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The Role of Anxiety in Executive Functions of Children with Attention Deficit Hyperactivity Disorder and Mathematical Learning Disability Comorbidity

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Abstract

Executive dysfunction is common symptom among patients with attention deficit hyperactivity disorder (ADHD) and/or Mathematical Learning disability (MLD). Current research evidences indicate that anxiety can lead to numerous cognitive deficits. Therefore, through comparing executive functioning in children with ADHD/MLD, who have high and low levels of anxiety, the present study examined the probable role of anxiety in intensifying their problems in executive functions, especially verbal and visuospatial working memory. In a retrospective quasi-experimental study, 8-12 years old children, who were diagnosed for ADHD and MLD comorbidity were selected using purposive convenience sampling (n=85). They completed the multidimensional anxiety scale for children. Then, due to their scores on this scale, 20 children with high anxiety (1.5 standard deviations and more above the mean) and 20 children with low anxiety (1.5 standard deviations and more below the mean) were selected and placed in two groups. Then, executive functions assessment tasks, including Tower of London test, Wechsler Memory Scale (WMS), and the Benton's Visual Retention Test, were carried out. Collected data were analyzed using independent t test. Findings showed that anxiety can be considered as an intensifying factor in executive functioning of children with ADHD and MLD. Therefore, executive functions can be improved by balancing the levels of anxiety and preventing further impairment of executive function in these children.

Keywords: Attention deficit hyperactivity disorder, Executive functions, Mathematical learning disability, Verbal working memory, Visuospatial working memory.

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1. Introduction

Attention deficit hyperactivity disorder (ADHD) is a complex neurodevelopmental condition characterized by symptoms of inattention and impulsivity or hyperactivity inconsistent with developmental level observed in counterpart children. It is identified with symptoms of difficulty in paying attention, excessive activity or difficulty in

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controlling the behavior, such that it is not proportionate to the age of the individual ([4]). This disorder is one of the most prevalent chronic developmental disabilities, which includes about 7% of school age children and 5% of adolescents and adults ([68]). In Iran, the general prevalence of this disorder has been reported in 8.62 percent among boys and girls ([74]). ADHD may have comorbidity with other developmental disorders such as learning disabilities ([12]; [60]; [30]), the most of which is mathematical learning disability (MLD) and consists of about 10 to 30 percent of children with ADHD ([25]); this disorder consists of difficulties in perceiving mathematical concepts and turning written questions into mathematical notations; identifying and understanding symbols and sorting numeral series, ability to perform the four fundamental operations of mathematics, and deficiency in correctly copying figures and correctly observing operating symbols ([56]). These children suffer mental turmoil in daily situations such as processing new information or a reading comprehension; thus, the field of "cognitive dysfunction" accounts for a significant part of these destructions in children ([35]). Executive functions as an important part of cognitive functions, are reported to be among the major difficulties for children with MLD ([54]; [16]). Executive functions are referred to an aggregate of cognitive and metacognitive processes that are employed in goal-oriented behavior management, and its components consist of autonomy, self-initiation, planning, organization, time management, attention, working memory, metacognition, prediction of the future, and problem solving, which are the prerequisites of institutional education and learning for the children ([40]). Children with ADHD disorder also show insufficiencies in most components of executive functions such as organizational management, organization, problem-solving, sustained attention and working memory, and power of inhibition ([49]; [65]; [21]; [29]; [39]; [46]; [43]; [73]). However, the available evidence from cognitive problems in children with ADHD or learning disability occasionally give incoherent results; while some studies indicate the presence of fundamental problems in these children in the areas of verbal problem solving, recognition of obvious information in problems, the use of self-regulation and self-regulatory strategies in the procedure of task and maintaining attention toward the end of it ([50], [37], [26]), other findings claim that children with learning disorder perform poorly in working memory tasks that include counting data; and have no difficulties in tasks involving verbal information ([5]). According to Baddeley's theory ([8]; [7]), among executive functions, working memory is a system consisting of related memory components which are used for short-term storage and manipulation of information necessary for various cognitive tasks. This memory includes a "Central Executive" and other subsystems called "phonological loop", "visuospatial sketchpad", and "episodic buffer". Investigating the role of Baddeley's working memory components has led to incoherent and inconsistent results, both for normal children ([33]), and for children with MLD ([5],[67]). For instance, Keeler and Swanson found no difference in the performance of working memory between children with MLD and normal children ([5]). Therefore, in this study, the performance of the components of working memory has been separately investigated. In addition to cognitive and behavioral problems, some studies indicate the presence of emotional difficulties in children with learning disabilities: For example, children with learning disabilities are found to be anxious, distressed, unreliable, and rebellious (Vales and Macloflin, 2004). However, in this case also, the researchers have led to incoherent results; while in their findings Fisher and Allen (2003), Steve, Avital, Falk and Vincent (2012), reported that anxiety causes further impairment in executive functioning components in children with ADHD disorder, Vloet et al. (2010) and Rodríguez et al. (2014), did not identify anxiety as a malicious factor in the destruction of the executive functions in children with ADHD. Therefore, the contradictory and opposing results with regard to the role of anxiety prompted researchers to investigate the role of anxiety in the performance of the executive functions of children with ADHD disorder and MLD. Researchers have shown that children with mathematics learning disabilities suffer various problems in executive functions such as inhibitory response and retain of information in working memory ([15]; Quoted from Ghamari Givi, Narimani, Rabiee, 2009). Moreover, researchers have demonstrated a strong relationship between mathematical functions and working memory ([13]; [15]; [3]; swoansoon, 2006).

