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Research Article

Auditory and Visual Attention in Normal and ADHD-Inattentive-subtype Children

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- Attention deficit disorder
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Abstract

Attention deficit hyperactivity disorder (ADHD) is one of the neurodevelopmental disorder that is common in children. Most of the studies showed the impairment of visual attention in ADHD children. Little investigations have also addressed the difference in auditory attention in children with and without ADHD.

In the current study, we investigated the difference between normal and ADHD children based on the performance in visual and auditory attention.

Twelve normal and eight ADHD-inattentive-subtype children participated in our study. They did an integrated visual and auditory attention test. Mean and variability of the correct reaction times and the accuracy of response were recorded during the test.

Results showed the performance decline (i.e., increasing mean and variability of reaction time and response error) of ADHD children with respect to the normal in auditory attention.

According to the results, more attention to the auditory stimuli in diagnosis tools is suggested.

ABBREVIATIONS

ADHD: Attention Deficit Hyperactivity Disorder; ADD: Attention Deficit Disorder; IVA: Integrated Visual and Auditory; CPT: Continuous Performance Test; RT: Reaction Time; V: Visual; A: Auditory

INTRODUCTION

Attention deficit hyperactivity disorder is one of the most common disorder among children that some of its symptoms usually last into adulthood. According to the symptoms, this disorder has been classified into inattentive, hyperactive, and combined subtypes. The inattentive subtype of the ADHD, which is the target group of the current study, suffers from sustained attention. That is, they cannot focus on a relatively long-term task. This sub-type is also called attention deficit disorder (ADD). To assess the sustained attention, continuous performance tests (CPT) have been used. There are several types of CPT. The most common types that are usually used in psychological or neurocognitive centers to diagnose ADHD and its subtypes are the test of variability of variance (TOVA) and integrated visual and auditory (IVA) test.

The first evaluates the visual and auditory attention in separate sessions. However, the latter tests the attention in both modalities in one session simultaneously. Differences between ADHD and normal groups have been investigated based on the visual attention in most of the studies. In comparison with the visual attention, fewer investigations have been done on the auditory attention. The fewer number of studies on auditory attention may be due to reasons such as the need for a quiet environment to prevent interference of distractions with the target auditory stimuli. Functional magnetic resonance imaging tools, which help the study of different brain regions operation, have also a considerable sound that may interfere with the auditory tasks. However, in some studies, the response of ADHD subjects to the auditory stimuli has been compared with the normal group. In various studies, different results have also been reported regarding the comparison of visual and auditory response time in normal subjects. In some studies, the visual reaction time is more than auditory, and in some cases vice versa [1,2]. The hardness of performing an auditory attention task with respect to a visual task has been shown in [3], just for normal subjects. It has been observed that the performance decline of ADHD subjects in visual attention task is more than the auditory [3]. However in [4], it has been shown that the pattern of response to the auditory stimuli with different intensity in ADHD children is different from normal the group. Scientists believe that factors such as age, gender, and stimulus intensity may lead to the observation of such differences in various studies [5].

In some studies, the correlation between ADHD symptoms and the central auditory processing disorder (CAPD) has been reported [6-12]. A difference between the activation of the event-

related component, P3b, has been observed in ADHD subjects in comparison with the normal ones[13].

In most of the studies, mentioned above, visual and auditory attention was investigated separately. That is, in one session, visual stimuli were presented for the subjects, and in another session, participants responded to the auditory stimuli. Then, the individuals' responses to the auditory and visual stimuli were compared. To investigate the response of individuals, specifically the ADHD ones, to pseudo-randomly presented auditory and visual stimuli in one task, some studies were done [14,15]. These investigations are more close to the real life where ones have to switch between different modalities in ordinary tasks. Such investigations also take shorter time (because both modalities are tested in one session), which is suitable for ADHD children. The results of these studies showed that the auditory sustained attention performance was better than the visual in the normal group. In contrast, ADHD subjects had better visual attention performance with respect to the auditory [15]. However, auditory speed was higher than the visual speed in both normal and ADHD group [15].

To find out more about the performance of ADHD subjects with respect to the normal group, in tasks with both auditory and visual stimuli, more investigations are required. In the current study, using a version of visual-auditory CPT, we have focused on the speed and accuracy of responses to the visual and auditory stimuli, which both have been presented pseudo-randomly in a task.

MATERIALS AND METHODS

Participants

Twelve normal children (9.2 ± 0.6 years old, 11 right-handed, 8 girls) and eight children with ADD (9.6 ± 0.8 years old, 6 right-handed, 3 girls) participated in the study. These children have not been treated with any medication or behavioral interventions. The diagnosis of ADD children was done by the experts in the Atieh comprehensive psychiatric center of Iran based on DSM-IV, IVA CPT, and QEEG indices. Mental health of normal group was evaluated using national institute for children's health quality (NICHQ) Vanderbilt assessment scales. Based on the Good enough (draw a person) test, all participants were almost in a same range of IQ. Participants had normal or corrected to normal vision, and there were no hearing problems.

