

The Effect of Auditory Distractions on Working Memory in People Diagnosed with Attention Deficit Hyperactivity Disorder

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Abstract

This study compared the effect of an auditory distractor on working memory in participants with and without ADHD. Undergraduate students (N=65) were asked to complete a memory task for 25 words in which a pulsating beep sounded from the computer during the middle 5 words. The results indicated that students with ADHD performed significantly worse in the presence of a distraction than those without ADHD. However, the present study also examined the effect of ADHD medication, taken the same day, on working memory. The results indicated that participants with ADHD who had taken medication performed better than those who did not.

Keywords: auditory distractions, working memory, ADHD

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Attention Deficit Hyperactivity Disorder is a psychological disorder characterized by distractibility, procrastination, disorganization, inattention to details, forgetfulness, and failure to complete tasks (Brown, 2005). This disorder presents itself in one of three types: primarily inattentive, primarily hyperactive-impulsive, or combined type (including a semi-even mix of inattentive and hyperactive characteristics). These types are not always stable across the lifespan. Children with the primarily hyperactive-impulsive type sometimes move to the combined type as they get older, while children with the combined type typically shift to the primarily inattentive type (Larsson, Dilshad, Lichtenstein & Barker, 2011). One specific cause of ADHD has not been discovered; instead the disorder has many contributing factors. Research has been unable to isolate one gene responsible for this disorder; however, they believe that problems with genes related to dopamine increase the likelihood of having ADHD. Scientists have debated the impact of social factors on ADHD. Some researchers believe that whether or not a caregiver teaches a child self-regulation impacts the probability of having the disorder, whereas others claim there is no significant connection. Evidence of diet contributing to ADHD is limited to hyperactivity. Therefore, genetics, environment, and diet all contribute to ADHD with genetics being the most prominent factor (Frank-Briggs, 2011).

Brown (2005) describes ADHD as a complex syndrome with six primary deficits. One of the characteristics he describes is limited activation, which could lead to problems in organization, prioritization, and procrastination. This is

different from simply not wanting to do something. Neurochemistry causes this problem in people with ADHD; their brain is not activated enough to do something until the assignment approaches crisis level. Stimulant medication has shown to significantly help in cognitive activation. Brown discusses problems sustaining and shifting attention in addition to focusing attention, one of the most well known problems associated with ADHD. Oftentimes, a person with ADHD struggles with selected attention, meaning they have difficulties focusing on the most important stimulus in the presence of multiple stimuli. People with ADHD also experience difficulties maintaining alertness and regulating emotions. He includes problems in working memory and regulating action as the final two symptoms of the ADD syndrome that he describes. While many people will encounter problems in these domains at some point, person with ADHD experiences chronic problems in these areas.

Executive functioning is the constant process of receiving, processing, organizing, and storing information. Individuals suffering from ADHD exhibit significant problems regulating thoughts or actions and maintaining attention, which inhibits executive functioning. Stimulant medication is the primary form of treatment for ADHD, which increases the levels of dopamine and norepinephrine in the brain. This treatment improves alertness and concentration while decreasing impulsivity and aggression (Huang & Tsai, 2011). To date, the evidence is inconclusive regarding the effects of medication on distractibility in ADHD. Research demonstrates that stimulant medication leads to improvements

in activation, alertness, focus, working memory, attention, and managing emotions and actions (Brown, 2005).

Jensen et al. (1999) conducted a fourteen-month examination of different treatment options. They separated 579 children into four groups: medication, behavioral, combined medication and behavioral, and community care. The children in the medication group received a stimulant and were monitored on improvements and negative side effects. The behavioral treatment children were placed in an intensive program modeled after Pelham's Summer Treatment Program (STP). Due to the length of this study, children participated in the STP and a school program based on the summer program. In the combined treatment group, the children received the medication while participating in the behavioral program. As they progressed, many children were able to receive lower doses of the medication due to the inclusion of the behavioral treatment. The community group received no specific treatment; however, most were prescribed stimulant medication from their personal doctors. When comparing all treatments, children in the medication group and the combined group showed more improvements than the behavioral group or community group. While medication and combined treatments did not differ significantly on improvements, children in the combined group had significantly lower doses of the stimulant than those in the medication group. The evidence from this study reveals that medication is a very effective, if not the most effective, way to manage the symptoms of ADHD. One purpose of the present study is to determine whether

participants with ADHD who have taken their medication outperform those who did not on a memory task.

