

# The Effect of Auditory Distraction on the Auditory Word Repetition Performance of Children with ADHD

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**Abstract** Educators have observed and suggested that an appropriate seating arrangement is vital for the classroom performance of children with Attention Deficit Hyperactivity Disorder (CADHD). The current study attempts to find a cognitive reason for this observation by exploring whether CADHD are distracted by classroom noises from different locations. The current study attempts to create an experimental setting, which is on the one hand intuitively related to the classroom situation, while also maintaining experimental control, exploring the causal relation and using a task which does not require excessive attentional resources to focus on the impact of distracters rather than on task difficulty. We explored whether CADHD are more vulnerable to auditory distracters from different locations even if an attended task does not demand excessive executive resources. CADHD and normal children verbally repeated auditorily presented familiar words. Auditorily presented random numbers from the front, left, or right of the participants were presented randomly as distracters. The results showed that the effect of distracter on error rate was significant as was the interaction effect of distracter and group. However, only distracters from the front led to significantly more errors for CADHD. The findings suggest that CADHD are vulnerable to distracters from the auditory modality even when they have to perform a simple auditory task such as repeating familiar words – in a situation intuitively akin to the classroom setting.

**Keywords** ADHD, Attention, Auditory Distraction

## 1. Introduction

Educators have stressed the importance of classroom seating arrangements for improving the performance of children with ADHD (CADHD). For instance, Carbone [1] suggested that CADHD should be seated at the front row to minimise distractions from other children. The distracters could be visual such as stationary items of other pupils, design or colour of the clothing, etc., and it could also be auditory such as other pupils chatting and whispering, the noise of turning pages, etc.

Experimental studies have consistently demonstrated that CADHD are worse than normal control groups on neurological tests assessing sustained attention (e.g. [2], [3]). It has also been demonstrated that CADHD are highly distractible by visual distracters when they have to sustain their attention to perform a specific task ([4], [5]). On the other hand, cognitive research on auditory distracters is inconclusive ([6]). Reference [7] found effect of novel sounds as distracters, which slowed down attended visual tasks. However, Bedi, Halperin and Sharma [8] examined the normal population and reported that auditory distracters did not significantly correlate to sustained attention scores.

It was strongly correlated to cognitive processing required for academic performance. They suggested that distractibility is modality specific. The most commonly used task to measure both sustained attention and distractibility is the Continuous Performance Test (CPT; [9], [10]). The test requires participants to respond to a particular stimulus only if it is preceded by another particular stimulus. Studies have demonstrated that CADHD were significantly slower and made more errors than control groups in the CPT task. The Gordon Diagnostic System (GDS; [11], [12]) is similar to the visual version of the CPT but includes an auditory task and a test of distractibility. In the distractibility test, distracter stimuli appear at the periphery rather than the centre of the computer screen and participants are instructed to ignore the distracter which could be a correct stimulus, but not at the centre of the screen. In the case of the auditory version, flashing lights at the periphery of the screen serve as distracters and numbers are played back auditorily. Although these tests are reliable ([13], however, see [12]), a) they do not resemble the tasks pupils are normally engaged in within their classroom environment. b) Significant distractibility is normally observed in those studies when visual stimuli are used as distracters. d) Distracters and the attended tasks normally use the same spatial channel. e) Attended tasks demand a high degree of attentional control and lack automaticity.

In a classroom situation, distracters come from different locations and not all of them are visual. The tasks normally used in the classrooms include, for example, responding to teacher's questions, reading notes on the blackboard, writing, reading narratives, etc. In order to understand how the attention of CADHD to desired classroom activities is disrupted by various distracters and to enable us to suggest a design of ideal seating arrangement supportive to CADHD, we need more controlled cognitive research on the effect of different types of distracters from different locations on different types of classroom relevant tasks, that may or may not demand executive resources.

Educators have observed that poor classroom activities in CADHD are attributed to poor classroom design ([14], [15], [16]). But we do not know whether the poor classroom activities result from their inattention, impulsivity, poor verbal processing or a general executive dysfunction. Neuropsychological test batteries suggest that a range of neuropsychological deficits exist in CADHD (for a review see [4], [17], [18]). Most studies have investigated the relationships between different deficits using correlational methods. When exploring the characteristics of ADHD, we also need to consider other factors such as how different cognitive processes are specifically integrated for CADHD when they encounter challenging tasks in their daily lives. For example, in a classroom situation CADHD may have to attend to information presented by their teachers, which is normally delivered in a combination of auditory and visual

modalities. During the processing of such information children have to maintain their attention and avoid being distracted by other children. Children are thus simultaneously processing multi-modal information by maintaining sustained attention to transmitted messages, while trying to avoid distraction from unattended channels. In order to understand the behavioural responses of CADHD, we need to carry out integrative and experimental manipulations of a number of relevant cognitive processes and investigate how deficits related to those processes affect the overall performance of CADHD.

