# Context-Dependent Memory Effects
# for Those with ADHD Symptomatology

By

Kira A. Kascha

************

Submitted in partial fulfillment

of the requirements for

Honors in the Department of Psychology

UNION COLLEGE

June, 2022

# ABSTRACT

KASCHA, KIRA Context-dependent memory effects for those with ADHD symptomatology. Department of Psychology, June 2022.

ADVISOR: Daniel Burns

Research has revealed a context-dependent memory effect in which stimuli tested in the same context that they were encoded in tend to be remembered better than stimuli tested in a different context. The impairments of those with ADHD suggest that the restoration of context may be less beneficial for these individuals. The present study examined context-dependent memory effects among individuals with high and low ADHD symptomatology. It was expected that those with higher ADHD symptomatology would benefit less from the restoration of context compared to those with lower ADHD symptomatology. Participants were presented with a series of words on colored backgrounds and later completed a recognition memory test where words were presented on the same background or a new white background. The results revealed a significant effect of context and a significantly higher number of false alarms for those with high ADHD symptomatology. There was no interaction. While those with higher ADHD symptomatology appeared to benefit less, this was not found to be significant.

*Keywords:* context-dependent memory, attention-deficit/hyperactivity disorder, background context

# Context-Dependent Memory Effects for Those with ADHD Symptomatology

Those with ADHD seem to struggle more with tasks of source memory according to the research. Individuals with ADHD also have some other challenges that could impact memory related to context such as working memory and inhibitory control. Therefore, it is possible that individuals with ADHD don't encode or retrieve the contextual information as effectively as individuals without ADHD, and as a result, may not benefit as much from the restoration of context in context dependent-memory tasks. In order to evaluate this possibility, the present study tests individuals with varying levels of ADHD symptomatology in a context-dependent memory task. To the best of my knowledge, context-dependent memory for those with ADHD or ADHD symptomatology is not something that has been studied in previous research.

First, I will address the deficits that Individuals with a diagnosis of ADHD have been found to have in areas that seem to support, or are related to, context-dependent memory effects, such as working memory, inhibition, source memory, and frontal lobe functioning. Next, I will describe what is known about context-dependent memory effects, with a focus on context-dependent memory effects related to background color context. Then, to explain why I have chosen strongly associated colors to serve as background contexts, I will detail how color can be important in task performance. Finally, I will outline the purpose of the study and the expected results.

Research suggests that about 16 million Americans, including around 6 million children and about 10 million adults, have attention-deficit/hyperactivity disorder (ADHD) (Centers for Disease Control and Prevention [CDC], 2021; Children and Adults with Attention-Deficit/Hyperactivity Disorder [CHADD], n.d.). Among children, an ADHD diagnosis is over twice as common for males than for females (CDC, 2021). ADHD may be categorized as being either inattentive type, hyperactive type, or combined type based on the challenges that the person is experiencing. The inattentive type involves memory difficulties, challenges staying organized and on track, carelessness, and difficulty staying focused. The hyperactive type involves a tendency to almost always be in motion, even when the task at hand requires the opposite behavior, such as the completion of assignments for school or work. The hyperactive type also includes impulsivity, which may lead to talking out of turn or doing things that may not be acceptable behavior at the time. The combined type involves a relatively equivalent mixture of symptoms from both of these forms of the disorder. In order to receive an ADHD diagnosis based on DSM-5 standards, a sufficient number of symptoms must be apparent and cause challenges in an area of the individual's life. For an adult, some of these difficulties must have appeared in childhood prior to the age of 12. Additionally, the symptoms need to be experienced in multiple environments. Comorbidity is common as anxiety, mood disorders, and learning disabilities can be present along with ADHD (CDC, 2021; CHADD, n.d.). Conduct disorder or oppositional defiant disorder may be present as well for youth with ADHD who have serious, ongoing behavioral challenges (CDC, 2021).

ADHD can have a wide-ranging impact on the individuals diagnosed as well as those around them. For just the United States, ADHD is thought to have a cost of over $30 billion each year, including the direct costs of medical care as well as lost wages and productivity for individuals with ADHD or their parents or other caregivers (CDC, 2021). Symptoms of ADHD can also cause individuals to be in danger, either due to impulsive behavior or distractibility leading to a loss of focus at a moment where that may have life or death consequences such as when driving a car. Of course the symptoms that make up each type of ADHD can create challenges in completing one’s day-to-day responsibilities at work or school. Therefore, it is critical to fully understand the pattern of deficits that make up the disorder and how those deficits may impact individuals’ lives so that they can be counteracted as much as possible to prevent these types of negative outcomes.

Among the challenges experienced by those diagnosed with ADHD are struggles with working memory (Willcutt et al., 2005). This is of note due to the relationships thought to exist between context memory and working memory (Ruffman et al., 2001). Working memory performance seems to involve the use of contextual features in some cases, such as recalling the order that items were shown or said in, in order to manipulate that information. Additionally, in the measures of frontal lobe functioning that some researchers utilized to link frontal operations to source memory skill, one of the tasks was a working memory digit span assessment (Glisky et al., 2001). Therefore, source memory, which involves the remembering of the "source" of learned information, such as knowledge of when or where the learning occurred, and working memory appear to be linked as well. Due to this apparent connection, it is possible that the memory effects that arise from restoration of context may also be associated with working memory. If poor working memory is a reflection of frontal lobe deficits, those same deficits would likely result in a lack of context-dependent effects for the individuals who possess them, given that frontal deficits seem to be associated with deficient management or deficient utilization of contextual information in tests of source memory (Glisky et al., 2001). The correlation between working memory task scores and source memory scores also suggests the possibility that working memory is one of the processes that supports memory for contextual information and therefore may be implicated in the use of that information to experience improved recognition when context is restored.