One specific problem associated with ADHD is interference with the proper functioning of working memory. Since people are constantly receiving information, they need the ability to divide their attention and remember multiple pieces of information at the same time. Working memory refers to holding information in conscious awareness while being able to process other information simultaneously (Tillman, Eninger, Forssman & Bohlin, 2011). In one study, the authors separated working memory into the Central Executive (CE), verbal memory, and visiospatial memory. 284 children participated in the study. Tilman found that problems in working memory and short term memory showed a significant correlation with elevated levels of inattention. In other words, children who have difficulty maintaining attention normally also struggle with remembering information properly. They also found that this problem worsened, as children got older. This observation is especially relevant to the current study, which focused on attentional problems in college age students.

Research suggests that people with ADHD experience problems in working memory, because they are more susceptible to distractions and thus unable to maintain thoughts or focus in the midst of interruptions (Beck, Hanson, Puffenberger, Benninger & Benninger, 2010). This creates problems with the individual's ability to participate in everyday conversations. Someone with ADHD might struggle to maintain a thought that they would like to say while

simultaneously listening to what the other person is saying. Usually, people with ADHD must choose between remembering their thought and hearing the other person. Working memory is an ongoing process holding information while processing other information; the basic problems associated with ADHD interfere with this process (Brown, 2005).

Fockert, Rees, Frith & Lavie (2001) showed that working memory directly influences selective attention. They predicted that someone who has a higher capacity for working memory would be able to filter distracters better, because they can hold more information in working memory including the distraction and the information being presented. To test this, they presented participants with a four digit number preceded by a zero and instructed participants to remember the order of numbers. In the low working memory load group, the numbers were always 1, 2, 3, 4. In comparison, the numbers were displayed in random order in the high working memory load group (such as 3, 1, 4, 2). After that, participants were instructed to classify the names of famous people into either politicians or pop stars while ignoring the distracter faces. Distracter faces were in the same category as the target, the opposite category as the target, or unrelated to the target. After the name classification segment, participants were asked which number followed a memory probe. The participants were measured by contrasting their reaction times to the faces that matched or contrasted the names. The results revealed that the distractions interfered more when the working memory load was high than when it was low. This study was conducted

on the general population. However, we can predict that ADHD people will be more affected by distracters than the general population, because people with ADHD are predicted to have problems with distracter processing and working memory.

In a study focused on the general population, Zeamer and Fox Tree (2013) conducted an experiment to test what type of auditory distraction would interfere most with memory. Participants listened to a lecture from TED talks then completed a memory test. In the first experiment, they compared the effects of another lecture playing at the same time, laughter, and three naturalistic background noises. The lecture and laughter impaired recall, possibly because it required more cognitive effort to filter that out and focus on the task at hand. The background noise did not significantly impair recall. Experiment two used three different distracters to test the effect incongruent distracters. Participants listened to the TED talks lecture with the original noises made by the audience, the original noises added where they did not belong, or strange noises that were not in the original at all. Unusual sounds distracted participants more, because those noises did not fit with what they expected to hear. In experiment three, they added short sound bites at random places during the lecture. This produced a significant impairment in recall that wasn't limited to any particular sound but was consistent throughout the test. Due to these findings, distraction occurs when an unexpected or unusual sound increases the cognitive load of the person interfering with their memory capacity.