The effective allocation of resources to different tasks and the dynamic reconfiguration of attention to relevant tasks require well-functioning executive control processes. Therefore, the main symptoms of ADHD are sometimes attributed to some level of dysfunction in such processes ([4], [18]). Although studies have demonstrated deficits related to executive control processes (e.g. [19], [20]), they do not always tell us how such deficits are associated with other deficits found in CADHD (but see e.g. [21]). Further empirical research is needed to understand the roles of executive control processes in the manifestation of such symptoms.

For instance, several studies (e.g. [22], [23], [24]) have shown that language-related skills of CADHD are worse than that in normal controls. However, it remains unresolved a) whether such a deficit in linguistic abilities is a consequence of a deficit in the attentional processes, b) whether all sub-processes of language are equally deficient in ADHD, and c) if not, which ones are more deficient than others, d) whether any such deficit is modality-specific, and finally e) whether any sub-processes of language are more vulnerable than others to impaired attentional processing. We need experimental manipulations of related factors to answer the above questions and understand how linguistic abilities and attention processes are integrated in CADHD.

The current study attempts to create an experimental setting, which is on the one hand intuitively related to the classroom situation, while also maintaining experimental control. The study explores causal relations and uses a task, which does not require excessive attentional resources to focus on the impact of distracters, rather than on task difficulty. We explored whether CADHD are more vulnerable to auditory distracters from different locations even if an attended task does not demand excessive executive resources. We selected auditory word repetition tasks for the following reason (a) in a classroom situation the CADHD need to respond to auditorily presented stimuli from the teachers and (b) it is a simple verbal task which does not demand excessive attentional resources. The use of a simple task avoids any confound due to task difficulty. Some researchers suggest that CADHD are more vulnerable to difficult tasks due to their limited processing capacity ([26], [27]). We used auditory distracters because it has been demonstrated ([8], [25]) that auditory

distractibility is highly correlated to verbal performance. We investigated whether and how unattended auditory stimuli in the classroom could distract CADHD from performing a simple verbal task. Unlike most previous studies on the effect of distracters on ADHD, we used auditory distracters from different spatial channels because these mimic auditory distracters in a classroom.

A distracter stimulus was presented from the front, left and right while participants repeated auditorily presented simple words from the front. We expected to find a left channel vulnerability since previous studies have demonstrated a right hemisphere deficit in CADHD ([28], [29], [30]).

## 2. Materials and Methods

### 2.1. Design

A two factor (2 x 4) mixed design was used. Two matched groups of CADHD and children without ADHD (controls) had to repeat auditorily presented words from the front in four conditions: a) noise from the front, b) noise from the left, c) noise from the right, and d) no noise. The dependent variables were their reaction times and errors. Four sets of matched stimuli were counter-balanced over the four conditions. The order of the location of the noise rotated over the participants.

### 2.2. Participants

CADHD and control groups were matched in terms of age and gender. Matched pairs of seven CADHD and non-CADHD took part in the experiment. The BPS code of conduct was strictly adhered to in the recruitment of the participants. All were eleven-years-old. And in each group, there were five male and two female participants. All children in the ADHD group had been clinically diagnosed as having ADHD. They were of the inattentive type with less pronounced hyperactivity. All CADHD took Ritalin on regular basis. The ADHD group was tested within one hour of their next medication to reduce the masking effect of Ritalin ([31], [16], [32]). They underwent a physical examination by specialists to rule out other causes. None were reported to have any hearing problems. All participants came from the same local school.

### 2.3. Materials and Apparatus

SuperLab auditorily presented words randomly through a personal computer (PC) speaker. A microphone and a voice key were connected to a response box, which measured the participants' repetition reaction times within one millisecond resolution. Numbers within the range of

one and ten were played back in a loop from a tape recorder. The random numbers served as auditory distracters. The tape recorder was connected to three speakers via a manual rotor switch. Two were placed at 90 degrees to the left and right and one at the front of the participants. The four conditions were rotated in the following sequential order: noise from left, front, right, and no noise. The experimenter sat behind the participants recorded the errors manually. Four matched lists of 12 monosyllabic words (the list of words is available from the first author) each were used in the experiment. These lists were matched for familiarity.