Similarly, inhibitory control seems to support memory involving contextual features (Ruffman et al., 2001) and is another process that seems compromised in ADHD (Boonstra et al., 2005; Willcutt et al., 2005). Inhibition is one of the areas that research has shown to be most often altered in ADHD (Willcutt et al., 2005). For instance, it tends to be more challenging for those who struggle with ADHD symptoms to successfully complete intentional forgetting exercises, and this is thought to be because these tasks are reliant on inhibition to allow participants to ignore the items that are no longer important (White & Marks, 2003). Struggles with inhibition may be linked to a lack of contextual memory effects because it is proposed that inhibition plays a role in remembering aspects of context (Ruffman et al., 2001). Ruffman et al. point out that in order to accurately remember the context associated with an object, the tendencies toward a familiar seeming response have to be inhibited. In situations where participants were required to recall or recognize the original presentation context, the prevention of false alarms was associated with stronger inhibitory control. Therefore, in a context-dependent memory task, those with ADHD symptomatology may be more likely to wrongly identify a new word presented in a context used during study as one of the words.

Offering evidence that those with ADHD symptomatology may experience context-dependent memory effects differently, memory for sources can be challenging for this population (Fuermaier et al., 2013). Those with ADHD have unusually low activity in frontal brain areas (Dickstein et al., 2006), so these source memory issues are understandable based on previous research that has linked decreased frontal functioning with decreased success in source discrimination (Craik et al., 1990; Glisky et al., 1995; Glisky et al., 2001). In these studies, participants completed assessments meant to evaluate skills that reflect their frontal lobes' performance such as the Wisconsin Card Sorting Test, the backward digit span task, and a verbal fluency task. Their source memory abilities were also evaluated. In one study, this consisted of distinguishing where they had read or heard each fact, during the course of the study or elsewhere (Craik et al., 1990), and in other research, experimenters focused on the ability to determine which speaker had previously said each sentence (Glisky et al., 1995; Glisky et al., 2001). Greater success in these source memory tasks corresponded with increased frontal functioning according to the researchers' assessments.

While these results were found among elderly participants who had age-related frontal issues, individuals with ADHD would also be expected to have lower frontal functioning than control participants (Dickstein et al., 2006) and perhaps this is why source memory tasks have seemed to be especially challenging for them. In two similar studies addressing potential source memory difficulties in this population, the source was made up of the placement of the word on the computer display and the font color of the word shown (Fuermaier et al., 2013; Butzbach et al., 2019), similar to many of the context-dependent memory studies that I will later discuss

(Bayen et al., 2000; Hockley, 2008; Murnane & Phelps, 1994). Using this type of source manipulation, unmedicated ADHD-diagnosed participants did not accurately identify as many of the sources in a source memory task compared to controls (Butzbach et al., 2019; Fuermaier et al., 2013). One study intentionally excluded medicated participants (Fuermaier et al., 2013) while the other found this result only among those participants who reported no ADHD related medication use (Butzbach et al., 2019). Source memory tasks call for participants to remember the context that a certain item was presented in (Fuermaier et al., 2013). This differs from a context-dependent memory effect, which, depending on whether the study context was restored at test, involves varying levels of success in remembering the item (Murnane & Phelps, 1994). While source memory tasks do not assess the identical concept as context-dependent memory tasks, it would be reasonable to anticipate that participants who struggle with source memory may not benefit as much from the restoration of that source. Researchers focused on source memory propose that connecting the context to the word or image it's paired with during encoding could be more difficult for those participants with decreased frontal functioning (Glisky et al., 2001). Therefore, those with ADHD may struggle to link the context and stimulus during encoding because neuroscientific research illustrates similar reductions in frontal functioning in this population (Dickstein et al, 2006). If the context and stimulus are not properly connected in memory, one would not expect the restoration of the study context to provide an advantage to these participants the way that it would for controls. As a result, context-dependent memory effects may not be present among those with high ADHD symptomatology.

When one's ability to remember something varies based on whether or not the context from studying or learning is restored at the time that they are called upon to remember, a context-dependent memory effect is happening (Murnane & Phelps, 1994). In a more naturally occurring scenario, an example of this would be if an individual can no longer remember that they went to get something like a pen from their bedroom when they get there, but they have an easier time recalling what they were going to get when they go back to the place where they were when they determined that they would need that object (Markopoulos, 2016). The context, which is the environmental setting in this case, helps in the experience of remembering (Markopoulos, 2016). In a laboratory setting, this may entail a similar switching of rooms by requiring participants in the experimental group to study in one room and take a subsequent test in another (Markopoulos, 2016, Smith & Vela, 2001). Researchers have investigated this phenomenon by changing many other aspects of the environment as well. Despite some null results, Smith and Vela (2001) report that remembering learned information is assisted by the restoration of context, and this is true for both recognition and recall forms of testing. Additionally, research has demonstrated that it is possible to reveal an effect of context even when the time between study and test is short, and this has been true in both types of testing as well (Dulsky, 1935; Murnane & Phelps, 1994; Sakai, 2010). Short distractor tasks, from around 5 min or even as small as 30s, between the learning and recall or recognition phases have been sufficient to illustrate the effects of context on participant responses (Dulsky, 1935; Murnane & Phelps, 1994; Sakai, 2010), though greater time between the two phases is particularly likely to reveal an effect (Smith & Vela, 2001).