In another related study, Hughes, Hurlstone, Marsh, Vachon & Jones (2013) conducted an experiment investigating the ability to resist two different types of auditory distractions in the general population. The first type of auditory distraction is interference-by-process which shows that changing the tone of the distraction has a greater effect than repeating the exact same tone. Habituation could be responsible for this decrease in effect. The second type, attentional capture is characterized by either something of personal importance or something that simply pulls attention from the current task. A major distinction between these two types is that interference-by-process is only applicable when remembering sequences whereas attentional capture is a general distracter. Hughes et al. (2013) theorized that since engaging in more difficult tasks requires increased focus, a person would be less susceptible to distractions. They had four categories: low and high difficulty with each having distraction and no distraction groups. In their first experiment, they found that the distraction affected memory more in the easy task. This is explained by the perceptual load model of attention, which says: when a task uses all your cognitive resources, you don't perceive irrelevant stimuli because your brain filters it out. They also noticed that participants with a greater capacity for working memory were better at ignoring the distraction. In their second experiment, they performed the same experiment adding two new categories: warning and no warning. They found that warning participants about the distraction eliminated the effect in all conditions (low and high difficulty and with and without deviant). In the final experiment,

they changed the deviant and no deviant category to a steady tone and a changing tone leaving all other aspects the same. Their results showed that neither high difficulty nor advance warning effectively combated the changing tone distraction. When they analyzed the relationship between these distractions and working memory, they found that participants with a higher capacity in working memory did not need to rely on difficult tasks or warnings to filter distractions. Those with low capacity for working memory needed these aids to perform on the same level as those with high working memory. Due to this study's conclusions relating higher capacity in working memory with increased ability to resist auditory distractions, we can infer that an ADHD person with low capacity for working memory and attentional problems would be significantly more affected by auditory distractions.

Similarly, End, Worthman, Mathews & Wetterau (2010) researched distractions among the general population. They used a cell phone ring as the distraction and tested memory performance. The participants were asked to take notes as they watched a video, then they were tested on the material. In the experimental group, a cell phone would ring as the video was playing to distract the participants. The control group watched the video without interruption. Participants in the experimental group performed worse on the test and failed to write down important items in their notes while the phone was ringing. This study shows that auditory distractions can have a major impact on memory performance in the average person.

In another study specific to people with ADHD, Lineweaver, Kercood, O'Keeffe, O'Brien, Massey, Campbell & Pierce (2012) investigated the relationship between distractions and working memory in ADHD college students. Their study included 44 ADHD participants and 42 control participants. The students participated in a preliminary session that evaluated their "mental restlessness," ADHD symptoms, and working memory capacity. Two weeks later, participants would return to complete the same working memory tests in one of three groups: no distraction, visual distraction, or auditory distraction. The auditory distraction was a recording of a group of students talking at a volume that sounded as if they were right outside the door. The visual distraction was a laptop showing a slideshow of random pictures sitting near the students taking the tests. The auditory distraction affected working memory in participants with ADHD more than the control as they had predicted. However, the visual distraction affected control participants more than the students with ADHD, which directly contrasted with their hypothesis. The students with ADHD in the visual distraction group improved their scores. They explained this phenomenon with the optimal stimulation theory, which says that participants with ADHD need more stimulation to reach their peak level of productivity. In theory, the computer created visual stimulation instead of distraction which served to aid those with ADHD yet interfered with those without ADHD due to over-stimulation. One thing to note is that the location of the computer could have influenced the results since it was not directly in their line of sight.

Increased distractibility is one of the symptoms of ADHD presented in the Diagnostic and Statistical Manual of Mental Disorders (4th ed., text rev.; DSM-IV-TR; American Psychiatric Association, 2000). Adams, Finn, Moes, Flannery & Rizzo (2009) theorized that this distractibility could be a result of people with ADHD struggling to maintain focus and inhibit sensitivity to stimuli. Adams et al. used a virtual classroom which allows the participant to interact in and with a computer program simulating a classroom in three dimensions creating a controlled, realistic setting. They used this program and scores on a continuous performance task to test if sustained attention in a setting with distracters would differentiate ADHD participants from the control group. The study consisted of 19 children with ADHD and 16 control children. They presented auditory distractions, visual distractions and mixed auditory and visual distractions similar to what one might encounter in a normal classroom. The auditory distractions included sounds like pencils dropping, people talking quietly, or chairs moving. The visual distractions were things like a paper airplane gliding across the classroom. Mixed distracters consisted of someone entering and exiting a door, a car making noise outside the window, activity in the hallway, etc. After completing the simulation, participants were asked yes or no questions about what happened to determine how much they were able to remember. Though there was no significant difference, they did see a distinct trend that showed ADHD participants performing worse on overall percent correct. One possible problem with this study was that half the participants had taken medication prior