Children with general learning disabilities or those with disabilities in a particular area such as math show poor performance in all aspects of working memory ([20]; [51]). Learning disability is the most important cause of poor educational performance. Studies have suggested that children with attention deficit hyperactivity disorder (ADHD) and learning disability are more vulnerable than normal children in all areas of executive and non-executive functions. Particularly, the disability in numerical operations in a group with mathematical learning disabilities has been attributed to a high degree of impairment in their executive function ([59]); Therefore, processing speed, control, planning, execution, and retrospective memory have a significant difference between normal children and children with ADHD

and learning disability in the same age ([16]).
Metacognitive activity lines in these children and adolescents who have mathematics learning disabilities are also different from the peers with the same age group ([19]). These children show disabilities in their daily activities ([16]). In addition to cognitive and behavioral impairments, some studies have reported emotional problems in children with learning disorder. Therefore, many children with learning disabilities are anxious, distracted, hesitant, and rebellious. There is evidence based on the relationship between anxiety and degradation of cognitive functions in children with learning disabilities; these children have higher attribute anxiety and severe situational anxiety compared to normal children ([24]). Fischer and Allen (2003) showed that although these children demonstrated an effective start in the problem-solving process comparable with normal children, they achieved lower scores in this skill than the normal children due to severe stress and anxiety experience. There is also some evidence that anxiety in children with ADHD induces problems in their social function.
A study on anxiety and selective attention in the subtypes of ADHD have shown that individuals with combined subtype and type III experience high level of attribute anxiety, while the inattentive subtype experiences situational anxiety ([18]).
Desoete and Royers (2002) evaluated the impacts of specific range of metacognitive active lines on adolescents with learning disabilities where these adolescents showed significant differences with normal peers.
In the light of the relationship found between the severity of anxiety and cognitive problems experienced by such children, there is hope to reduce or control the symptoms of this disorder. Therefore, if we can prove the role of severity of anxiety in increasing the symptoms of the disorder, it is possible to provide health and education centers with health plans to reduce or control anxiety in these children, in order to be able to better and more effectively control the symptoms of ADHD disorder and its associated cognitive problems in these children, and provide a better and brighter future for them. Therefore, the main goal of the present research was to compare executive functions and working memory in children with concurrent ADHD and MLD with high and low anxiety. With regard to theoretical considerations and research findings on the studied subject, the following hypotheses were tested.