Background color is one context that has been effectively manipulated in a number of studies (Bayen et al., 2000; Dulsky, 1935; Hockley, 2008; Murnane & Phelps, 1994; Sakai et al., 2010; Weiss & Margolius, 1954). Early studies by Dulsky (1935) and Weiss and Margolius (1954) found that memory performance was influenced by whether the background colors of the flashcards on which nonsense syllables were typed were maintained from study to test. In trials where the colors of the cards were not altered between study and test, participants successfully remembered a greater amount of the nonsense syllables that they had practiced. It also took participants fewer attempts going through the flashcards to remember all the syllables perfectly in the condition where the background color of each card for the study phase was identical to the color used for the recall phase. For both studies, in some of the conditions tested, only one syllable pair was assigned to each background color context during the study phase. This resulted in a strong effect on performance of maintained background compared to when the cards were presented in gray instead (Dulsky, 1935; Weiss & Margolius, 1954).

In more recent years, a similar pattern of results has been obtained utilizing computers to complete the experiment, with background color alterations on the display (Bayen et al., 2000; Hockley, 2008; Murnane & Phelps, 1994; Sakai et al., 2010). Real words were used as stimuli and recognition was a common method of testing used in computer-based studies where the background and font color as well as the placement of the stimulus made up the context (Bayen et al., 2000; Hockley, 2008, Murnane & Phelps, 1994). In both free recall and recognition-based testing, participants experienced the greatest success in instances where the test phase context was not altered in any way from the colored background used during the study phase (Bayen et al., 2000; Hockley, 2008; Murnane & Phelps, 1994; Sakai et al., 2010). For instance, participants in one study were asked to learn pairs of nouns that were displayed with background and font color, and placement of stimuli (corner in which the word appeared) as their contexts (Hockley, 2008). As would be expected due to context-dependent memory effects, words that were paired with the learning context again at test were more likely to be recognized as words that were from the study phase. This result was also found in a study in which only the background had been altered (Sakai et al., 2010). This study instructed participants to come up with as many of the study words as they could in a free recall test where the color of the screen at the time served as the test context – participants remembered more of the words whose background was not modified between learning and test, revealing an influence of context on memory performance. However, in the condition where the background color switched back and forth between the two options this effect was not apparent. Performance was better only for the condition in which the backgrounds displayed during the study phase were unpredictably ordered.

Some potential insight into the relationship between context-dependent memory and ADHD symptomatology may be drawn from a study in which participants over 50 were compared to those participants younger in age (Bayen et al., 2000). Like a number of other researchers in this area of study, the experimenters manipulated the colors of the background and the font, as well as the position of the words on the screen. Nouns were shown during the learning phase and during the test phase participants indicated for each word whether it was one that they had seen in the learning portion of the experiment. The results for the college students that participated, who were in their late teens to early twenties, were compared to the results for those in their late fifties to early eighties. The hit rate, or how well participants correctly recognized the words that they had studied, was influenced by context in the group of undergraduate students only. The false alarm rate of both groups was impacted by the change in context. In another experiment, the context was made up of drawings of different settings, and the researchers tested the two age groups for recognition of words displayed on those backgrounds. In this instance, the hit rates for both groups of participants were influenced by a change in context, though the results also reflected that older participants struggled to link the words to their context in memory. It is suggested that this challenge may be the reason that struggles with source memory have also been revealed for this older group, which has been evident in numerous studies (Craik et al., 1990; Glisky et al., 1995; Glisky et al., 2001). Because both source memory and environmental context effects involve making use of context, it would be reasonable that a group who struggles with source memory would benefit less from context as well. Therefore, considering source memory difficulties are evident for those with an ADHD diagnosis (Fuermaier et al., 2013), perhaps those individuals with high ADHD symptomatology would experience similar challenges in binding in memory or would face other challenges in making use of the context. They, like the older individuals, may not be as likely as controls to experience benefits from the restoration of context during the test phase. As a result, in an experiment involving a background color context, they may struggle to correctly identify as many of the studied items as "old" just as the older participants in this study did.

While in many studies evaluating context-dependent memory using color the specific color or colors chosen is relatively insignificant, how related a color context is to the stimuli can also be an influential factor in producing large context effects. How strongly an item and its color are linked is known as color diagnosticity (Tanaka & Presnell; 1999). Broccoli, grass, and spinach are some items whose diagnostic color is green. However, book, house, and hat do not qualify as diagnostically green items because they can come in many colors and are not so strongly linked to any particular one. Color diagnosticity can be an important feature that guides the accurate identification of items we encounter and assists in directing attention and memory (Boucart et al., 2008; Foerster & Schneider, 2018; Rappaport et al., 2013; Therriault et al., 2009, Wichmann et al., 2002; Zhou et al., 2021). For example, typically colored photos of items were revealed to be identified more rapidly compared to those photos shown only in shades of gray (Therriault et al., 2009). Additionally, items shown in colors that would be atypical for that item were identified the slowest. Abnormal coloration provided a disadvantage to identifying the item.