to testing, which could be hiding the symptoms. Another possible problem is the fact that it is known that inattention symptoms tend to increase with age. In the present study, we studied an older population to determine how they manage distractions. In addition, more realistic distracter and an increased sample size are utilized.

In a similar study, Parsons, Bowerly, Buckwalter & Rizzo (2007) used a virtual reality classroom to compare attention in young boys with ADHD to boys without the disorder. The boys participated in three different conditions to test their attentiveness and hyperactivity. Participants in the first condition were asked to push a button when they saw the letter "A" followed by "X." The second condition was conducted the same way except the researchers added three types of distracters: auditory, visual, and mixed auditory and visual. The final condition was developed to simulate a more realistic classroom experience. The virtual teacher presented a symbol on the blackboard then stated the name of the symbol. For the first half, the boys were instructed to push a button if he mistakenly named the object. During the second half, they were exposed to distractions and told to push the button when she was correct. In all conditions, the researchers measured the participant's hyperactivity by monitoring their movements. ADHD participants continually showed more evidence of hyperactivity as was expected. The test results showed that ADHD boys consistently made more mistakes than the control group. They found a trend showing that ADHD boys made more omission errors than the control group.

This could be used as evidence that those with ADHD were more distracted, thus missing the appropriate stimuli completely. The small sample size of 20 boys (ten ADHD and ten without) could be the reason they found a trend instead of statistical significance. Other studies have shown that inattention increases with age while hyperactivity decreases, and the boys in this experiment were on average ten years old.

One question that the above studies left unanswered is: Do distracters have a greater impact on working memory in people with ADHD compared to people without ADHD? The primary purpose of the present study is to address this issue by testing the impact of distracters on working memory in a controlled setting. A computer program will present participants with a list of 25 words in which the middle five words contain an auditory distracter similar to a cell phone alarm. The participants will be asked to list as many words as they can remember. Due to ADHD impairments in both working memory and distracter processing, we hypothesize that word recall when the distracter is present will be significantly lower in participants who have ADHD compared to those without ADHD.

Method

The purpose of the present experiment was to compare the effect of an auditory distractor on working memory in people who have ADHD and those who do not have ADHD. Participants were asked to complete a computer test for memory that includes the auditory distractor followed by a questionnaire about

ADHD. We predicted that the auditor distractor would cause participants with ADHD to recall fewer critical words than those without ADHD.

Participants

Sixty-five undergraduate students at the University of Mississippi participated in this study. These students were recruited through the Sona system and offered .5 research credit hours. Thirty-one participants had been diagnosed with ADHD. Seventeen of the ADHD participants had not taken their medication the day of testing.

Materials

All stimuli were presented and all responses recorded using a personal computer. The word list came from Van Overschelde, J. P., Rawson K. A., Dunlosky, J. (2004). We selected the first word from 25 different categories provided (see Appendix A). For the ADHD questionnaire see Appendix B.

Procedures

When they arrived at the study, they were given an informed consent form. Participants were told that they would be taking a memory test. Participants were asked to read and follow the instructions presented on the screen. Participants studied a 25-item word list in which each word appeared individually in the middle of the screen for two seconds. When word number 11 appeared, an internal beep from the personal computer pulsed for the duration of the word presentation. The tone continued to play through word 15. Following the tone, the participants were presented with the ten remaining words. After the

presentation of the 25th word, they were instructed to estimate the amount of time that they studied the words. Then they completed a 30 second math test of simple addition and subtraction. Participants were then instructed to complete a self-paced free recall test. They were asked to type responses on the screen and press enter after each entry. The words remained on the screen. Finally, they completed a questionnaire about ADHD. Participants were thanked and debriefed.

