International Journal of Children and Adolescents

Original Article
IJCA, Vol. 1, No. 2, Oct, 2015.1-9.

Executive functions in students with high functioning autism and educable Down syndrome

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Received: 05 April 2015 Accepted: 20 May 2015

Abstract

Background and Objective: The present study investigated executive functions in students with high functioning autism (HFA) and students with educable Down syndrome (DS) with normal healthy students.

Methods: Fifteen boy students with HFA, 15 boy students with educable intellectual disability and 15 normal healthy boy students (aged between¬ 7-15 years) were recruited from educational services. The study samples were controlled and matched based on their demographic criteria. The utilized research instruments were the 2nd version of Gilliam Autism Rating Scale (GARS2), Wechsler Intelligence Scale for Children (WISC) and its Digit Span subscale (direct and reverse) memory test, Color-Word Stroop test, Wisconsin Card Sorting Test (WCST) and Continuous Performance Test (CPT). To analyze the data, one-way ANOVA, multivariate analysis of variances, univariate covariate, multivariate covariate and Bonferroni and Tukey post-hoc tests were used.

Results: Analysis of covariance showed that there was significant difference only between students with HFA and control groups in the response inhibition, mental flexibility index and continuous attention. Moreover, there was significant difference between students with Down syndrome and control group in short- term memory, while comparisons between other variables revealed no significant difference between groups.

Conclusion: The results indicated that students with HFA considering their close IQ to normal students showed impairment in the executive functioning. This finding implicates the minor role of intelligence in the executive function level in these children.

Keywords: Executive functions, High functioning Autism, Educable Down syndrome

Introduction

There is growing evidence that individuals with high functioning autism (HFA) are weak in some cognitive processes, although the cognitive component is not the main factor of diagnosing autism (1). Many autism diagnostic symptoms do not appear until a period of growth and otherwise not unique to autism, which may lead to incorrect diagnosis. One of the underlying factors for delay in diagnosis of autism is the common diagnostic criteria that tend to identify autism based on the patients' behaviors rather than presence of a special index (2). Rapid advances toward understanding cognitive ability of autistic people are due to study of executive functions like inability to control some activities, behavioral problems and deviations from normal growth and unsocial behavior of children with autism (3). The most common situations in need with executive functions include: paying attention in the classroom even in the case of hearing the play of children in the yard, first studying and then playing, having a good role play in a sport team, waiting for the turn, putting the toys in their own place after the end of the game (4), going to the store and prepare a report for school and using notepad, and do the work in absence of a supervisor. Executive functions are essential to the growth of children and adolescents, and problems related to executive functioning probably impairs functional abil-

ities and growth disorders may occur because of deficit in the various categories of executive function (5).

Autism comorbidity with the low mental retardation is a complicated mystery for researchers and specialists, and the association between low mental retardation and impaired psycho is discussed widely in the literature (6). Children with low mental disability such as Down syndrome (DS) may also show symptoms similar to that of autism's disorders (7), making it difficult to diagnose these disorders in early childhood (8). Executive functioning and adaptive behavior are mainly impaired in people with autism and DS, however limited research are done regarding these dimensions (9). Current study tries to provide a better understanding of the issue and help in developing a more effective differential diagnosis in these children.

In various studies, deficits in executive function has been proposed as a lifelong deficit in autism, though a specific sign for autism has not been mapped in this area. Therefore, we can say that as the deficiencies in executive functions exist during the life of autistic people but there is no evidence for normal and abnormal growth of some executive functions in these people (10). Despite of our poor knowledge about various dimensions of executive functions in autism spectrum disorders (ASD), the potential impact of IQ on executive function in this group, the possibility of overlapping functions in tests may confirm the complexity of executive functions. Therefore, it is not clear whether the executive function deficits in autism are associated with autism features or IQ (11). Due to extensive overlap in terms of behavior and symptoms of autism disorder and DS, diagnosis of pervasive developmental disorders in individuals with a low mental power is difficult (12). Also, there is little information about the executive function of individuals with DS who has low mental power. One study showed that people with DS have general or special weaknesses (13) compared with normal people in tasks associated with executive functions (14).