The assistance that color provides in the identification of many items is particularly vital to those who have impaired vision (Boucart et al., 2008). Individuals in one study were required to classify images as a face, an animal, or a distractor image of another type of item. Those experiencing vision loss had greater success in classifying the images when they were in color, and when the items were shown in color, these individuals were able to sort them into the correct category more rapidly. Though this study did not take color diagnosticity into account, it is likely that diagnostic color would be even more beneficial to participants with vision loss based on other research results (Therriault et al., 2009). It's also possible that a number of the images were shown in a diagnostic color (or combination of colors) when they were shown in color even though this was not intentionally done (Boucart et al., 2008). Many animals usually have standard patterns of coloration that are associated with them so they may have been easier to identify as a result. For example, one of the images shown was of a tiger, which has a pattern of colors that people are familiar with.

Besides being valuable in object identification, color diagnosticity affects attentional processes. This is true for tasks involving a search for a particular object where attention is quickly directed to the item if it is displayed in the expected color. In one study, when tasked with finding an image of a piece of corn in an array of other fruits and vegetables, the corn was shown in its standard yellow or in purple or orange (Rappaport et al., 2013). In other trials, the vegetable to find was a red pepper which would be presented in purple on trials where the color was not supposed to be strongly linked with the item. Both the target vegetables and the rest of the vegetables and fruits shown were strongly related to certain colors. Participants were able to find the target vegetable much more quickly when it was displayed in the color that they would be most likely to connect to it.

Attention has also been shown to be influenced by the presence of a color that the viewer has grown to associate with the object. Researchers had participants view a target item in a particular color (Foerster & Schneider, 2018). Then participants were shown two items, the object that had just been shown and a new one, and their task was to move their eyes to the item that they had been shown initially. In some trials, the researchers presented the distractor item in the color that the target item was originally presented in. There were also trials where the target item was the color that it was first shown in. The associations between item and color were simply a creation of the experimenters, and the color did not always lead participants to the correct answer, but it still impacted where their attention was drawn. Participants directed their eyes to the target more quickly in instances where its color corresponded to the initial color that it was shown in, and they were more likely to glance at the distractor before directing their eyes to the correct object in the trials in which the distractor color corresponded to the initial target color. Therefore, performance can even be influenced by experimenter-assigned diagnostic colors in an immediate test scenario.

Memory is also significantly impacted by the color of the stimuli and how well it seems to be suited to the items shown (Wichmann et al., 2002; Zhou et al., 2021). In one study, participants had greater success in recognizing photographs of the outdoors as “old” when they were displayed in color, and this was found to be true for their normal colorations in particular (Wichmann et al., 2002). When the colors utilized were abnormal for the setting depicted, the ability of participants to recognize these photos and those shown in black and white was comparable. In other words, the assistance to memory provided by color only existed when the colors made sense for the items displayed. Single objects and words also see this benefit to recognition memory when these items are displayed in a closely linked color (Zhou et al., 2021). Items displayed in a strongly linked color during the decision phase of the experiment were more often correctly recognized as being from that stage when participants were later tested. An additional experiment by these researchers with words as the stimuli to be studied found that words printed on screen in a linked color were more often correctly recognized as having been seen previously in the course of the experiment. Although neither of these studies assessed context-dependent memory, it is reasonable to believe that in that type of experiment, words and items would also be more likely to be remembered if they were displayed in a standard color for that item. Combining that likelihood with the results from previous research of context effects (Bayen et al., 2000; Dulsky et al., 1935; Hockley, 2008; Murnane & Phelps, 1994; Sakai et al., 2010; Weiss and Margolius, 1954) suggests that the items that have the strongest chance of being remembered are those shown in a strongly linked color during both study and test. Due to this, the present study displayed words with background colors that they would be most associated with (for instance, broccoli on a green background) in the study phase and this was the context restored for words that were presented on the same background in the test phase.

The purpose of the present study was to evaluate context-dependent memory effects in individuals with ADHD symptomatology. Though memory for presentation sources among participants with ADHD has been addressed in previous research, to the best of my knowledge, this is the first study to address context in the form of context-dependent memory effects, specifically among populations with low and high levels of ADHD symptomatology. Based on previous research highlighting source memory challenges among people who have ADHD, as well as problems successfully engaging in other processes that seem to be implicated in this type of memory (Fuermaier et al., 2013; Willcutt et al., 2005; Dickstein et al., 2006), it was expected that participants with high ADHD symptomatology would either not see an advantage in item memory due to restoration of the study context, or that the advantage would be smaller than that found for control participants. While control participants were expected to recognize more of the items that were presented with the context they were linked to during the study phase, participants with high ADHD symptomatology were expected to perform similarly in both the same and different context conditions at test.

## Method

### Participants

Participants were recruited from Amazon’s MTURK online subject pool. There were 104 participants who began the study, however, 24 were excluded because they did not finish. Another nine participants were excluded for failing to get at least 50% of the items on the distractor task correct (explained below). This was done because it was thought that those participants who did that poorly on the distractor task weren’t attempting to do their best in their completion of the study. The decision to exclude these participants was made prior to data analysis. This left a final total of 71 participants, 44 male and 27 female, with a mean age of 37.03 years old. Participants who were ultimately sorted into the high ADHD symptomatology group had a mean age of 31.71 years old, and those who were ultimately sorted into the low ADHD symptomatology group had a mean age of 41.92 years old. All participants who took part in the experiment were paid for their time. Participants were all presented with the same stimuli during learning.