1. In children with concurrent ADHD/MLD, higher anxiety is associated with deficits in executive functions.
2. In children with concurrent ADHD/MLD, higher anxiety is associated with deficiency of the performance of verbal working memory.
3. In children with concurrent ADHD/MLD, higher anxiety is associated with deficiency of the performance of visuospatial working memory.

2. Methods

The statistical population of this ex-post facto study was included all children 8-12 years of age with comorbidity of ADHD and MLD, who were referred child psychiatric medical centers in the city of Tehran. Using convenience purposive sampling, the children who had been diagnosed with comorbidity of ADHD and MLD, were selected and enrolled in the research with regard to enrolment criteria. The criteria were as follows: getting diagnosed with comorbidity of ADHD and MLD (according to DSM-5 criteria diagnosed by child psychiatrist); being in the range of normal intelligence that was obtained from the psychiatric records of the children; not taking psychiatric medications (except for drugs associated with the treatment of ADHD with short-term effects, which had not to be used during past 24-48 hours); and not to have any other psychiatric disorders and physical diseases (according to psychiatric records and parents statements). All subjectives filled Multidimensional Anxiety Scale for Children, then those with anxiety score of 1.5 standard deviation higher than the mean, were involved the high anxiety group (n=10),(girl=3, boy=7) and those anxiety score of 1.5 standard deviation lower than the mean, were assigned as low anxiety group (n=12),(girl=5,boy=7).

3. Tools

(A) The Multidimensional Anxiety Scale for Children: To measure the subjectives' levels of anxiety, the Multidimensional Anxiety Scale for Children of March, Parker, Sullivan, Stalling, and Conners (1997) was used. This scale has acceptable psychometric characteristics for Iranian society, and is proved to be a proper screening tool to identify children with anxiety disorders ([42]). The total test-retest reliability and internal consistency of multidimensional anxiety scale for children are 0.48 and 0.79, respectively. Also, the correlation between this scale and Manifest Anxiety Scale and Children Depression Scale were 0.38 and 0.02, respectively, which indicated the convergent and divergent validity of the abovementioned scale. The results of the confirmatory factor analysis (CFA) showed that the four-factor model of the Multidimensional Anxiety Scale for children is a good fit in Iranian society ([42]).

(B) Tower of London Task: This task was first designed by Shallice (1982) and measures some aspects of executive functioning such as planning, ability to predict future events, goal-directing behavior, working memory, inhibition (consciously disposal of desires and unacceptable thoughts), attention (cognitive process of the selective attention on one aspect of the environment and ignoring the other aspects), and problem solving (reaching from the beginning stage to the target stage) ([34]). Present study utilized the computerized version of this task made by Sina Psychometric Institute in 2014.

(C) Wechsler Working Memory Scale (WMS): consists of 20 descriptions of behaviors that are characteristic of children with working memory deficits ([3]). The digit span (forward and backward) and letter–number sequencing tests from the WISC-IV ([72]) were administered to the low and average WM groups. The raw scores were converted into scaled scores (M=10; SD=3). These were summed and converted into a standard score to represent the Working Memory Index (WMI). It is worth noting that the digit span score in the WISC-IV is a composite of forward and backward digit span. However, traditionally, forward digit recall is considered as a measure of verbal short-term memory as the processing load is minimal. In contrast, in backward digit recall the added requirement to recall the digits in reverse sequence imposes a substantial processing load (see Alloway, Gathercole, & Pickering, 2006).

(D) Benton Visual Retention Test (BVRT): This test is a clinical research tool that was invented by Benton (1967). This task is used to evaluate visuospatial perception in both children and adults and is among the ten most commonly used neuropsychological sensitive tasks in identifying cognitive damages ([38]). Scoring this test is objective and based on sound principles and the "inter-rater agreement" with regard to the total score is very high (0.95). The validity of this test is reported in the range of 0.85 to 0.97 ([11]). Its correlational coefficient with other visual memory measurement tests is also high ([38]). In Iran, this test was normalized by Hosseini-Nasab, Fathi-Azar and Hassanpour (2001).