Results and Discussion

Analyses focus on participants' recall on the five critical words presented with an auditory distractor. The thirty-one participants with ADHD had a mean recall of 1.16 with a *SD* of 0.898. The thirty-four participants without ADHD had a mean recall of 1.71 with a *SD* of 1.115. An independent samples t-test in which equal variances were assumed was conducted to compare critical recall for those with and without ADHD. There was a significant difference in the recall of participants with ADHD and those without; $t(63) = -2.16, p = 0.035$ (see Figure 1). These results suggest that people with ADHD exhibit impaired memory when compared to those without ADHD. Specifically, the presence of an auditory distractor accentuates this distinction between groups. A second independent samples t-test was conducted to compare critical recall for participants with ADHD who had not taken medication on the day of testing and participants without ADHD. There was a significant difference in the recall of ADHD participants without medication ($N = 17, SD = 0.827$) and participants without

ADHD ($N = 34$, $SD = 1.115$); $t(49) = -2.499$, $p = 0.016$. These results further emphasize the difference in memory between those with and without ADHD by addressing a possible third variable. When medication is removed from the analysis, the difference in word recall becomes more significant. Finally, an analysis of variance was conducted to compare critical recall for ADHD participants with medication, ADHD participants without medication, and participants without ADHD (see Figure 2). The ANOVA was statistically significant at the $p < .05$ [$F(2,62) = 3.24$, $p = 0.046$]. Post hoc comparisons using the Turkey HSD test indicated that the mean score for those without ADHD ($M = 1.71$, $SD = 1.115$) was significantly different from the ADHD participants without medication ($M = 0.94$, $SD = 0.827$). However, ADHD participants who had taken medication ($M = 1.43$, $SD = 0.938$) did not significantly differ from ADHD participants without medication or those without ADHD. These results suggest that ADHD medication expressively improves recall in those with ADHD, in that recall for participants with ADHD and those without ADHD showed no significant difference. A t-test was also performed comparing non-critical recall. There was no significant difference in the recall of ADHD participants ($N = 31$, $SD = 2.723$) and participants without ADHD ($N = 34$, $SD = 2.938$); $t(63) = .662$, $p = .510$. An independent samples t-test also showed no significant difference in total recall with or without ADHD. Results showed no significant difference in total recall of participants with ADHD ($N = 31$, $SD = 3.58$) and participants without ADHD ($N =$

34, SD= 3.326); $t(63) = -.794, p = .430$). These final two t-tests suggest that the distractor is the variable causing the poorer working memory performance.

Consistent with Parsons et al. (2007) and our hypothesis, participants with ADHD demonstrated more susceptibility to the auditory distraction than those without ADHD. Participants with ADHD showed significantly less recall for the critical words not only because of increased vulnerability to distractions, but also due to an impairment in working memory (Brown, 2005). Since our experiment specifically tested the effect of a distraction on working memory, it represents a very relevant and unique contribution to the current research about ADHD.

Although the results were significant, the limitations of the study should be considered. The study lacked a control group of ADHD and non-ADHD participants who took the memory test without any distraction present. This would be a good way to differentiate between the effect of the distraction and the disorder itself. The study only included college students as participants, so the application of the results is fairly limited. Future studies could test varying the tone, volume, or duration of the auditory distraction. Another interesting direction would be to repeat the study with adults over the age of 30. Many studies have suggested that the inattention symptoms of ADHD increase with age as hyperactivity decreases. Moreover, Tilman (2011) found that problems with sustained attention and memory increase, as children get older. Adams et al (2009) studied the effect of distractions on children, but they only found a trend not statistically significant data. In light of these two studies, the present study

seems to add support to the theory that inattention and memory problems in people with ADHD increase with age.

The results of this study provide useful information in a college classroom setting. We can predict that a cell phone alarm or other similar noise will interfere more with the memory of an ADHD student than a student without ADHD. For the non-critical recall, there was no significant difference between the groups. From this, we can see the major impact of auditory distractions on people who have ADHD in college. If a cell phone does go off in class, the professor could stop lecturing and repeat what might have been said during the distraction to help those who may have ADHD remember the full lecture.

