

Executive Dysfunction in Children and adolescents with Attention Deficit Hyperactivity Disorder (ADHD)

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Objective: The purpose of this study is to compare the executive functions in children and adolescents who suffer from attention deficit hyperactivity disorder (ADHD) with normal children.

Method: Twenty children with ADHD were compared to 19 healthy children in terms of some executive functions using the computerized version of Tower of London, Continuous Performance Test (CPT), and Stroop Color Test.

Results: In "Tower of London", the performance of children with ADHD was worse than normal children ($p < 0.05$). In Continuous Performance Test, the commission errors in children with ADHD were significantly more than the normal group ($p < 0.01$). In Stroop Test, the time spent to name the colors was significantly higher in ADHD group. A significant correlation was also found between the performance of children on Tower of London and CPT ($P < 0.05$).

Conclusions: This study demonstrates that children and adolescents who suffer from ADHD have some impairment of executive functions, particularly planning and inhibition to response, but not in attention.

Keywords:

Attention deficit disorder with hyperactivity, attention, inhibition, Neuropsychology

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Individuals with attention deficit hyperactivity disorder (ADHD) are characterized by having hyperactivity, impulsivity, and inattention. Executive dysfunction is one of the cognitive deficits which have been suggested in ADHD. Executive function is the ability to maintain an appropriate problem solving set to attain future goals. An executive function (EF) deficit theory of ADHD, has been proposed by several researchers (1). Executive functions include set – shifting and set maintenance, interference control, inhibition, integration across space and time, planning and working memory (2). In neuropsychology, executive functions are described as the performance on tasks that patients with frontal lobe lesions do badly on. Persons with ADHD have been found to exhibit deficits in most of EF abilities. In his review on executive functions in children with ADHD, Pennington found that 15 out of 18 studies have established a significant difference between ADHD patients and controls on one or more executive functions measures. He then concluded that the most consistently impaired measures are Tower of Hanoi, Matching Familiar Figure Test, Stroop Test, and measures of inhibition (2). The main cognitive model linking executive deficit to the behavioral symptoms of ADHD is that three cardinal symptoms of ADHD

(hyperactivity, inattention and impulsivity) can be reduced to deficit in inhibition which is one of the executive functions (2-4).

Moreover, it has been proposed that these children have some impairment in frontal lobe functions (5). In his review on studies of frontal lobe functions in children with ADHD, Barkley found that most of these tests assess the ability of response inhibition. It is believed that these tests are mediated by the frontal lobes; particularly, the orbital–prefrontal and medial-prefrontal areas and their rich connections to the striatum (6).

Wisconsin Card Sorting test, Stroop Test, Matching Familiar Figures Test, Tower of Hanoi, and Tower of London are several neuropsychological tests used to assess executive functions.

Planning and organizing are the two executive functions believed to be impaired in children with ADHD. Tower of London is one of the neuropsychological tests which measures planning.

The main aim of this study is to find whether children and adolescents with ADHD are impaired in planning, inhibition, set-shifting, and attention compared to the normal group and to find the correlation between the variables of Tower of London task and those of Continuous Performance Test and Stroop Test.

Materials and Method

Participants: A total number of twenty boys aged 7 to 15 were recruited for this study. ADHD was diagnosed according to DSM-IV-TR classification by a child and adolescent psychiatrist (author) at a child psychiatry clinic. They did not have any other psychiatric or medical problems except for oppositional defiant disorder. Their IQs were above 90. Nineteen children from the mainstream schools whose IQs and ages matched with their counterparts were examined as the control group. Based on interviews with their parents and using the Conners' Parent Rating Scale, the control group did not have any psychiatric problems.

Measures

All of the participants were examined using the measures below :

1) Conner's Parent Rating Scale – 48 (CPRS-48): a 48-item questionnaire which was completed by parents. Five indices have been derived from this scale: conduct problem, learning problem, hyperactivity impulsivity problem, psychosomatic-anxiety problem, and hyperactivity index. This questionnaire was used to compare the symptoms of hyperactivity, impulsivity, and inattentiveness between the two groups.

2) Raven Progressive Matrices: The Color Raven Progressive Matrices type was used to measure the subjects' intellectual abilities.