### 2.4. Procedure

Participants were tested individually. Students' class teacher was present during the experiment for reassurance. The experiment took place in a room at participants' school. The voice key was calibrated for each participant before the start of the experiment. They sat in front of the computer screen. They were verbally instructed to repeat the words they would hear from the computer. They were encouraged to repeat them as quickly and accurately as possible and to ignore the numbers. They were each given a practice session before the real experiment. Each of them were given a practice session before the real experiment. During the practice session, sound volume was adjusted to make it clearly audible to the participants. The sound volume was constant throughout the study. Four blocks of 12 trials each were then presented. The distracter condition was changed after each block. There was five-second interval between each block. The end of each block was indicated by a visual message on the computer screen. At the end of the experiment participants were thanked and given a small chocolate egg.

## 3. Results

For the purposes of analysis, the experimental data were examined in terms of accuracy (i.e. percentage of errors) and speed (i.e. reaction time). A two factor (2x4) mixed model analysis of variance (ANOVA) was used to assess the effects of condition (ADHD versus non-ADHD) and location of the distracter (left, right, front, no distraction) in terms of differences in mean scores; post hoc analysis was conducted to test for differences in performance between conditions.

Speed, the mean reaction times in all but the front condition were shorter for the ADHD than for the non-ADHD group (see Table 1). The main effects of condition and location, both  $F < 1$ , and the interaction effect,  $F(3, 30) = 1.659$ ,  $p > 0.05$ , were not significant, however.

**Table 1.** Descriptive statistics for reaction time

Condition	Location of distracter				Overall
	Left	Right	Front	None	
	M (SD)	M (SD)	M (SD)	M (SD)	
ADHD	<sup>a</sup> 447 (116)	464 (173)	506 (132)	442 (97)	465 (108)
Non-ADHD	521 (240)	534 (209)	448 (130)	498 (229)	500 (194)
Overall	484 (183)	499 (186)	477 (129)	470 (170)	482 (151)

<sup>a</sup> milliseconds

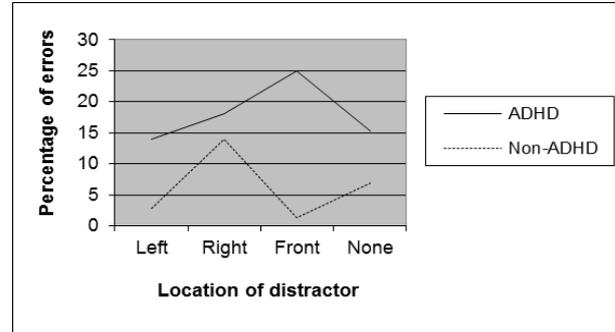
Accuracy. The ADHD group committed more errors than the non-ADHD group in all conditions. The difference between mean errors committed by the ADHD group as compared to non-ADHD group was the largest (see Table 2).

**Table 2.** Descriptive statistics for errors

Condition	Location of distracter				Overall
	Left	Right	Front	None	
	M (SD)	M (SD)	M (SD)	M (SD)	
ADHD	14 (4)	18 (3)	25 (7)	15 (6)	18 (3)
Non-ADHD	3 (4)	14 (9)	1 (3)	7 (11)	6 (3)
Overall	8 (7)	16 (7)	13 (14)	11 (10)	12 (7)

<sup>a</sup> percentage of errors

The effect of condition,  $F(1, 10) = 41.286$ ,  $p < 0.001$ , and the interaction effect of condition by location,  $F(3, 30) = 4.658$ ,  $p < 0.01$ , were significant and the main effect of location was marginally significant,  $F(3, 30) = 2.778$ ,  $0.05 < p < 0.10$  (see Table 2 and Figure 1). Simple effect tests showed that the effect of condition was significant for left,  $t(10) = 4.472$ ,  $p = 0.001$ ,  $d = 2.6$  (effect size), and front locations,  $t(10) = 7.059$ ,  $p < 0.001$ ,  $d = 6.9$ .

**Figure 1.** Interaction between condition and location of distracter for percentage of errors

A further simple effect test which tested the ADHD and non-ADHD groups separately showed that the effect of location was significant for the ADHD group,  $F(3, 15) = 4.750$ ,  $p < 0.05$ , but not for the non-ADHD group,  $F(3, 15) = 3.182$ ,  $p > 0.05$ . Pairwise comparisons within the ADHD group revealed that only the distraction from the front differed significantly from no distraction,  $t(5) = 2.907$ ,  $p < 0.05$ .