Therefore, according to the comorbidity between ASD and DS, and the possibility of differential diagnosis, this study sought for the differences in the performance of students HFA and children with DS and normal learners in executive functions tests? Also, whether impairment in executive function abilities is associated with IQ or symptoms of DS?

The study attempts to show the relation between executive functions of inhibition to achieve success. Other studies have examined the relationship between the function of working memory, inhibition and displacement, and have shown that the inhibition is the underlying factor of executive functions, particularly working memory; though the amount of this relation fluctuates in various studies (15).

Despite the lack of a general consensus about the components of executive functions, the inhibition and working memory have been considered as the major elements of executive functions (16). According to the theory of executive function impairment, the main feature of autism disorder is the inability to control executive function and changing the way of attention (17). In a prospective study which conducted by Corbett and colleagues (3) executive functions in children with autism and normal children aged 7 to 12 years were compared. The results revealed no significant differences in cognitive flexibility, change and working memory compared with the normal group. They suggested that children with autism suffer from the executive functions. To this regard, Robinson et al (11) showed that difficulty in response inhibition and self-directing is the properties of ASD that is independent from intelligence and is constant throughout childhood. Also, some studies showed that all executive functions are not related to the intelligence (18-19, 13).

The results of some studies indicated the extensive damage because of executive functions in persons with DS (20,14), which are not consistent with those of Pennington, Moon, Edgin, Stedron and Nadel (21), Lee et al (19), and Costanzo et al (13). Pennington et al found that people with DS undergo no damage in inhibition duties and working memory at the age of 11 to 19 compared to normal children. Some researchers believe that some cognitive abilities such as intelligence play an important role in the performance of executive duties while these abilities are not directly associated with specified executive functions. Also when a relationship between executive function and cognitive tasks was achieved, it is not clear that this relationship is the result of executive processing, or non-executive duties. Thus, Pennington et al. emphasized on the need of controlling the non-executive functions.

In a study by Lanfranchy et al (20) executive functions such as changing attention and working memory in individuals with DS were studied and the results showed that executive functioning of individuals with DS significantly was weaker

than normal group.

Current study attempts to compare the performance of children with autism and DS with a healthy control group regarding executive function.

Methods

Samples

The study population consisted of all individuals with DS and autism, who were studying in two special schools for children and adolescents with autism and DS, and one ordinary state school (controls) in Karaj, from September 2013 to May 2014. Due to the limited available samples, a convenient sampling was used; thus, at the final stage 15 students with high autism, 15 students with educable DS, and 15 normal healthy students (as control group) participated in this study.

The inclusion criteria for diseased samples included: diagnosis of autism or DS based on the opinion of the schools' attending psychologists; diagnosis of high autism by psychiatrists confirmed by Gilliam Autism Rating Scale (GARS) and Wechsler tests (IQ>70), diagnosis of DS based on fourth version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), DS children with IQ 50 to 70 as educable subjects (according to Wechsler test), age 7 to 15 years, having the ability of reading and writing, and having no other disorders except for autism/DS based on their medical records and statements of their parents.

In this study, control group were normal healthy children with IQ between 90 and 110, confirmed by Wechsler scale for children.

All the samples were matched regarding their age, sex, and their family socioeconomic status. The data were analyzed using descriptive statistics, the mean and standard deviation, analysis of variance, multivariate analysis of variance, multi factor analysis of covariance, analysis of covariance, and multiple post-hoc Bonforroni and Tukey tests through SPSS v. 17.

The subjects' proxies signed the consent form of participating in the study. The study design was confirmed in the Ethics Committee of Kharazmi University.

Tools

In the present study we used Color-Word Stroop test to measure response inhibition, and selective attention. Color-Word Stroop is the most common way to assess response inhibition, administrative abilities, cognitive set and also the processing speed. Stroop test is also considered as a classic tool to measure selective attention.

Wisconsin Card Sorting Test (WCST), as one of the main and most widely used neuropsychological instruments to assess forming concepts, abstract thinking, cognitive flexibility, and the ability to shift cognitive sets. This test includes four subscales, including categories achieved, staying errors, other errors, and the total error.

