures comprise processing speed, depth of vocabulary, semantic memory, inhibition, and set maintenance (13). In this study, the letter fluency task was performed to measure verbal fluency and FAS (for the Turkish people KAS). Subjects are provided one minute to name as many words as they can for each letter (K-A-S consequently), excluding proper nouns and plurals. The number of words given was counted to get the total score (31,34). The replication of the same word in each category was recorded as a perseverative error. For the category fluency tasks, children were asked to categorize as many names of animals and fruits as possible in order, (e.g., Lion-Apple) in one minute. The number of completed categories was counted to obtain the total category fluency score. Category perseveration indicates the inability to shift between categories. Verbal fluency task was standardized for the Turkish primary school children by Dikmeer et al. (35).

Stroop Test

This task is used to assess selective attention and response inhibition. The basic principle of the Stroop test is to create interference between word reading and color naming. Through interference control, the test measures the participant's perceptual set-shifting ability to conform to changing demands, e.g., naming the ink color without taking into account the printed words or reading the words while ignoring the color of the print. The completion time/duration of naming the ink color was recorded. In this study, the Stroop test TBAG (Scientific and Technical Research Council of Turkey) was used. It is based on the original Stroop test and the Victoria version (36). The Stroop TBAG form was standardized for Turkish children aged between 6 and 11 years by Kılıç et al. (37). The reliability measures were conducted by the test–re-test method after a 2-month period and reliability coefficients were found to be between 0.63 and 0.81.

Wechsler Intelligence Scale-Revised Digit Span Subtest

WISC-R digit span subtest comprises two parts that are digit forward (for assessing auditory attention) and digit backward (for assessing working memory). Digit span comprises the repetition of 3–9 digit forwards and 2–8 digit backwards.

Procedure

In the ADHD group, each child was required to have been diagnosed as having ADHD-I, ADHD-C, or ADHD-Comorbid type according to DSM-IV criteria by a child psychiatrist. None of the children in study group received any medication (e.g., methylphenidate). These children were directed to further neuropsychological assessment. In the first meeting, informed consent was provided by the parents. Parents (and teachers) of each child completed the Conners' Rating Scale, and the children were provided the WISC-R. In the second meeting, children who had FSIQ scores of 90 and over were provided EF tasks in a mixed order. Following the neuropsychological assessment, the children's parents were interviewed using DSM-IV TR assessment scales for ADHD, ODD, and CD, and the demographic assessment sheet was completed. The control group was recruited from local schools with the permission of parents and teachers. At the end of the neuropsychological assessment, a comprehensive report was sent to the referring child psychiatrist. In addition, the parent of each child was informed regarding the outcome of the assessment.

Exclusionary factors included low intelligence (FSIQ score below 90), history of seizure disorders, history of traumatic brain injury warranting medical attention, or a previous diagnosis of any psychiatric disorder, including behavioral disorder, learning disability, and autism.

RESULTS

The study comprised two phases. In Phase I, children were screened according to their IQ level and ADHD subtypes. In phase II, the executive functions of children were measured by several neuropsychological tests. The results will be separately presented for Phase I and Phase II to easily understand the research design.

The data were analyzed by one-way ANOVA between subjects for all variables that were measured by scales. Post hoc analysis of group differences was tested by Tukey's AD post hoc pairwise comparison test.

Phase I: Results for WISC-R and Conners' Teacher Rating Scales

CPRS-48 and CTRS-28 were used to collect information regarding symptoms of attention deficit and disruptive (hyperactive/impulsive) behavior. The cut-off points (30) for parent and teacher's scores of inattentiveness were 5 and 8, respectively. Similarly, the cut-off points for parent and teacher's scores of hyperactivity were 6 and 7, respectively. The results of CPRS-48 and CTRS-28 confirmed the clinical diagnosis of ADHD-I, ADHD-C, and ADHD-Comorbid groups. WISC-R Verbal IQ scores revealed significant group differences [F (3,143)=3.12, p=.028], and post hoc comparison of groups indicated that Verbal IQ score of control group was significantly higher than ADHD-Comorbid group (p=.038). No significant differences were observed in performance IQ and total IQ scores as expected (Table 2).