3) Computerized Version of Tower of London: Tower of London was originally designed by Shallice (1982) to investigate planning abilities in patients who suffer from frontal lobe damage. In this test, participants are required to move an array of colored beads mounted on three vertical rods to match a particular goal arrangement(7). Robin Morris (1993) produced a computerized version of this task in which the beads are shown as discs to represent three dimensional structures (8). The subjects are shown two arrangements on a touch sensitive screen. The top one remains static for each trial and represents the goal arrangement. The bottom one contains the discs that can be arranged by the participant to match the top arrangement. Discs can be moved by touching the disc first and then touching the required destination. The goal position for the discs is varied, but the starting position is kept static. The problems can be solved in two, three, four and five moves(9). The variables are as listed: 1) "number of moves", the mean number of moves above the minimum number possible which is calculated as a general measure of performance; 2) "planning time", is the time between the presentation of the problem and touching the first disc; 3) "subsequent thinking time", is the time between selection of the first disc and completion of the problem and can be used as a measure of performance (8) .

Tower of London was used to evaluate planning ability and is supposed to be sensitive to frontal lobe (7, 8, 10, 11).

(4 Continuous Performance Test (CPT) was used to measure impulsivity and attention. There are several versions of CPT. The main procedure is that a target stimulus is presented on the screen randomly among different stimuli. The participant is instructed to tap a button when the target is presented. In this version, the participant is shown some patterns containing a number and a figure. When two identical patterns (number and figure) are presented, the participant should tap a button. The variables are as follows: 1) the "number of Commissions" which is the index of impulsivity. The commission error will occur if the subject responses to a stimulus other than the target; 2) the "number of Omissions", indicating the inattentiveness. The omission error will occur when the subject misses the target; 3) The " Reaction Time" , the time between the presentation of the target and the response of the participant (12).

(5 Stroop Color Test was used to measure attention, set shifting, and cognitive flexibility. Three cards are presented to the participant. The first one is called Dots Cards with several dots in colors of green, red, blue and yellow and the subject is told to name the colors. The second card which is called Word Card has several common words printed in the same colors of the Dots Card. The participant is required to name the colors of the printed words without reading them. The third card is called Color Card on which the words of green, red, blue, and yellow are printed in the same colors of the Dots Card but in different color of its own. The subject is instructed to name the printed colors regardless of the meaning of the words. The "errors" and the "time" to complete reading in each card are recorded. The subtraction of time in Dots Card from the time in Color Card is used as a "Difference Index".

Procedure

After participants were interviewed by a child and adolescent psychiatrist and permission was obtained from their parents, they were referred for additional assessments. Participants were examined using the computerized Tower of London, CPT, Stroop Test, and Raven. The order of the tests varied randomly to avoid the influence of the order effect. The participants were allowed to have a rest between the two tests. Meanwhile, their parents were also asked to complete the Conner's Parent Rating Scale.

Analysis

The data was analyzed using the SPSS 11.0. T-test was used to find the significance of differences in variables between the two groups. Pearson Correlation Test was used to find the correlation between the variables in each of the two tests in ADHD group. P value less than 0.05% was noted as significant.

Results

Demographic characteristics of the participants are demonstrated in Table 1.

Table 1. Demographic Characteristics of participants

	ADHD (N=20)		Control (N=19)		P
	M	SD	M	SD	
IQ	121.36	13.32	126.86	6.66	0.11
Age (months)	110.7	18.66	117.7	20.24	0.26

Table 2. Characteristics of two groups in Conners' Parent Rating Scale

	ADHD (N=20)		Control (N=19)		p
	M	SD	M	SD	
Conduct problem	75.60	13.69	44.84	12.38	0.00
Learning problem	71.90	11.34	42.84	6.37	0.00
Psychosomatic	51.35	9.54	49.73	9.35	0.59
Hyperactivity impulsivity	71.90	8.05	47.26	8.28	0.00
Hyperactivity index	74.30	7.57	43.52	6.12	0.00

T-test revealed no significant difference between the ADHD and control children on their ages and IQs.

The results of Conners' Parent Rating Scale in two groups were shown in Table 2.

A significant difference was found between the two groups in terms of hyperactivity index $t(37)=14.69$; $P<0.01$. Except for psychosomatic problem, a significant difference was also observed between the two groups in other indices of CPRS. Conduct problem was more prevalent in hyperactive children than the control group, $t(37)=7.35$; $P<0.01$.