Continuous Performance Test (CPT) paper version (AA - paper) was used to measure sustained attention. Test stimuli include numbers 0 to 9. The determined stimulus was the number 6 which the participants should mark in 20 rows of 38 numbers that were randomly assigned. The response time was 120 seconds. Researchers believe that the response to the target stimulus is the sign of consciousness, response to stimuli other than the target stimulus is the sign of irritation, and inattention to the main stimuli is the symptoms of eliminated error. This test is obviously required selective attention.

Wechsler Intelligence Scale for Children (WISC) was used to measure short-term memory and working memory. We used WISC for estimating IQ of participants. In this research, IQ of students with autism was ≥70 and students with DS 50 to 70. Because of verbal limitation, only nonverbal section of WISC was administered to diseased students, but for normal students (IQ=90-110) both nonverbal and verbal tests were administered, although nonverbal IQ was used for comparison among all of the groups. The Digit Span subscale (direct and reverse) was used in all three groups to compare and assess short-term and working memories.

In autism group, we used second edition of Gilliam Autism Rating Scale (GARS 2). GARS test is suitable for 3 to 22 year individuals, and can be completed by parents and professionals of school or home.

Procedure

Autistic students

At the first stage, diagnosis of autism was confirmed based on interviews with teachers of autistic students and assessing these people using the nonverbal section of WISC. At the second stage, subjects who received lower than 70 in WISC excluded from the study (totally 16 autism students) and the top students were selected as high autistic subjects. In the third stage, the teacher and mother of autistic students were asked to complete the GARS criteria at the presence of the researcher. At the fourth stage, executive func-

tion test was performed on high autistic students individually.

Down syndrome students

Diagnosis of DS was confirmed on the basis of their appearance, interviews with their parents and teachers, and also their medical records; their age, and ability to read and write was also checked. In the second stage, nonverbal WISC was implemented and subjects with IQ in the range of 50 to 70 were selected as educable DS subjects; others were excluded (totally 6 persons). In the third stage, executive function test was implemented in two stages on educable DS subjects individually.

Normal healthy students

Normal controls participated in the study recruited from an ordinary state school. Their IQs were between 90 and 110 based on WISC. Totally 11 volunteers were excluded.

Results

In the present study, executive functions including inhibition response (selective attention), cognitive flexibility, sustained attention and memory (short-term and working) were evaluated. Tests were conducted in a quiet room in one special school for autistic and DS subjects and in one ordinary state school for healthy students from morning until noon. Wechsler Scale for Children (about 45 minutes to 1:30 hour) was performed for each person. GARS test for autism group lasted about 20 minutes. Stroop test took about 10 minutes, WCST (about half an hour), continuous performance test about 5 minutes and direct and reverse Digit Span Wechsler test took about 5 minutes for each person (to avoid interference effects of sequence, the turn was randomly changed for each participant). At the beginning of each test a chocolate was given to each subject and in the end, a gift was given to the participants. Table 1 represents the demographics of the participants.

The Table 2 shows the mean and standard deviation of the studied groups in the subscales of the WISC. This was performed because of possible overlap of nonverbal intelligence and executive functions in performance of studied groups.

According to Table 2, there are significant differences between the three groups in terms of total achieved scores on the test of WISC ($F_{(2,42)}$= 136.06 P>0.0001), and nonverbal intelligence ($F_{(2,42)}$=119.24, P>0.0001). The Bonferroni post hoc test showed there were significant difference between the performance of autism group compared with DS in total scores and nonverbal intelligence (P=0.001), and between the control group and the DS group in the same scale (P=0.001). There were no significant differences between controls and autism group. Based on the significance of overall difference between the groups, nonverbal intelligence was considered as a covariate. Based on the GARS 2 test, diagnosis of autism was confirmed in autistic children (Table 3).

Table 4 shows the mean, standard deviation and results of single-factor analysis of covariance (ANCOVA) of study variables. Considering the nonverbal intelligence as an auxiliary variable (non-significant) on selective attention and response inhibition, the effect of group on selective attention and inhibition responses was significant (number of correct responses and reaction time) ($F_{(4,80)}$=2.64; P<0.040;Wilks's lambda=0.94; η^2=0.11). The effect of group for mental flexibility and perseveration (number of categories completed, and incorrect responses and perseveration) ($F_{(6,78)}$=8.80; P<0.001;Wilks's lambda=0.35; η^2=0.40) was significant with great effect size.