### Materials

Thirty-two words were presented during the study phase. The words were selected because each was associated with one of the colors used as a context. An additional 32 words were presented at test as distractors and all distractor words were also strongly associated with a color used as a context. The list words and distractor items are listed in the Appendix. Study and test words were presented in black 60-point Calabri Light font. Background color served as the context for this experiment. Red, orange, yellow, green, blue, pink, brown, and gray were used as contexts. Each context was used for four words during the study phase. Previous research has demonstrated that the more unique the context is to the word presented, the stronger the effect of context on memory performance (Dulsky, 1934; Weiss & Margolius, 1954). The different context used at time of test was black font on a white background. Participants used their own computers to complete the experiment.

The Adult ADHD Self-Report Scale (ASRS) was given to all participants. The 18 questions that make up the scale correspond to DSM-IV indicators and requirements for a diagnosis of attention-deficit/hyperactivity disorder (Kessler et al., 2005). Participants indicate how often they struggle with each of the ADHD related challenges with options ranging from “never” to “very often” (Adler et al., 2018). One of the ways to score this self-report questionnaire is by assigning “never” to a value of 0, with each frequency worth an additional point leading to a maximum of 4 for “very often” (Kessler et al., 2005; The World Health Organization, 2005). This results in a maximum of 72 and this is the method that I chose to use to analyze the data. There is evidence of both test-retest and internal reliability for the full, 18 question version of the ASRS, with an 0.86 test-retest correlation found (Matza et al., 2011) and Cronbach’s alpha ranging from 0.75 to 0.89 for the questions in this scale (Taylor et al., 2011). Validity data suggest that, using the method of scoring described above, a cutoff between 30 and 35 would lead to correctly diagnosing participants with ADHD or not 80 to 88% of the time (Brevik et al., 2020).

**Procedure**

Participants remotely completed the study at their own convenience (they did not go to a lab for any phase of the experiment). Upon agreeing to participate, they were directed to the experiment in Qualtrics. All instructions were presented on the screen for the participants to read. They were first told to study the words that were about to be presented to them and to do their best to remember each word without writing them down while studying them. Words were presented individually on the screen and were displayed for 4s before the screen moved on to the next word automatically. The order of stimulus presentation was randomized but the order was the same for all participants.

After all of the words had been presented, the screen proceeded to display four questions and four boxes in which participants were instructed to write their responses. Participants were given a string of 65 letters in each question and asked to respond with the number of a particular letter that was present in that string. Each question asked participants to focus on a different letter. For example, the first question asked participants to count the number of Xs in a series of letters, while the second question asked them to record the number of Os.

After participants clicked to move on, instructions were presented for the recognition test. Participants clicked to start the test when they had finished reading these directions. The recognition test presented one word at a time, either in the same context that it was presented in during the study phase or in a different context, which was the new white background context. Participants were given one of two versions of the recognition test. Each previously shown word was assigned to be presented along with the same context used during the study phase in one version of the test and with the new context in the other version of the test such that each test had half of the words displayed in the same context and half of the words in a new context. This also ensured that each word was presented once in each type of context across the two test versions. Each of the 32 distractor words that were shown to participants only at test were presented in either one of the previously used colored contexts or the new white context, with a random half presented in each. For those presented with a colored context, there was an equal number of distractor words assigned to each color. The context assigned to each distractor word was the same in both versions of the test. Participants indicated their judgment on whether or not they had studied the word by clicking “old” or “new.” The presentation order for the recognition test was random, but this random order was the same for both versions of the test.

After indicating their response for the final word of the recognition test, participants completed the ASRS and then moved on to the next screen where they were presented with a demographic questionnaire which included questions on age, gender, and ethnicity. Participants were asked to indicate any psychological diagnoses including ADHD. Participants were also asked to indicate whether they were on any medications commonly used to treat ADHD, because other studies have found that these medications improve performance on memory tasks, and may therefore hide an effect of context if this is not accounted for. Once participants clicked to submit these responses, they were provided with a written debriefing of the purpose of the study.

## Results

Participants were divided into low and high ADHD symptomatology groups by doing a median split on the data. The median value for ADHD symptomatology on a scale of 72 was 32.00. Participants with scores from 0 to 32.00 were assigned to the low ADHD group and participants with scores greater than 32.00 were assigned to the high ADHD group. The low ADHD symptomatology group contained 37 participants and the high ADHD symptomatology group contained 34 participants due to this split. A score between 30 and 35 on the scale is able to distinguish whether an ADHD diagnosis is appropriate 80% to 88% of the time, so a cutoff of 32.00 should be effective (Brevik et al., 2020).

The mean hits for each context by ADHD symptomatology level condition are presented in Figure 1. As can be seen, participants with lower ADHD symptomatology recognized more of the words that they had studied (hits) compared to those with higher ADHD symptomatology in both context conditions. Both groups recognized more of the studied words when the background context was kept the same (color for study and test) than when it was changed (color for study, white for test).

A 2 (background context: same or different) x 2 (participant ADHD symptomatology level: low or high) mixed-factor analysis of variance (ANOVA) performed on the mean hit scores revealed that the main effect of context was significant ($F(1, 69) = 8.66$, $p = .004$, $\eta_p^2 = .11$). The main effect of ADHD symptomatology level approached significance ($F(1, 69) = 3.25$, $p = .076$, $\eta_p^2 = .05$) and there was no significant interaction ($F(1, 69) = 2.27$, $p = .136$, $\eta_p^2 = .03$). These results demonstrate that individuals lower in ADHD symptomatology have more hits (more often correctly recognize a word as having been studied) compared to those with low ADHD symptomatology.