In the Tower of London Test, the "number of moves" was higher in children with ADHD than the normal group. This difference was significant at level 2 and 3, $t(36) = 2.15$; $P<0.05$, $t(37)=2.06$; $P<0.05$.

"Subsequent thinking time" was also significantly higher in ADHD group compared to normal children. In terms of "planning time" a significant difference was found at level 2, where the planning time in ADHD group was higher ($P<0.01$).

Table 3 shows the results of Tower of London Test in the two groups.

In Continuous Performance Test (CPT), the "number of commissions" in patients who suffer from ADHD was significantly higher compared to the normal group $t(37)=3.11$; $P<0.01$. Nevertheless, no significant difference was found between the two groups in

Table 3: Result of Tower of London test in two groups

Number of moves	ADHD (N=20)		Control (N=19)		p
	M	SD	M	SD	
Level 2	2.36	0.55	2.06	0.14	0.03
Level 3	5.01	2.77	3.63	0.92	0.04
Level 4	9.17	4.25	7.38	2.61	0.12
Level 5	11.03	3.66	9.40	4.20	0.20
Sub Thinking time					
Level 2	14.81	7.25	9.08	2.85	0.00
Level 3	31.28	24.60	18.34	10.30	0.04
Level 4	57.90	29.33	36.70	15.18	0.00
Level 5	66.14	33.57	47.09	25.14	0.05
Planning time					
Level 2	5.71	2.00	4.06	1.10	0.00
Level 3	6.84	2.32	6.05	2.00	0.25
Level 4	5.95	1.88	5.35	1.08	0.23
Level 5	6.36	1.95	6.91	3.05	0.50

Table 4. Characteristics of two groups in CPT

	ADHD (N=20)		Control (N=19)		P
	M	SD	M	SD	
Commission errors	6.65	4.19	3.21	2.41	0.00
Omission errors	2.90	2.93	1.63	1.73	0.11
Reaction time	0.77	0.14	0.78	0.11	0.71

Table 5. Characteristics of two groups in Stroop Test

	ADHD (N=20)		Control (N=19)		p
	M	SD	M	SD	
Time in dots Card	23.47	7.23	18.23	5.15	0.04
Errors in dots card	0.15	0.36	0.10	0.31	0.68
Time in word card	36.07	13.61	28.37	9.51	0.04
Errors in word card	0.15	0.48	0.21	0.71	0.75
Time in color card	42.82	11.93	34.20	10.54	0.02
Errors in color card	1.15	2.81	0.31	0.58	0.21

"omission errors". "Reaction Time" in the two groups was not significantly different. Table 4 shows the differences between two groups in terms of the variables of CPT.

Time taken to name the colors in Dots Card, Word Cards, and Color Card were significantly higher in ADHD children than normal group. [Dot: $t(37)=2.59$; $P<0.05$; Word: $t(37)=2.03$; $P<0.05$; Color: $t(35)=2.32$; $P<0.05$]. In terms of errors, the difference between the two groups was not significant. The "Difference Index" which is the subtraction of Dot time from Color time (C time – D time) was higher in ADHD group. This difference, however, was not significant. Table 5 shows the difference between two group in term of the variable of stroop test.

Pearson Correlation test was used to find the correlation between different tasks. With respect to the correlation between Stroop Test and CPT, there was a correlation between commissions in CPT and the number of errors in Color Card, $r=0.49$; $N=20$; $P<0.05$. Concerning the relation between Tower of London Test and CPT, there was a significant correlation between the number of moves at levels 3, 4 and 5 in Tower of London and the number of omissions in CPT (level 3: $r=0.45$; $N=20$; $P<0.05$, level 4: $r=0.53$; $N=20$; $P<0.05$, level 5: $r=0.53$; $N=20$; $P<0.05$).

Regarding the correlation between "hyperactivity index" in Parent Conner's Rating Scale and CPT, there was a significant correlation between this index and "commissions" in CPT, $r=0.63$; $N=20$; $P<0.01$.

Table 6 represents the correlations between Tower of London Test and the other neuropsychological measures used in this study. "Difference Index" (C time – D time) in Stroop Test showed a significant correlation with "omissions" in CPT, $r=0.44$; $N=20$; $P<0.05$.