## 4. Discussion

The auditory repetition reaction times for the CADHD were not significantly slower than those for non-CADHD. On the contrary, there was a general non-significant trend for the mean reaction times of CADHD to be shorter than those for non-CADHD. In terms of mean reaction times no effects were significant either. Previous studies have shown that the performance of the CADHD in tasks measuring sustained attention is worse than that of normal control groups (e.g. [2], [10]). Unlike auditory word repetition, both of the CPT and GDS require considerable attentional demands, and the distracter in the GDS is intrinsic to the task. The auditory word repetition task demands very little attentional resources. Distracters used in the current study could be considered as extrinsic to the main task because the lexical processing of numbers requires accessing resources from the mental lexicon which are different from those for words ([33], [34]). Therefore, it is plausible that trying to ignore the numbers while attending to words is less distractible than trying to ignore stimuli that belong to the same class but are irrelevant for the task (e.g. in the GDS participants ignore numbers presented at the periphery while attending the numbers presented at the centre). In fact, previous studies have demonstrated that CADHD are more vulnerable to intrinsic than to extrinsic distracters (e.g. [35]).

However, the results from the error data depict a completely different picture: the CADHD made significantly more errors than the non-CADHD. The CADHD made significantly more errors in the front and left distracter conditions. If we consider an auditory word repetition task to be highly automatic and the random generation of numbers as extrinsic to the task and therefore ineffective as a distracter, then we would expect the error data to show null effect, too. We can rule out the possibility that CADHD group had Central Auditory Processing Disorder (CAPD) because it should have been equally manifested in the RT data which confirm previous findings ([36], [37]). The significant difference that was found between the front distracter and the no-distracter conditions in CADHD suggests that a distracter from the front was effective for CADHD. Other distracters did not significantly differ from the baseline. The participants may have perceived the auditory word repetition task to be easy. This may have influenced the strategy used by the CADHD to perform the task in the current study. They may have dropped their guard against impulsive responses and were very quick to respond, committing errors as a result (non-response was very rare). This finding is consistent with Peters' [38] and Crosbie and Schachar's [39] finding that CADHD were unable to inhibit responses to irrelevant stimuli. But it remains unresolved why they were only vulnerable to distractions from the front. It seems that they strategically used the front channel as a default and de-emphasized the additional task of channel orientating to maximise their resources for performing the required task. Alternatively, a lack of relevant cues may have discouraged them from attending to other spatial channels. Therefore, we did not find any additional disadvantage for presenting the distracter from another location ([29] demonstrated a left visual field disadvantage for CADHD).

We can rule out the possibility that CADHD group had Central Auditory Processing Disorder (CAPD) because poor performance in the front condition should have been equally manifested in the response time data which confirms previous findings ([36], [37]). CAPD is associated with marked vulnerability in prosody localized in the right hemisphere and coordination with semantic and syntactic processing in the left hemisphere. This is attributed to volumetric reduction in the corpus collosum ([40]). The word repetition task in the current study used isolated words, which demands minimal syntactic and prosodic processing as compared to phrases. Therefore, any potential confound from CAPD in the current study should be non-significant. However, the symptoms of CAPD include a vulnerability to background unstructured noises and we manipulated the sources of the noises/distracters [41]. Although the sound volume was adjusted to make it clearly audible to the participants and all CADHD in the studies underwent physical examinations by specialists to rule out other causes, in future studies, the participants should be screened for

CAPD and auditory acuity to rule out potential confounds. Volumetric reduction in the corpus collosum has been demonstrated in both ADHD and CAPD ([42],[43]). Additionally, in the healthy population, the corpus collosum undergoes rapid development during maturity. Since female maturity is earlier than male, the gender difference could confound with auditory performance for CADHD [44]. In the current study, experimental and control groups were matched by gender. However, there were fewer female participants than male in each group. In future studies, a more gender balanced participant group would address this issue.

To sum up, we suggest that accuracy and speed should be compared carefully in the assessment of cognitive deficits in CADHD. CADHD may perform better in terms of speed due to inherent impulsivity (e.g. [40]). Therefore, the inhibition to response effect may confound with the overall performance of CADHD. The present study demonstrated that even in a simple task with a distracter that was relatively easy to suppress in relatively old CADHD who should manifest relatively less pronounced behavioural dis-inhibition ([41]; however, see [42]), we still detected dis-inhibition to respond and commission errors. More importantly, CADHD of this age group seem to be vulnerable to auditory distraction from the front even when they have to perform a simple auditory word repetition task. This finding provides a cognitive explanation for the previous observation by educators (see [1]) that the performance of CADHD improves when they sit at front and close to the teachers in the classroom. CADHD are not distractible by the noises from the left or the right. Therefore, the outcome of this study augments the suggestions by educators that CADHD should be seated at the front bench during lessons.

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