The mean false alarms for each context by ADHD symptomatology level are presented in Figure 2. As can be seen, participants with higher ADHD symptomatology incorrectly identified a new word as a word that they had previously studied (false alarm) more often than participants with lower ADHD symptomatology in both the same and different context conditions. Additionally, both the low and high ADHD symptomatology groups had greater false alarms in the same context condition compared to the different context condition.

A 2 (background context: same or different) x 2 (participant ADHD symptomatology level: low or high) mixed-factor analysis of variance (ANOVA) performed on the mean false alarm scores revealed a significant main effect of both context ($F(1, 69) = 7.34$, $p = .009$, $\eta_p^2 = .10$) and ADHD symptomatology level ($F(1, 69) = 8.15$, $p = .006$, $\eta_p^2 = .11$). There was no significant interaction ($F(1, 69) = .11$, $p = .742$, $\eta_p^2 = .00$). These results demonstrate that those with high ADHD symptomatology make more false alarms (incorrectly recognize new words as having been shown previously) compared to those with low ADHD symptomatology.

## Discussion

The purpose of the present study was to evaluate how individuals with high ADHD symptomatology experience context-dependent memory effects compared to individuals with low ADHD symptomatology. It was anticipated that those with more ADHD symptomatology would experience either no context effects or would benefit from the restoration of context to a lesser degree compared to those with less ADHD symptomatology due to the deficits associated with ADHD (Dickstein et al., 2006; Fuermaier et al., 2013; Willcutt et al., 2005). It was also expected that those with low ADHD symptomatology would remember more of the words that were presented with the same context at study and test compared to words presented in a different context at test. This would be due to the context-dependent memory effect that has been illustrated in previous studies (Bayen et al., 2000; Dulsky, 1935; Hockley, 2008; Murnane & Phelps, 1994; Sakai et al., 2010; Weiss & Margolius, 1954). While the data revealed that individuals in the low ADHD symptomatology group did perform better when the context was not changed, this was also true for those with high ADHD symptomatology, and no interaction was found that would suggest that those with high ADHD symptomatology benefited less from this restoration of context. Those with high ADHD symptomatology did tend to perform worse, though the main effect of ADHD symptomatology group did not quite reach significance for hits. This result may reflect that those with greater ADHD symptomatology don't attend to any of the stimuli as well as those with lower symptomatology. In other words, this result could be explained by a general attentional deficit rather than an issue with context in particular, which would require an interaction to have been found.

False alarms were more common for those with higher ADHD symptomatology, as would be expected based on research that has linked ADHD with lower inhibition (Boonstra et al., 2005; Willcutt et al., 2005) as well as research that has linked lower inhibition to increased false alarms (Ruffman et al., 2001). False alarms were also more common when the background of the new word was one of the old backgrounds from the study phase, which replicates the findings of previous research (Murnane & Phelps, 1994).

Though some researchers have struggled to demonstrate context-dependent memory effects or have only found small effect sizes (Bayen et al., 2000; Smith & Vela, 2001; Murre, 2021), this study revealed a relatively strong effect of context on both hits and false alarms. This is likely due to how few words were assigned to each context. Many context-dependent memory studies involve a single change for all of the words (such as changing the room between study and test or having a single presentation color of the background) or have few contexts divided among many stimuli (Bayen et al., 2000; Markopoulos, 2016; Murnane & Phelps, 1994; Smith & Vela, 2001). On the other hand, studies in which only one stimulus was assigned to each context used have been successful at finding strong context effects, and, like the present study, this was true for background color contexts (Dulsky, 1935; Weiss & Margolius, 1954). In the present study, the aim was to use few words with each context because the more unique the context is to the item, the better it seems to be remembered based on these previous studies. This endeavor was successful in producing a context-dependent memory effect. Using a color for the background context that is strongly associated with the stimulus presented was also likely advantageous in revealing an effect of context. Previous research has demonstrated that stimuli displayed in a closely linked color tend to be more often correctly recognized (Wichmann et al., 2002; Zhou et al., 2021). Therefore, it is possible that the closely linked background colors were especially beneficial to participants' recognition in cases where that background was restored, resulting in a larger context effect.

It was unexpected that participants who reported higher ADHD symptomatology were affected similarly by context restoration compared to those with lower ADHD symptomatology, though there are a number of reasons why this may be true. It may simply be that only individuals with *diagnosed* ADHD would benefit less from the restoration of context compared to controls. Only one participant reported having received an ADHD diagnosis. Although participants had high symptomatology according to the self-reports, a diagnosis from a trained clinician would be more precise and may also involve talking to friends, family members, or coworkers to get a more accurate view of each individual's functioning (Butzbach et al., 2019). While the self-report results of some participants suggested a potential diagnosis of ADHD, it is possible that there was only that single individual who participated in the study who would ultimately receive an ADHD diagnosis. The self-report would not have been 100% accurate at sorting only individuals who would truly have ADHD into a high symptomatology group and only those who don't actually have ADHD into a lower group because there is not perfect overlap in the scores of the ADHD Self-Report Scale and clinician diagnosed ADHD (Kessler et al., 2005). Due to this, differentiating people into groups of diagnosed and undiagnosed ADHD could produce different results than those found by differentiating participants using a median split, as was done here. Much of the research addressing source memory and other related areas of functioning looks at participants who have been diagnosed with ADHD and the researchers often bring in a clinician to confirm those diagnoses as well (Butzbach et al., 2019; Fuermaier et al., 2013). This could be why the source memory research that my hypothesis was based on led me to a different conclusion than what was actually revealed in the present study. It is possible that individuals *diagnosed* with ADHD would experience context effects differently even though those with high ADHD *symptomatology* did not, especially because the results for those with ADHD symptomatology trend in the expected direction.