Discussion

The executive dysfunction hypothesis in attention – deficit hyperactivity disorder has been proposed in several studies. It has been found that children and adolescents who suffer from ADHD have impairment in response inhibition and this leads to hyperactivity, impulsivity and inattention. It has been suggested that these patients have deficit in other types of executive

Table 6. Correlation between Tower of London Test and Stroop Test and CPT

	Stroop Test			Continuous Performance Test (CPT)	
	Time	Error	Difference score	Commissions	Omissions
Tower of London Test					
Number of moves					
Level 2	0.42	0.36	0.38	0.36	0.11
Level 3	0.40	-0.06	0.32	0.10	0.45*
Level 4	0.59*	-0.04	0.56**	0.12	0.53*
Level 5	0.48*	0.24	0.31	-0.02	0.53
Subsequent Thinking time					
Level 2	0.42+	0.03	0.30	0.39	-0.006
Level 3	0.33	-0.12	0.20	0.17	0.35
Level 4	0.43+	-0.14	0.38	0.18	0.31
Level 5	0.11	0.15	-0.05	-0.11	0.26
Planning time					
Level 2	0.09	-0.04	-0.02	0.12	-0.38
Level 3	-0.01	0.39	-0.08	0.17	-0.02
Level 4	0.07	-0.06	-0.24	0.23	-0.09
Level 5	0.07	-0.10	-0.10	0.05	-0.04

Notes: ** P< 0.01, * P<0.05, P<0.06

functions such as planning. To find any deficits of planning, attention and set shifting in patients with ADHD compared to normal children we conducted this study.

This study shows that compared to normal children, children with ADHD perform poorly on Tower of London Test, which assesses planning, and problem solving. This result is consistent with findings in Pennington's review (2).

Culbertson and Zilmer compared children with ADHD to normal group using manual type of Tower of London. They found that ADHD group performed poorly on this task (13). In Kempton's study, children with ADHD were examined by computerized version of Tower of London. It was found that before treatment, these children had a poor performance on this task compared to the normal group and the ADHD group who took medication. These findings support the hypothesis that ADHD children have impairment in executive functions including planning (2-4).

This study also indicates that compared to normal children, the ADHD group had impairment in impulsivity index on Continuous Performance Test (CPT). This difference was not significant in attention index of this test. This finding is supportive of the theory that states impairment in response inhibition is the main deficit of ADHD. One possibility is that ADHD children have impulsive responses; therefore, their commissions in CPT will increase, and their omissions will decrease by chance.

Another test used in this study was Stroop Test which assesses a number of cognitive functions including attention, response inhibition, and set shifting.

According to Pennington's review, Stroop Test is one of the tasks found to be impaired in children and adolescents with ADHD (2). In this study, no significant difference was found on number of errors between the two groups. It was, however, discovered that the time spent to name the colors in all cards was significantly higher in children and adolescents with

ADHD. Since children with ADHD are distractible, it takes more time for them to complete a task, especially when they need to shift from one category to another.

This study also found that there is a significant correlation between Tower of London test and CPT in children with ADHD. It means that the planning performance of these children is related to their impulsivity. This finding is consistent with the results found in the Anderson's study which showed a significant correlation between Tower of London and other measurements of executive functions (14). Since the tests used in this study are sensitive to frontal lobe (8, 10, 11), this study can support the frontal lobe theory of ADHD (6). This hypothesis has been suggested in several studies (15, 16). According to these findings, ADHD children have impairment in executive functions due to frontal dysfunction (2). This theory has also been confirmed by some functional neuroimaging studies. Namely, Rubia's study which found a lower power of response in the right mesial prefrontal cortex during the motor response inhibition tasks in children with ADHD using fMRI (17). In her study, Smith found a decreased activation in the left rostral mesial frontal cortex during performance of tasks that assessed motor response inhibition using fMRI in adolescents with ADHD (18). In his study on children with ADHD, Pliszka also found that participants failed to activate the anterior cingulate cortex and the left ventrolateral prefrontal after unsuccessful inhibition during the stop task using fMRI (19).

In Summary, this study found that ADHD children have impairment in executive functions including response inhibition and planning.

One of the limitations of this study may be the high level of the participants' IQs which could influence their performance of executive functions tasks even though the two groups were matched on their IQs.

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