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Figure 1

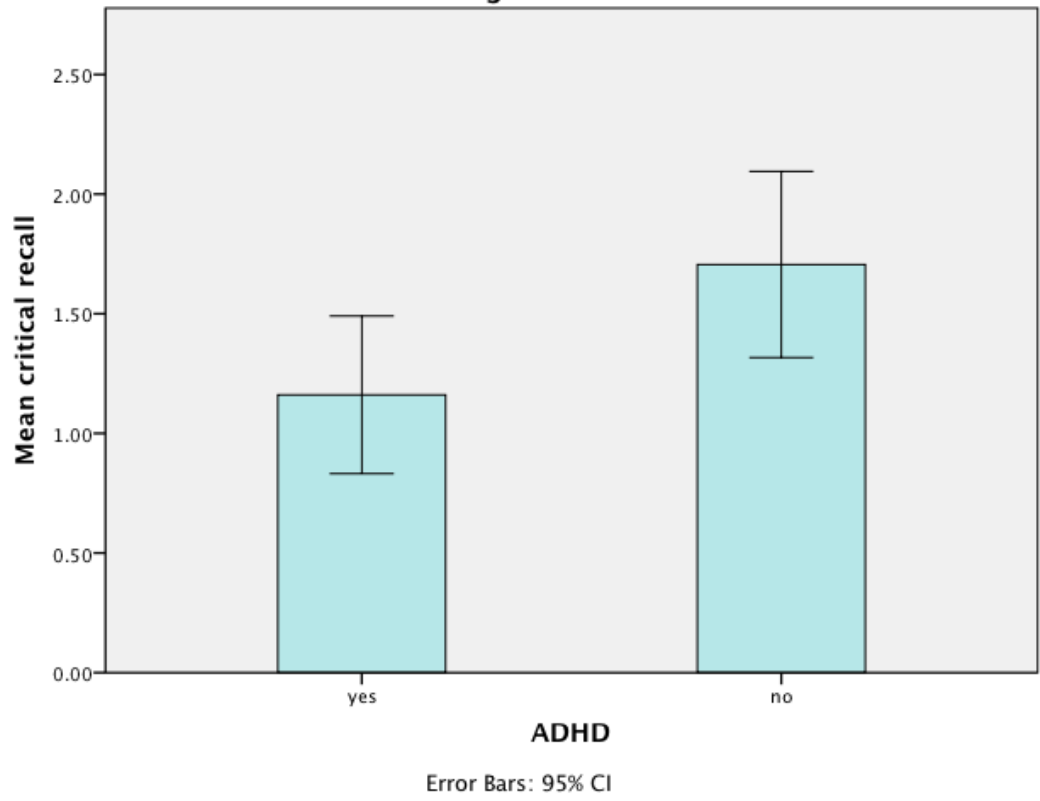
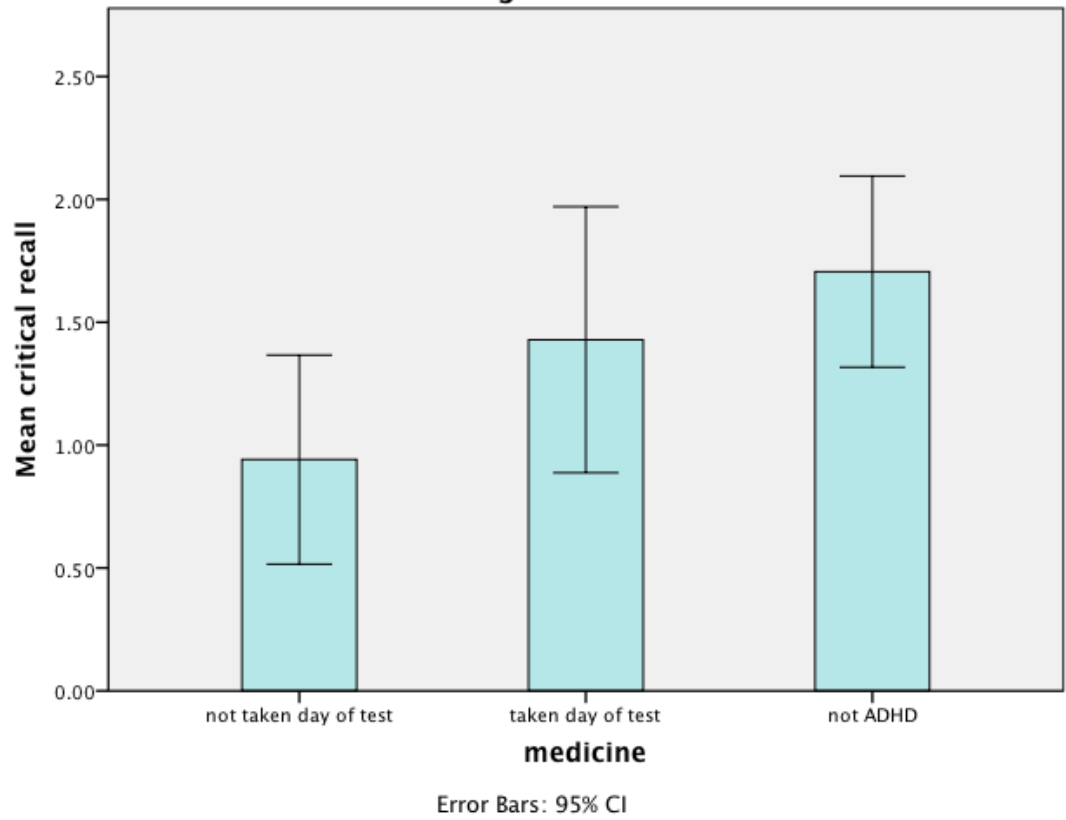