Children and their parents were aware of the test procedures and the parents signed the informed consent forms before the test. To motivate children, the promise of receiving a gift was given to them if they perform the test correctly. However, to prevent children from getting upset, they were all given a prize after the test. The experiment was done under the approval of Iran University of Medical Sciences (# IR.IUMS.REC.1395 90133916).

Experiment

In this study, participants are requested to perform an integrated visual and auditory continuous performance test. This test evaluates auditory and visual sustained attention, simultaneously. The task of the subject is pressing a button as soon as seeing or hearing number "1" (target stimulus) and inhibits any motor responses in the presentence of number "2" (non-target stimulus). Numbers were presented in Persian. Therefore, subjects are expected to remember the following goals through the test, which lasts for about 20 minutes.

1. Press the button by seeing number "1"
2. Press the button by hearing number "1"
3. Do not press the button, if seeing number "2"
4. Do not press the button, if hearing number "2"

In this test, visual stimuli were presented for about 167 msec and auditory stimuli were played for about 500 msec.

Subjects sat on a comfortable chair at a distance of about 60 cm to a 14.6-inch LCD screen with a resolution of 1600 by 900 pixels and a refresh rate of 60 Hz while a headphone was on their ears. A button was also under the dominant hand of the participants to show the motor response to target stimuli. The interval between stimuli was about 1540 msec. The height of visual stimuli was 1.5 inch. The test had four stages:

1. Warm-up
2. Training
3. Main test
4. Cool-down

Warm-up had 64 trials. In the first 32 trials, the number "1" was presented visually and the subject was requested to press the button by seeing number "1." In the second 32 trials, the number "1" was presented auditory and the subject was requested to press the button by hearing number "1." The warm-up stage was about one minute. In the training stage, both numbers "1" and "2" were presented randomly visually or auditory. This stage was about 1.5 minutes. The main stage had four blocks. Each block contained 100 trials. In the first 50 trials, which were called frequent part, 84 percent of trials were target stimuli. In the second 50 trials, which were called rare part, 84 percent of trials were non-target stimuli. The numbers "1" and "2" were arranged pseudo-randomly in these trials and were presented randomly visually or auditory. However, numbers of auditory and visual targets and non-targets were equal in each block of the test. The main stage was about 13 minutes. The cool-down stage was the same as the warm-up stage. This test is somewhat boring and requires sustained attention to the visual and auditory stimuli.

Measurements and Statistical Test

Subjects' reaction times and accuracy of responses were recorded during the test. To evaluate the visual and auditory attention in normal and ADD groups, correct reaction times (i.e., Responses to target stimuli) and error of responses (i.e., Reponses to the non-targets or no response to the targets) were examined for visual and auditory stimuli, separately. Three features, 1) mean reaction time (correct responses), 2) reaction time variability, and 3) percentage error were extracted from the recorded responses for both visual and auditory trials. Considering each of these features, the significant differences between normal and ADD children have been examined by an unpaired-ttest with a significant level of 0.05.

Table 1: Results of statistical comparisons between normal and ADD children considering different features.

Feature	Normal children N=12 mean ± SEM	ADD children N=8 mean ± SEM	Stats p=0.05
mean RT V	887.6 ± 22.26	946.7 ± 45.76	t=1.3; p=0.2
mean RT A	1108 ± 15.88	1233 ± 45.44	t=3.1; p=0.006
Std. RT V	174.6 ± 11.32	206.3 ± 28.77	t=1.2; p=0.23
Std. RT A	177.8 ± 10.66	221.5 ± 20.26	t=2.1; p=0.049
Error V	29.50 ± 1.4	39.25 ± 3.2	t=3.1; p=0.006
Error A	14.75 ± 0.7	19.63 ± 1.6	t=3.1; p=0.006

Abbreviations: RT: Reaction Time; V: Visual; A: Auditory; Std.: Standard Deviation; SEM: Standard Error of Mean

RESULTS AND DISCUSSION

Figure 1 shows the difference of the mean correct reaction time between normal and ADD children in both visual and auditory stimuli. As shown in this figure and reported in Table 1, in both group, responses to visual stimuli were faster than the responses to auditory stimuli. As mentioned in the introduction, in some studies, the visual reaction time is more than the auditory and in some cases vice versa [1,2,15]. The results of our study are consistent with those that reported faster responses to the visual stimuli than the auditory. Different factors such as age, gender, and stimulus intensity can lead to the contradiction with studies that showed higher speed in response to the auditory stimuli [5].

It has also been shown that both auditory and visual responses are faster in normal children than ADD ones. This difference is just statistical significant for auditory stimuli ($p < 0.05$). That is, ADD and normal children are considerably different in response to auditory stimuli. This result is consistent with the outcomes of studies on the performance of ADHD and normal groups in the IVA test [15].