A greater number of participants would also likely be required in order to evaluate context-dependent memory effects in this manner. It was estimated that 128 participants would be required to achieve adequate statistical power (to detect a medium-sized effect 80% of the time) in the present study. Only 71 participants had results that were suitable for analysis after excluding those who did not finish and those who performed especially poorly on the distractor task. Therefore, more participants may be needed to reveal an interaction between context and ADHD symptomatology group if an interaction was truly present.

Additionally, It is possible that participants wrote the words down as they were presented even though they were asked not to and that could have influenced the results. Perhaps those with higher or lower ADHD symptomatology were more likely to cheat and write the words down, which would impact the results. It would likely be beneficial to run a similar study that requires participants to come into the lab so that the experimenter could watch and prevent cheating at the task. Completing the study in the presence of an experimenter would also likely encourage participants to take the study more seriously and go through the study at an appropriate pace instead of rushing to choose answers and get it done, as may have been the case with our MTURK participants.

Another potential issue that could hide an effect is the difference in ages between the two ADHD groups. The high ADHD group was younger in age compared to the low ADHD group. The mean ages of the ADHD groups were about 10 years apart, which was a significant difference ($t(69) = 4.26$, $p < .001$). Research has shown that older individuals benefit less from the restoration of context (Bayen et al., 2000). Based on this, perhaps those with higher ADHD symptomatology did not benefit significantly less because those in the low ADHD group may not have benefited as much as expected due to age. Though the mean age of the low ADHD group is not nearly as large as the mean age of the “old” group in the Bayen et al. study, it’s possible that because the low ADHD group skewed older, it may have influenced the results of the two ADHD groups just enough to hide the results that were expected. It’s also possible that the difference in age could relate to another difference between the groups that would change the results.

Finally, the performance of the ADHD groups may rightly be similar for a recognition-based test, contrary to what was hypothesized, but that performance may have differed if participants were instead given a recall task. Source memory research has revealed that those with ADHD struggle with identifying the presentation context at the time of test, and these source memory tasks have been dependent on recall (Butzbach et al., 2019; Fuermaier et al., 2013). The expectation that those with high ADHD symptomatology would experience context-dependent memory effects differently was based on this deficit in source memory. However, the present study tested participants’ recognition memory. It’s possible that those with higher ADHD symptomatology would be less likely to benefit from context when responding to questions requiring recall rather than recognition. There may be something about a recognition test that facilitates the use of context for those with higher ADHD symptomatology while they may be less likely to use that context in a recall situation, which is more similar to what is asked of participants in a source memory task. For instance, participants may not rely as much on context to aid memory in recognition testing because more information to help the participant remember what they need to is given for recognition (Smith & Vela, 2001).

Certainly the finding of a context-dependent memory effect has implications for learning and education. Though it is unlikely that individuals will be given their tests in color in an educational setting, individuals can give themselves practice tests in this manner as a way to help them study. It is also valuable to know that it seems that if fewer items are associated with a context, the effect is stronger. Again, in an individual's own studying, they can assign a few items to each color using flashcards or other mediums. This would be especially useful for learning a foreign language because, like in the present study, individuals could associate the color to the word to be remembered as well. While the color wouldn't be reinstated in an actual test scenario in a school setting, the reinstatement during the process of studying could allow individuals to memorize the material more quickly. They could use the color when they are testing themselves at home as part of their studying, which will assist them in learning the material more easily. For example, Dulsky (1935) and Weiss and Margolius (1954) found that fewer attempts going through their flashcards were needed to remember the items when the context was reinstated during recall. If individuals used this technique in testing themselves, they would likely also require less reviewing of their flashcards before being able to recall what is on them, allowing them to study more effectively.

The finding that those with higher ADHD symptomatology struggle more with memory tasks, which was evident in this study, is also useful in knowing how to help those with ADHD succeed in educational settings where memorization is critical. Again, while the use of color in a test is less likely in a school setting, the finding that participants with higher symptomatology were especially vulnerable to false alarms may be important in other ways. In an educational setting they may also be liable to trip up in this way when answering multiple choice questions whose answers seem familiar but are ultimately incorrect. Knowing that those with greater attentional challenges struggle with false alarms can help teachers and students themselves by first guiding them to an area that needs practice and subsequently working to build the skill to avoid the familiar options.

While in the present study, the number of hits for those with higher ADHD symptomatology was not significant, there was a tendency for those with higher ADHD symptomatology to perform worse on the memory task. This suggests, as previous research has (Butzbach et al., 2019; Willcutt et al., 2005), that those with attentional deficits or ADHD will need additional support in an academic setting, which requires at least some level of memorization for success. Educators, parents, and students will need to seek out techniques and tactics that will benefit performance and help students to succeed.

ADHD and other attentional deficits may impact encoding or retrieval of contextual information. ADHD is marked by some deficits in memory (Willcutt et al., 2005), and so a potential difference in how context is utilized in memory is certainly also possible. Source memory research has indicated that those with attentional challenges like ADHD may process environmental context differently from those that don't struggle with attention, and that they may have more trouble recalling that context later (Fuermaier et al., 2013). If the results of the present study are supported with further research, and those with ADHD symptomatology do experience context effects similarly to those without attentional challenges, it may indicate that retrieval is the issue in their difficulty recalling environmental context. If those with ADHD are able to use the context to benefit them in the same way as those without ADHD, then it is reasonable to assume that the contextual information was encoded. However, it is possible that the benefit from the restoration of context occurs at a more unconscious level, and therefore, it may still be challenging for these individuals to recall the context when asked. Certainly, more research is needed to evaluate this possibility and gain more insight into how those with ADHD process environmental context.