Figure 2



Appendix A

"diamond"	"apple"
"sandal"	"president"
"uncle"	"house"
"shovel"	"beer"
"steel"	"eagle"
"magazine"	"hammer"
"carrot"	"priest"
"dog"	"salt"
"cotton"	"gasoline"
"water"	"doctor"
"gun"	"mountain"
"church"	"football"
"chair"	

(James P. Van Overschelde, Katherine A. Rawson, John Dunlosky, 2004)

Appendix B

ADHD questions

Please answer the following questions as honestly and as accurately as possible.

All responses are completely confidential, and will not be associated with your name in any way.

In general, how easy / difficult is it for you to concentrate or focus on a task for 10 to 15 minutes?"

1	2	3	4	5"
not difficult		difficult		very difficult

Have you ever been diagnosed with a form of Attention Deficit Hyperactivity Disorder by a medical professional?"

A. Yes

B. No

If you have been diagnosed, what type of professional did you consult for the diagnosis?

A. Social Worker

B. Psychologist

C. Medical Doctor (or Psychiatrist)

D. Not sure"

E. Not applicable"

If you have been diagnosed, please indicate which subtype of ADHD diagnosis you were given.

A. Inattentive type

B. Hyperactive/Impulsive type

C. Combined type

D. Not otherwise specified

E. Not sure"

F. Not applicable

Are you currently taking any medication for ADHD?

A. Yes

B. No

C. Not applicable

Please indicate which type of medication as been prescribed to you.

A. Stimulant (Adderall, Concerta, Focalin, etc.)

B. Non-stimulant (Intuniv, Stratera, etc.)

C. Antihypertensive (Catapres, Tenex, etc.)

D. Antidepressant (Aventyl, Norpramin, Wellbutrin, etc.)

E. Not sure

F. Not applicable

Are you currently taking any of the previously mentioned medication for another reason?"

A. Yes

B. No

C. Not applicable

Have you taken any of the previously mentioned medication today?"

A. Yes

B. No

C. Not applicable

In general, how effective do you believe your ADHD medication is at controlling your attention / distractibility?

1	2	3	4	5
not effective		effective		very effective