4. Results

In order to examine the first hypothesis t-test for independent groups was used. Descriptive Statistics of Tower of London and Benton Tasks are shown in Table 1. According to the results, the high anxiety group had significantly more errors in task performance in Tower of London Task, while low anxiety group obtained better scores in other subscales, none of their differences were statistically significant (Table 2).

To measure the participants' verbal working memory, Wechsler's Working Memory test was used (Table3). Using t-test for independent samples the results revealed that the value of t for backward auditory, total auditory, forward visual and visual span subscales is significant (Table 4), implying that high anxiety participants performed weaker than low anxiety group in these subscales.

To compare functioning of visuospatial working memory in high and low anxiety subjects, t test for independent groups was used (Table 5). Results revealed that there is a significant difference between two groups of high and low anxiety via their errors; high anxiety participants significantly committed more errors than the group with low anxiety.

5. Discussion

This study showed that ADHD/MLD children with high levels of anxiety, comparing to those with low anxiety level, performed weaker in Tower of London Task regarding their amounts of errors; while there were no significant differences between performance of two groups regarding other components of the task including: “duration of each test”, “delay time”, and “total time of the test”, ADHD/MLD children with high and low anxiety levels did not differ significantly.

Attentional control theory is an approach to anxiety and cognition representing a major development of Eysenck and Calvo’s (1992) processing efficiency theory. It assumes that anxiety impairs efficient functioning of the goal-directed attentional system and increases the extent to which processing is influenced by the stimulus-driven attentional system. However, anxiety may not impair performance effectiveness (quality of performance) when it leads to the use of compensatory strategies (e.g., enhanced effort; increased use of processing resources)([23]).

According to the “attentional control theory” of Eysenck et al. (2007), anxiety impairs the efficiency of two types of attentional control: (1) negative attentional control (involved in inhibiting attention to task-irrelevant stimuli); and (2) positive attentional control (involved in flexibly switching attention between and within tasks to maximize performance). Attentional control theory also assumes that in addition to decreasing attentional control, anxiety increases attention to threat-related stimuli. Adverse effects of anxiety on processing efficiency depend on two central executive functions involving attentional control: inhibition and shifting. So, anxiety makes people to pay more attention to a threatening stimulus and their response becomes relatively autonomous ([22]; [47]).Although in present study no threatening stimuli was presented to the subjects, according to the researchers’ observations, the Tower of London task could be considered as a difficult task for children with ADHD/MLD, and therefore act as a threatening matter which has increased their level of anxiety that caused high anxiety children to have more errors in performing the task comparing to children with low anxiety.

Concerning the other components of Tower of London test including “time of each testing”, “delay time”, and “total testing time”, two groups of high and low anxiety children with ADHD/MLD, revealed no significant differences. Children with MLD grapple with anxiety and mental stress, and their interaction with learning that is referred to as mathematical anxiety ([10]; [2]). “The Low Arousal Approach” has evolved from an original definition ([44]) to a cognitive reconceptualization ([45]). It refers to the fact that the biological arousal in people with learning disabilities, especially in those who have attention deficit, does not function properly. Therefore, it is assumed that people who have ADHD, due to attention deficit, lose their ability to maintain the optimum level of arousal ([64]). With an increase in the level of mathematical anxiety, the ability to dedicate sufficient attention to maintain the optimum level of arousal, even becomes less than before ([37]). Therefore, it is likely that in case of MLD children, mathematical anxiety functioned independently in all subjectives, disregarding their levels of anxiety. Therefor it may have the same effect on both groups regarding the components of “time of each test”, “delay time”, and “total time of the tests”. Unfortunately, the possibility of measuring and controlling mathematical anxiety of the subjectives was not provided in this research.