Table 1. Age and educational distribution of the studied groups

Variable	Age	Mean age	Education					
			First grade	Second grade	Third grade	Fourth grade	Fifth grade	Sixth grade
Autism group	7-14	11.45	1	1	4	4	3	2
Down syndrome group	9-15	12.64	4	4	3	3	1	0
Control group	8-12	10.64	0	0	1	6	0	8

Table 2. The mean and standard deviation of the studied groups in the subscales of the Wechsler nonverbal intelligence

Variables	The studied groups	Mean	Standard deviation
The total score of Wechsler nonverbal intelligence	Autism group	49.26	9.70
	Down syndrome group	16.66	3.86
	Control group	52.06	4.35
Wechsler nonverbal intelligence	Autism group	98.53	13.42
	Down syndrome group	56.13	5.54
	Control group	100.02	6.04

Table 3. Raw scores, standard scores, percentages, and rates of autism in GARS-2 scale.

			Standard scores			Raw scores		
Autism amount	The total of standard scores	Percentile rank	Social interaction	communication	Stereotyped behaviors	Social interaction	Communication	Stereotyped behaviors
52-63	9	3 >3.5	1	1	7	7	6	12
83	23	10.5	11	1	11	33	11	23
52-63	10	3 >3.5	4	1	5	20	14	6
52-63	8	3 >3.5	3	1	4	17	14	4
79	21	8.5	10	3	8	31	25	15
52-63	8	3 >3.5	1	1	6	10	12	9
52-63	11	3 >3.5	4	1	6	19	11	10
74	18	7.5	4	6	8	20	30	15
52-63	11	3 >3.5	3	3	5	17	21	6
70	16	6	5	1	10	23	4	21
52-63	9	3 >3.5	1	1	7	10	8	11
52-63	8	3 >3.5	3	1	4	17	9	5
63-70	13	3.5>6	3	1	9	18	13	18
52-63	8	3 >3.5	1	1	6	12	6	9
52-63	8	3 >3.5	1	1	6	12	5	10

Table 4. The mean, standard deviation and one factor covariance analysis of Stroop test subscale, Wisconsin, consistent performance and memory span in three groups

Variables	Control group (n=15)		High action autism group(n=15)		Educable Down syndrome group (n=15)		One variable test		
	mean	Standard deviation	mean	Standard deviation	mean	Standard deviation	sizes	F	P
The number of correct response (Stroop)	23.33	0.72	23.26	0.59	20.60	3.01	controlled	2.47	0.124
							uncontrolled	0.107	0.000
Reaction time (Stroop)	33.46	4.62	48.13	14.42	55.93	13.76	controlled	2.096	0.155
							uncontrolled	4.95	0.000
The number of errors (Wisconsin)	37.73	16.22	77.13	13.30	77.40	5.12	controlled	2.98	0.091
							uncontrolled	33.116	0.000
Perseveration response (Wisconsin)	32.26	25.34	87.73	30.10	94.80	14.43	controlled	1.58	0.215
							uncontrolled	28.519	0.000
Categories completed	4.86	1.64	1.86	2.61	1.06	0.25	Controlled	2.09	0.155
							Uncontrolled	18.812	0.000
Intelligence (continuous performance)	46.60	12.08	29.60	10.55	19.66	6.72	Controlled	1.78	0.189
							Uncontrolled	27.574	0.000
Excitation (continuous performance)	0.00	0.00	0.66	0.25	0.53	2.06	Controlled	0.183	0.671
							uncontrolled	0.877	0.424
Remove (continuous performance)	38.40	12.08	55.40	10.55	65.33	6.72	controlled	1.78	0.95
							uncontrolled	27.574	0.000
Direct span (short term memory)	6.93	2.31	6.26	2.01	2.00	0.92	controlled	0.25	0.61
							uncontrolled	31.373	0.000
Reverse span (working memory)	4.66	0.89	3.13	2.87	0.80	0.86	controlled	0.80	0.37
							uncontrolled	17.374	0.000