Phase II: Results for Tests/Tasks Measuring Executive Functions

Data Cleaning

Before assessing the differences and relationships between the groups, outliers were analyzed to assess normality. Skewness and kurtosis statistics were calculated to overview the distribution of continuous variables. Variables that were indicating outliers were assessed using whisker plots. After de-

Table 2. Descriptive statistics for WISC-R Verbal IQ, WISC-R Performance IQ, WISC-R full scale IQ and Conners' Parent Rating Scale, Conners' Teacher Rating Scale of the groups

	ADHD-I (n=37)		ADHD-C (n=37)		ADHD-Comorbid (n=37)		Control (n=36)		
	M	(SD)	M	(SD)	M	(SD)	M	(SD)	F
WISC-R verbal IQ	102.95	(12.81)	102.97	(10.96)	102.05	(12.41)	109.44	(11.04)	3.12***
WISC-R perform. IQ	103.81	(12.81)	103.78	(13.26)	102.27	(12.06)	105.61	(13.28)	.42
WISC-R total IQ	103.57	(11.23)	103.62	(11.43)	102.32	(11.40)	108.31	(11.63)	1.93
CPRS-inattentive	7.30[a]	(2.18)	7.81[a]	(2.59)	8.59[a]	(3.33)	2.86[b]	(2.38)	34.06***
CPRS-hyperactive	4.76[a]	(2.24)	8.46[b]	(2.53)	8.57[b]	(2.20)	3.11[c]	(2.21)	51.31***
CTRS-inattentive	11.30[a]	(4.86)	8.30[b]	(3.69)[S]	12.70[a]	(4.52)	3.08[c]	(2.63)	40.70***
CTRS-hyperactive	4.78[a]	(3.04)	12.11[b]	(3.75)	13.19[b]	(4.78)	4.28[a]	(3.57)	55.29***

WISC-R: Wechsler Intelligence Scale for Children-Revised; CPRS: Conners' Parent Rating Scale; CTRS: Conners' Teacher Rating Scale.
***p<.001. Means with differing subscripts with rows are significantly different at the p<.05 based on Tukey's AD post hoc pairwise comparison.

tecting outliers, the z value was computed. The z value=±3.26 and above was used for excluding subjects that unexpectedly deviated from the normal distribution. One boy in the ADHD-I group did not complete any category in WCST. Four outliers were excluded (three from ADHD-C, one from the ADHD-Comorbid) because of their category fluency perseverative scores and resulting z values. Two subjects (one from ADHD-C and two from ADHD-Comorbid group) were determined as outliers and were excluded from the Stroop test analysis. In addition, one subject in ADHD-Comorbid group could not complete the Stroop test.

Comparisons of the ADHD Groups and Control Group in Terms of Executive Function Tests/Tasks

The means, standard deviations, 95% Confidence Interval of the means, F values, and results of post hoc analysis (as subscripts) are presented in Table 3.

The number of correct responses [F (3,143)=3.47, p=.018], number of total moves [F (3,143)=5.13, p=.002], and total initiation time [F (3,143)=3.21, p=.017] scores of ToLDX task were significantly different between groups. According to Tukey's AD post hoc pairwise comparison, the number of total moves scores in the ADHD-C (p=.017) and ADHD-Comorbid groups (p=.005) were significantly higher than in the control group. The control group's total initiation time was significantly longer than the ADHD-Comorbid group (p=.032) (Table 3). ADHD-I group's number of correct responses score was significantly higher than that of the ADHD-Comorbid (p=.020) group.