Figure 2 demonstrates the reaction time variability in both groups in response to visual and auditory stimuli. Consistent with previous studies, children with ADD have more variability than normal ones [16]. According to the Figure 2 and Table 1, this difference is just statistically significant in response to auditory stimuli.

Children with ADD showed more response error than normal groups in both auditory and visual trials. Previous studies also reported less accuracy of responses in ADHD subjects with respect to the normal ones, which is because of the attention and inhibitory control problems[17].

As shown in Figure 3 and Table 1, similar to the mean and variability of reaction time, auditory response error in ADD subject is statistically different from normal children. Therefore, results of the current study show that auditory stimuli cause more differentiation between ADD and normal children in comparison with the visual stimuli. In our previous study, we have shown a significant difference between ADD and normal children considering the pattern of responses to the sound intensity [4]. Other previous studies also showed the power of auditory stimuli to differentiate ADHD subjects from the normal [18]. The results are, to some extent, contradictory with what was reported in Reference [3]. In this reference, visual attention makes more distinction between ADHD and normal groups in comparison with the auditory attention. In addition, the auditory attention performance has been worse than visual attention, just in the normal group. But, in our study, this result was obtained in both groups. The observed contradictions may be due to differences in the features of the attention tasks or the type of ADHD. Therefore, in studies that are done to evaluate the convergent and discriminant validity of the integrated visual

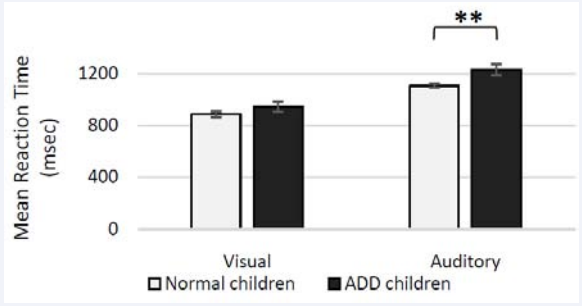

Figure 1 A comparison of mean reaction time values in auditory and visual trials in normal and ADD children. Error bars indicate between-subjects variability (SEM); Bars with star show groups with statistically significant differences.

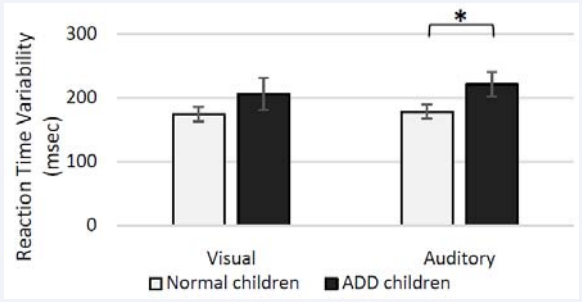

Figure 2 A comparison of reaction time variability in auditory and visual trials in normal and ADD children. Error bars indicate between-subjects variability (SEM); Bars with star show groups with statistically significant differences.

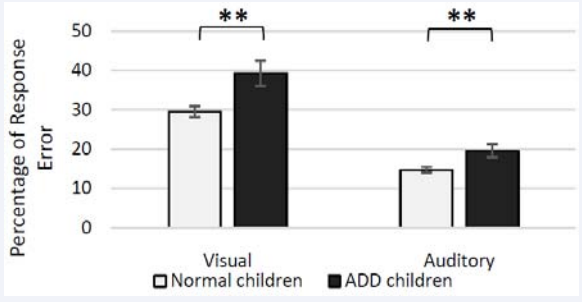

Figure 3 A comparison of the percentage of response error in auditory and visual trials in normal and ADD children. Error bars indicate between-subjects variability (SEM); Bars with star show groups with statistically significant differences.

and auditory CPTs, more over than considering the age and the gender of the participants, paying more attention to the following points is also suggested:

1- Some features of the test such as the intensity of the visual stimulus with respect to the auditory one can affect the results, specifically, the response time. That is higher intensity usually leads to faster responses [4].

2- Types of the ADHD can also change the power to distinguish between the normal and abnormal cases.

3- Since both modalities are checked in one task, the interaction between the modalities and the switching between them can also affect the final outcomes. Therefore, the condition and convenience of the subject in receiving stimuli in both modalities should be approximately the same. For instance, if the headphone does not work correctly, the performance of the subjects in response to the auditory stimuli may reduce. Inappropriate response to an auditory stimulus can also have negative effect on its response in the next trial that may be a visual stimulus.

CONCLUSION

In this study, the difference between normal and ADD children was investigated using and integrated visual and auditory attention. According to the results, children with ADD was slower, showed more response time variability, and had more error of response in comparison with the normal children. Statistical tests demonstrated that the difference between normal and ADD group is just significant in response to auditory stimuli. Therefore, more emphasis on auditory attention is suggested for designing diagnosis tools to differentiate ADHD children from normal ones. For future work, 1) investigating the response of three types of ADHD to the auditory stimuli and 2) a comparison between the response of both groups in experiments that visual and auditory stimuli are presented in one session pseudo-randomly and in two sessions separately, 3) switching effect between different modalities, have been also suggested.

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