The effect of group for constant attention, attention deficit and inhibition (intelligence, excitation and remove) ($F_{(4,80)}$=4.30; P<0.003;Wilks's lambda=0.67; η^2=0.17) was significant. Also, the effect of group for short-term and working memories (digits span forward and backward) ($F_{(4,80)}$=2.57; P<0.044;Wilks's lambda=0.78; η^2=0.11), was significant. According to multifactor analysis of covariance for significance of function difference in measurement criteria of executive functions between groups, the analysis of one factor covariance (Table 3) based on intelligence control showed no significant difference among three groups in the number of correct response in Stroop test; but according to Tukey's and Bonferroni post hoc tests, significant difference was revealed between HFA and control groups. In perseveration response and completed categories and wrong answers of Wisconsin test, the performance of HFA group had significant difference with control group. There is significant difference between the control and HFA groups in intelligence and remove variables in CPT; but there was no difference among three groups in excitation variable, and in direct memory test, there was a significant difference between DS and control group. In reverse memory test, there was no difference between three groups.

Discussion

The results of this study showed that there is no significant difference between HFA and educable DS students in selective attention and response inhibition in factor of number correct response in Stroop test with control group. Despite the short distance between HFA and normal students' IQs, there was significant difference in selective attention and response inhibition in the components of reaction time in Stroop test for these two groups. Overall, these findings were in line with findings of a number of previous studies such as Chan et al (22) and Robinson et al (11) and inconsistent with the study of Happe, Boos, Charlton and Hughes (23).

Harlow and Miller showed that executive function can be severely impaired despite of normal intellectual ability (24). Therefore, this finding depicts that all autism people even HFA with normal IQ have problem in changing from one stimuli to other one, though the ability of preserving attention (in the number of correct answer) will drop comparatively less in autistic patients. Thus, slower reaction time in selective attention and inhibitory response of HFA can be attributed to the pathological level and type. Studies results have shown that functional disorder in setting excitation system can lead to high or low expected excitation and adaptation and distributing of new stimuli will reduce in autism. Therefore attention in people with autism is selective, they may hear environmental sounds and be attentive to them well, but do not pay attention to human voices. To this regard, usually parents complain that their autistic child can react excitingly to the sounds of inanimate objects (25), though passive to human voices. Therefore, people with autism compared with normal individuals have more problems in paying attention. Executive function deficits in autism are attributed to abnormalities in frontal lobe. This area is used for the representation and storage of information on a subject or situation. Thus, the role of growing neuron components is stronger in this disorder (26).

According to the results of this study, it seems that if the intelligence is controlled, there would be no significant difference between DS and the normal groups. In this regard, our research is consistent with Pennington et al (21) results. They showed that in the case of intelligence control, DS group do not show any difference in executive functioning compared with the normal group. The problem in response inhibition reflects a characteristic feature of autism which is independent of intelligence and verbal ability and is relatively stable in childhood (11).

The findings of current research based on intelligence control in evaluating mind flexibility and perseveration which is done by WCST, showed that HFA students have significant difference with control group. This finding was consistent with previous studies that found ASD students incur damage in terms of flexibility. To this regard, the significant difference between the normal group and HFA students in this study is consistent with Endedijk and colleagues (27). But inconsistent with Maes and colleagues (28) findings who found no significant difference between autism characteristics and executive functions. According to the executive functions theory, the main issue of autistic people is their inability in controlling executive controls and directing attention (mental inflexibility) (17). According to this theory, repetitive behavior can be explained in autism disorders. Thus, the significant difference between HFA and the control groups explains the defect in flexibility as the property of autism with its core in disordered neurodevelopmental processes, especially executive functions (29). Thus, executive functions can be severely impaired despite normal intellectual ability and this matter reduces the role of intelligence in executive functions.

The insignificant difference in educable DS with the control group depicts that based on intelligence control, the DS group has no weakness in intellectual flexibility and perseveration of executive function. For example, HFA children interest to special things (piece of lint, yarn, turning the wheels of the car) and strange behaviors (excessively to turn around themselves) is more than normal and DS children.