Significant differences were found in WCST for the number of categories completed [F (3,142)=2.97, p=.034] and perseverative errors [F (3,143)=3.34, p=.021]. Tukey's AD post hoc pairwise comparison revealed that the control group had significantly more completed categories than the ADHD-Comorbid group (p=.024) and less perseverative errors than the ADHD-C group (p=.026).

There was no significant difference among the groups in verbal fluency (K-A-S), perseverative errors of K-A-S, and category fluency test scores. In contrast, significant group differences were observed in the category perseverative errors [F (3,137)=3.20, p=.025]. Post hoc comparison revealed that category perseveration (being unable to change categories and continuing with previous ones) of the ADHD-C group was significantly higher than the control and ADHD-I (p=.031) groups.

There was no significant difference between the groups in Stroop naming color of color words or Stroop interference effect/control score.

There was no significant difference between the groups in the digit span forward test. However, the digit span backward test results were significantly different between the groups [F (3,143)=5.03, p=.002]. Tukey's post hoc group comparison indicated that children in the ADHD-I group repeated significantly more numbers backwards than children in the ADHD-C (p=.017) and ADHD-Comorbid groups (p=.009).

DISCUSSION

The purpose of this study was to examine the difference of EFs, such as inhibition, working memory, planning, set shifting, and verbal fluency in four groups (ADHD-I, ADHD-C, ADHD-Comorbid, and controls).

In terms of the ToLDX test, there were significant mean differences in the number of correct responses, number of total moves, and total initiation time. Between the ADHD-Comorbid and ADHD-I groups significant difference was observed in the number of correct responses in ToLDX. Concerning the number of total moves, performance of the ADHD-C and ADHD-Comorbid groups was significantly lower than in the control group but not in the ADHD-I group. Significant difference in the total initiation time was observed between the ADHD-Comorbid and control groups but not between the ADHD subtypes. In other words, planning ability significantly differed between the control and ADHD groups but not between the subtypes of ADHD-I and ADHD-C. The outcome was not concordant with Barkley's ADHD theory of EF difference between the ADHD subtypes. He proposed that ADHD-I type is impaired in selective attention, ADHD-C children exhibit problems with behavioral inhibition and self-control that are associated with poor executive control and planning (5,38,39). Some of the previous literature did not support this theory, and no significant difference was observed between the ADHD subtypes (4,17,40). Except the number of correct responses, the present study reported a similar outcome; only the control and ADHD-Comorbid groups were significantly different in their planning ability. In contrast, in the present study, only the number of correct responses was able to discriminate the ADHD-I group from the ADHD-Comorbid group, indicating that the ADHD-Comorbid group had more impaired planning ability than the ADHD-I group.

Cognitive flexibility and set shifting were assessed using WCST. The WCST scores of the number of categories completed and perseverative errors were significantly different between the groups. Overall, the control group performed better than the other groups; however, concerning statistically significant outcomes, the ADHD-I and control groups did not differ at all. The control group had less perseverative errors than the ADHD-C group.