According to the results, children with high anxiety had poorer verbal working memory. Obtained scores of high anxiety group in subscales “backward auditory”, “total auditory”, “forward visual”, and “visual span” of Wechsler’s working memory, were lower than the group with low anxiety. Whereas, in the case of other components of Wechsler’s working memory, including “forward auditory”, “backward visual”, “auditory span”, and “total visual”, ADHD/MLD children with low and high levels of anxiety reflected no differences.

According to some researchers (e.g. [17], [22]; [48]), anxiety causes interference in the function of verbal working memory. Since concerns and intrusive thoughts have a verbal nature, they are considered to be processed mostly by the central executive and phonological loop components of working memory ([52]). It may be better explained regarding ”processing efficiency theory” developed by Eysenck and Calvo, (1992). This theory assumes that there is a fundamental distinction between performance effectiveness (quality of performance) and processing efficiency (the relationship between performance effectiveness and use of processing resources), and that anxiety impairs processing efficiency more than performance effectiveness. It also assumes that anxiety impairs the efficiency of the central executive component of the working memory system ([22]). Since working memory has a limited capacity, less parts of working memory capacity would be available to deal with effective cognitive functioning ([23]). One could say that ADHD should be considered as a cognitive deficit of working memory (Alderson, Kasper, Hudec & Patros, 2013 [58]). Evidence indicates that when the function of working memory is disrupted, learning, attention, concentration, decision-making, and planning would be impaired ([71]), These also will often in case of anxiety and depression ([71]).

But as mentioned before, regarding other components of Wechsler's working memory, including "forward auditory", "backward visual", "auditory span", and "total visual", performance of ADHD/MLD children did not differ regarding their levels of anxiety. Based on Humphreys, & Revelle (1984), anxiety has generally a facilitative effect on easy tasks; but there is another way of action in difficult tasks. Performance in difficult tasks suffers because anxious individuals focus their attention on their own, rather than on carrying out the task. It seems that as for "forward auditory" component, since it was presented as the first component of the task, both groups considered it as an easy task, and as a result, children with high anxiety were more motivated to carry it out. So this facilitatory role of anxiety may be modifying the negative effects of anxiety on task performance in high anxiety group, which resulted in relatively equal performance in both groups. However, regarding the researchers' observations, for the "backward visual" component, reversing the given numbers backwardly was creating anxiety in both groups, so it may had been the effect of mathematical anxiety, as an independent factor, to have affected the performance of both group in a fairly similar way.

The results showed that in the "visuospatial memory task", the amount of errors in high anxiety group were significantly more than the group with low anxiety. According to Eysenck and Calvo, (1992), in the occasions of encountering difficult and complex tasks, the visuospatial pad component of working memory deals with a shortage of capacity, and the presence of anxiety also causes it to become even more limited. This will be a good explanation for high anxiety children with ADHD/MLD do more errors in visuospatial sketchpad tasks comparing to low anxiety ones.

6. Conclusion

The results of this study showed that anxiety negatively affects the executive functioning in children with ADHD/MLD. According to the results, ADHD/MLD children who experience high levels of anxiety, made more errors in the executive function and had poorer verbal and visuospatial working memory performance, comparing with ADHD/ MLD children with low anxiety , due to the fact that goal-driven care system was replaced by stimulus-driven attention system in their attentional processing system; but no significantly difference was observed between two groups in some components of executive functions and verbal working memory. Perhaps the reason was related to another important issue called mathematical anxiety, which has acted as an independent factor, in both groups. Optimal arousal level was another issue that remained unclear; because due to low arousal level approaches, mathematical anxiety play as a decisive factor in cognitive tasks of the children in both groups. Also, no difference was observed in some components of verbal working memory. The facilitative role of anxiety in easy tasks (if this components of verbal working memory could be considered as easy tasks according to researchers' observations) might be an adequate justifier for the lack of difference between the two groups; as most concerns have verbal nature, it can be stated that anxiety has negative effect on verbal working memory aspect in children suffering ADHD/ MLD with high and low levels of anxiety. Also, it can be concluded that anxiety affects visuospatial working memory and all ADHD/MLD children with high anxiety, had much poorer performance in this part comparing to children without anxiety. There exist some evidences that MLD children are more likely to experience a specific type of anxiety called math anxiety ([14]), it is possible that the function of both high/low anxiety groups, had been influenced by this type of anxiety; but unfortunately, math anxiety was not controlled as a potential intervener variable. Also, factors such as the absence of a comparison group of normal children, or inaccessibility to severity of the symptoms in subjectives, methodologically limits the generalization of the obtained results. So, would be useful to regard such potential variables in upcoming studies.