The results from comparing continuous functional test in three studied groups showed that based on intelligence control between control and autistic group, there was difference between intelligence and removing variables, and other dual comparisons in every three variables were not significant. Also, in terms of excitation parameter between three groups, there was no significant difference. We can infer that choosing incorrect answers was not the distinguishing characteristic in these three groups but intelligence and removing error is an important factor. The result of this study revealed deficits in executive function of continuous attention (intelligence and removal) in individuals with autism compared to control group. This finding, in the case of comparing control group with HFA, is consistent with find-

ings of Chan et al (22), and Robinson et al (11). Klein et al (30) provided evidence that autistic people do not pay attention to important nonverbal tasks or do not stare for watching others, thus they fail in understanding nonverbal communications. In contrast, in this regard children with low IQ act like normal children and pay attention to others and face to others when they are called by them (31). Continuous attention has an important role in children learning, and its deficiencies affect the HFA people performance in daily works and education. Therefore, it seems that the role of intelligence component is low in this task.

Comparison of short-term and working memory of three groups showed there are no differences between HFA and control groups, but there was a significant difference between DS and control groups in direct digit span. Based on this and previous studies, one of the most important problems of people with DS is difficulty in recalling information. We can infer that in people with DS mental growth like memory and attention is lower than normal children. The results of neuroimaging studies of people with DS show that abnormal structure of the brain with the specified deficiencies in this people relates to abnormal growth of frontal lobe, low performance of hippocampus and reduction of brain capacity and gray matter (9).

The underlying factor that DS children are in trouble on memory skills is that they do not have effective learning strategies in learning such as organizing strategies. Also, they use mental strategies like rehearsal less frequently. In regard to no significant difference in working memory in DS and control group, we can say that all executive functions are not related to intelligence. The results of this study support the findings of Pennington et al (21). They found that people with DS have deficiencies in some executive functions like short term memory and lack in some other executive functions like working memory. Hence, the lack of differences in working memory of DS group and control group (despite severe weakness in working memory of DS group) can be attributed to intelligence control. However, weaknesses in working memory in DS may be due to the relationship of working memory with short-term memory in this group, and since the deficiencies of memory usually attributed to executive function disturbance and the incorrectness of frontal lobe, we can infer that bad performance relates indirectly to damages in verbal ability. According to findings of Landry et al (32), the verbal intelligence is a better predictor of working memory and independent from nonverbal intelligence in DS.

In case of performance of executive function memory (short-term and working) there was no significant difference between individuals with autism compared with control group. This result is consistent with the results of Cran et al (8) and inconsistent with the results of Williams et al (33) and Corbett et al (3). Some researchers stated the ability of recalling a long list of the subjects and also the tendency of vocal cords of autistic patients shows their auditory memory more than normal. According to some research, the short-term auditory memory of autistic children is as well as healthy individuals. Children with autism can learn vocabulary easily like healthy children and better than children with low mental retardation with a higher verbal ability (34).

Totally, the results of this research is inconsistent with Roelofs et al (24) who did not find any significant difference between executive functions of autistic people and other special group with low intelligence. Also the results of this study are inconsistent with the results of Borella et al (14) who revealed general deficiencies in DS in executive functions. Our study results are consistent with Costanzo et al (13) and Lee et al (19) that shows special deficiencies of DS people in executive functions.

Conclusion

According to close IQ level of HFA group with the control group, there revealed more deficiencies in executive functions. In DS group who had a low IQ, we encountered deficits in short-term memory. Thus, they may develop different developmental disability because of failure in various categories of executive functions.

Using a cross-sectional design and small number of participants are notable as limitations. Due to the limited sample, we used non-random sampling which limits generalizing the research results. Lack of control over the type and amount of used drugs by diseased samples is also another limitation.

Due to the nature of the relationship between executive functions and their significant role in real life and factors like social competence and academic achievement, further research is suggested to gain a holistic view of executive functions in this field.

Acknowledgements

The authors are grateful to all students, their parents and teachers who graciously devoted

their time and participated in this study.

Conflicts of interest

The authors declare no conflicts of interest.

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