Table 3. Mean values of executive function tests

	ADHD-I			ADHD-C			ADHD-Comorbid			Control				
	M	(SD) (n=37)	95% (CI)	M	(SD) (n=37)	95% (CI)	M	(SD) (n=37)	95% (CI)	M	(SD) (n=36)	95%[CI]	F	p
Tower of London														
Num. of correct responses	3.43[ab]	(1.62)	[2.89, 3.97]	2.95[ab]	(1.27)	[2.52, 3.37]	2.54[a]	(1.02)	[2.20, 2.88]	3.30[b]	(1.24)	[2.89, 3.72]	3.47	.018*
Number of Total Moves	40.46[ab]	(18.76)	[34.20, 46.72]	47.68[b]	(18.02)	[41.67, 53.68]	49.30[b]	(15.38)	[44.17, 54.42]	36.19[a]	(12.77)	[31.88, 40.51]	5.13	.002**
Total Initiation Time	42.08[a]	(31.61)	[31.54, 52.62]	39.54[ab]	(29.82)	[29.60, 49.48]	26.89[b]	(12.27)	[22.80, 30.98]	43.64[ab]	(25.06)	[35.16, 52.12]	3.21	.025*
Wisconsin card sorting test		(n=36)			(n=37)			(n=37)			(n=36)			
Number of categories completed	3.83[ab]	(1.63)	[3.28, 4.38]	3.54[ab]	(1.74)	[2.96, 4.12]	3.08[a]	(1.50)	[2.58, 3.58]	4.17[b]	(1.58)	[3.63, 4.70]	2.97	.034*
Perseverative errors	29.57[ab]	(15.36)	[24.45, 34.69]	35.27[b]	(17.64)	[29.39, 41.15]	34.14[ab]	(16.40)	[28.67, 39.60]	24.42[a]	(15.79)	[19.07, 29.76]	3.34	.021*
Verbal fluency (K-A-S)	(n=37)	(n=37)	(n=37)	(n=36)										
Number of words	19.50	(7.78)	[16.87, 22.13]	15.61	(7.78)	[12.98, 18.24]	15.05	(5.87)	[13.10, 17.01]	17.94	(9.25)	[14.81, 21.08]	2.59	.005
K-A-S perseverative	.03	(.17)	[-.03, .08]	.00	(.00)	[.00, .00]	.08	(.36)	[-.40, .20]	.06	(.33)	[-.06, 1.17]	.65	.582
Category fluency (animal–fruit)	5.17	(1.42)	[4.68, 5.65]	4.67	(1.76)	[4.07, 5.26]	4.57	(2.01)	[3.90, 5.24]	5.14	(1.66)	[4.58, 5.70]	1.19	.317
Number of categories		(n=37)	(n=34)	(n=36)	(n=36)									
Category perseverative	.14[a]	(.35)	[.02, .26]	.53b	(.83)	[.25, .84]	.25[ab]	(.60)	[.05, .45]	0.17[a]	(.56)	[-.02, .36]	3.08	.025*
Stroop	(n=37)	(n=35)	(n=36)	(n=36)										
STR/5 naming color of colors	50.37	(21.39)	[43.25, 57.51]	53.60	(16.82)	[47.82, 59.38]	58.58	(20.25)	[51.73, 65.43]	48.19	(18.50)	[41.93, 54.46]	1.96	.122
WISC-R digit span	(n=37)	(n=37)	(n=37)	(n=36)										
Digit span forward	5.95	(2.04)	[5.27, 6.63]	5.49	(2.17)	[4.76, 6.21]	5.27	(1.57)	[4.75, 5.80]	5.78	(1.79)	[5.17, 6.38]	.92	.435
Digit span backward	4.70[a]	(2.07)	[4.01, 5.39]	3.54b	(1.46)	[3.52, 4.03]	3.46[b]	(1.26)	[3.04, 3.88]	4.39[ab]	(1.79)	[3.78, 4.99]	5.03	.002**

**p<.01, *p<.05 . Means with differing subscripts with rows are significantly different at the p<.05 based on Tukey's AD post hoc pairwise comparison. Numbers in square brackets are 95% confidence intervals of the means.

These differences between the groups indicated that the ability to develop problem solving strategy in a new environment, in other words, cognitive flexibility, was greatest in the control group. Concordant with Barkley's (5) assumptions regarding hindsight (the ability to adjust subsequent responses based on the immediate past incorrect ones) and forethought (planning ability), children with ADHD had difficulty to use hindsight and forethought in a novel situation. The ADHD-C group had a higher level of inability to suppress an ongoing activity despite being told that it is no longer appropriate. Even though the ADHD-Comorbid and ADHD-I groups did not significantly differ from the controls, the total of their perseverative errors was still higher. The control and ADHD-Comorbid groups had significant differences in the score of categories completed. This indicated that the control group subjects' concept formation, with the requirement of the subject to make use of positive and negative feedback to formulate problem solving strategies, was significantly better than the ADHD-Comorbid group and slightly better than the ADHD-I and ADHD-C groups.