Regarding cognitive abilities, ADHD/LD children with high levels of anxiety were not able to optimally utilize the cognitive functions and higher brain processes, and encountered difficulty in their performance. Therefore, we can identify the improper cognitive functions, by controlling and identifying different types of anxiety and also by measuring the levels of mathematical anxiety and the arousal level in children with ADHD/ MLD, and help them to utilize properly cognitive functions.

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Table 1: Descriptive Statistics of Tower of London and Benton Tasks

	Index	Tower of London Task				Benton test
		Time of each effort	Delay time	Mean time	Number of errors	
High anxiety	Mean	534	314	25.8	24.35	13.3
	Standard deviation	240	806	7.4	3.2	6.17
Low anxiety	Mean	651	189	30	21.3	9.5
	Standard deviation	353	129	10.5	4.3	4.3
Total	Mean	591	251	27.9	22.83	11.42
	Standard deviation	3.4	573	9.28	4	5.58

Table 2: Results of independent t-test for comparing executive function in high and low anxiety groups

Subscale	Levene's F-test		t-test		
	F score	Significancy	T score	Degree of freedom	Significancy
Time of each effort	1.7	0.2	1.25	38	0.22
Delay time	2.25	0.14	-0.6	38	0.5
Mean of time	0.86	0.36	1.48	38	0.14
Number of errors	1.15	0.29	-2.53	38	0.05

Table 3: Descriptive Statistics of Wechsler Working Memory Scale in tow groups

Group	Index	Forward auditory	Backward auditory	Total auditory	Forward visual	Backward visual	Total visual	Auditory span	Visual span
High anxiety	Mean	3.15	2.8	5.95	2.6	2.9	5.5	3.9	3.4
	Standard deviation	1.5	0.95	2	1.8	1.4	2.7	1.1	1.7
Low anxiety	Mean	3.75	3.6	7.35	3.6	3.1	6.7	4.3	4.3
	Standard deviation	0.91	1.35	1.1	1.2	0.93	1.8	0.5	0.8
Total anxiety	Mean	3.45	3.2	6.65	3.1	3	6.1	4.1	3.8
	Standard deviation	1.26	1.22	1.7	1.6	1.2	2.3	0.9	1.3

Table 4: Results of independent t-test comparing verbal working memory in two groups

Subscale	Levene's F-test		t-test		
	F score	Significancy level	T score	Degree of freedom	Significancy
Forward auditory	3.56	0.07	1.5	38	0.13
Backward auditory	1.3	0.26	2.1	38	0.05
Total auditory	4.8	0.05	2.68	29.77	0.01
Forward visual	4	0.05	2	33.73	0.05
Backward visual	2.8	0.1	0.51	38	0.61
Total visual	5.8	0.05	1.62	32.7	0.11
Auditory span	0.64	0.5	1.6	38	0.12
Visual span	6.4	0.05	2	27.04	0.05

Table 5: Results of independent t test comparing two groups in visuospatial memory

Subscale	Levene's F-test		t-test		
	Value of F	Significancy level	Value of t	Degree of freedom	Significancy level
Error in Benton's test	1.03	0.31	2.22	38	0.05