The outcome of the present research was consistent with previous articles, concluding that perseverative errors of WCST can differentiate between ADHD and control groups (13,41) but cannot differentiate between the ADHD subtypes (4,42). In addition, same studies evidenced no significantly different outcomes between the subtypes ADHD-I and ADHD-C or between the subtypes and control groups (17).

Verbal fluency (K-A-S) and category fluency (animal–fruit) measures were used to measure organized memory search, sustained production, and semantic fluency. The study groups were significantly different in category perseverative scores of category fluency measures. Children in the ADHD-C group had significantly more category perseverative errors than children in the ADHD-I and control groups, indicating that children with ADHD-C have difficulty in switching between the two different categories, and category perseverative errors may differentiate between the ADHD subtype groups and control groups.

In their meta-analysis study, Sergeant et al. (13) reported that three out of the six studies found a significant difference between the ADHD and control groups in terms of verbal fluency task, and two out of the nine studies of category fluency tasks found a significant difference between the ADHD and control groups. Although Grodzinsky et al. (40) found that the verbal fluency (K-A-S) task has good positive predictive power, correctly identifying 90% of children with ADHD, the outcome of the present study was inconsistent with their results. Cohen et al. (42) yielded that the performance of the ADHD group was not found to be impaired in verbal fluency task, and they concluded that the significant difference of

verbal fluency in children with ADHD may be because of a comorbidity of developmental dyslexia or a learning disability.

Selective attention and verbal inhibition was assessed using the Stroop color-word test, the TBAG version. In the present study, no significant difference was observed between the study groups, indicating that Stroop interference effect/control did not discriminate between the ADHD subtypes and control groups. Previous studies reported different outcomes; some of them concluded that Stroop interference effect/control would differentiate ADHD from the control group, whereas others reported no significant differences (13,41,44,45,46).

The WISC-R digit span forward subtest was performed to evaluate short-term memory and auditory attention. The study groups revealed no significant differences, suggesting that auditory attention of children may not be impaired. The WISC-R digit backward subtest was performed to assess verbal working memory. The children in the ADHD-I and control groups performed significantly better than children in the ADHD-C and ADHD-Comorbid groups. The ADHD-I and ADHD-C groups were significantly different; in other words, verbal working memory differentiated the ADHD-I and ADHD-C groups. This outcome supports Barkley's EF hypothesis (5) that children in the ADHD-C group would have impairment in working memory but not children in the ADHD-I group.

In conclusion, the outcome of this study partly supports Barkley's EF hypothesis of ADHD. Children in the AHDH-I and ADHD-C groups are significantly different concerning verbal working memory and perseverative errors in category fluency, indicating that children in ADHD-C group had difficulty in verbal working memory as well as inability to switch between two different categories. In contrast, there was no significant difference between the ADHD-I and ADHD-C groups in terms of inhibition, set shifting, verbal fluency, cognitive flexibility, and planning. Stefanatos et al. (14) concluded that Barkley mainly describes deficits in inhibition as a core executive functional pathology that causes impairment in other EF abilities, including working memory. However, Denney et al. suggested that working memory problems, primarily impaired in ADHD, leads to deficit in inhibition and impulsivity (14). This conclusion is partly supported in this study. The ADHD subtype groups were significantly different from each other in verbal working memory performance.

ADHD-Comorbid (ADHD-C+ODD/CD) group displayed more severe impairments than the ADHD-C group; however, the difference in severity was not statistically significant. Two recent studies examined the relationship between ODD and executive dysfunction by comparing subjects with ADHD, subjects with ADHD+ODD/CD, and subjects with ODD/CD; the authors concluded that ODD/CD did not reveal higher impairments in EF. Subjects with ADHD+ODD/CD displayed more impairments than subjects with ADHD and subjects with ODD/CD (19,22). The EF test performances of the children in the ADHD-I group were similar to those in the control group.

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