**References**

Adler, L. A., Faraone, S. V., Sarocco, P., Atkins, N., & Khachatryan, A. (2018). Establishing US norms for the Adult ADHD Self-Report Scale (ASRS-v1.1) and characterising symptom burden among adults with self-reported ADHD. *The International Journal of Clinical Practice, 73:*e13260. https://doi.org/10.1111/ijcp.13260.

Bayen, U. J., Phelps, M. P., & Spaniol. J. (2000). Age-related differences in the use of contextual information in recognition memory: A global matching approach. *The Journals of Gerontology: Series B, 55*(3), 131-141. https://doi.org/10.1093/geronb/55.3.P131.

Boonstra, A. M., Oosterlaan, J., Sergeant, J. A., & Buitelaar, J. K. (2005). Executive functioning in adult ADHD: A meta-analytic review. *Psychological Medicine, 35*(8)*,* 1097-1108. doi:10.1017/S003329170500499X.

Boucart, M., Despretz, P., Hladiuk, K., & Desmettre, T. (2008). Does context or color improve object recognition in patients with low vision? *Visual Neuroscience, 25*(5-6)*,* 685-691. doi:10.1017/S0952523808080826.

Brevik, E. J., Lundervold, A. J., Haavik, J., & Posserud, M-B. (2020). Validity and accuracy of the Adult Attention-Deficit/Hyperactivity Disorder (ADHD) Self-Report Scale (ASRS) and the Wender Utah Rating Scale (WURS) symptom checklists in discriminating between adults with and without ADHD. *Brain and Behavior, 10*(6), 10:e01605. https://doi.org/10.1002/brb3.1605.

Butzbach, M., Fuermaier, A. B. M., Aschenbrenner, S., Weisbrod, M., Tucha, L., & Tucha, O. (2019). Basic processes as foundations of cognitive impairments in adult ADHD. *Journal of Neural Transmission, 126*, 1347-1362. https://doi.org/10.1007/s00702-019-02049-1.

Centers for Disease Control and Prevention. (2021, September 28). *Attention-deficit/hyperactivity disorder (ADHD).* https://www.cdc.gov/ncbddd/adhd/index.html.

Children and Adults with Attention-Deficit/Hyperactivity Disorder (CHADD). (n.d.).

*Understanding ADHD for adults: Overview.* https://chadd.org/for-adults/overview/.

Craik, F. I M., Morris, L. W., Morris, R. G., & Loewen, E. R. (1990). Relations between source amnesia and frontal lobe functioning in older adults. *Psychology and Aging, 5*(1), 148-151. http://dx.doi.org/10.1037/0882-7974.5.1.148.

Dickstein, S.G., Bannon, K., Xavier Castellanos, F. & Milham, M.P. (2006), The neural correlates of attention deficit hyperactivity disorder: An ALE meta-analysis. *Journal of Child Psychology and Psychiatry, 47*(10), 1051-1062. https://doi.org/10.1111/j.1469-7610.2006.01671.x.

Dulsky, S. G. (1935). The effect of a change of background on recall and relearning. *Journal of Experimental Psychology, 18*(6), 725–740. https://doi.org/10.1037/h0058066.

Foerster, R. M. & Schneider, W. X. (2018). Involuntary top-down control by search-irrelevant features: Visual working memory biases attention in an object-based manner. *Neuro-Cognitive Psychology, 172,* 37-45. https://doi.org/10.1016/j.cognition.2017.12.002.

Fuermaier, A. B. M., Tucha, L., Koerts, J., Aschenbrenner, S., Weisbrod, M., Lange, K. W., & Tucha, O. (2013). Source discrimination in adults with attention deficit hyperactivity disorder. *PLoS One, 8*(5), e65134. https://doi.org/10.1371/journal.pone.0065134.

Glisky, E. L., Polster, M. R., & Routhieaux, B. C. (1995). Double dissociation between item and source memory. *Neuropsychology, 9*(2), 229-235. https://doi.org/10.1037/0894-4105.9.2.229.

Glisky, E. L., Rubin, S. R., & Davidson, P. S. R. (2001). Source memory in older adults: An encoding or retrieval problem? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*(5), 1131-1146. https://doi.org/10.1037/0278-7393.27.5.1131.

Hockley, W. E. (2008). The effects of environmental context on recognition and claims of remembering. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*(6), 1412-1429. https://doi.org/10.1037/a0013016.

Kessler, R. C., Adler, L., Ames, M., Demler, O., Faraone, S., Hiripi, E., Howes, M. J., Jin, R., Secnik, K., Spencer, T., Ustun, T. B., & Walters, E. E. (2005). The World Health Organization adult ADHD self-report scale (ASRS): A short screening scale for use in the general population. *Psychological Medicine, 35*, 245-256. DOI: 10.1017/S0033291704002892.

Matza, L. S., Van Brunt, D. L., Cates, C., & Murray, L. T. (2011). Test-retest reliability of two patient-report measures for use in adults with ADHD. *Journal of Attention Disorders 15*(7), 557-563. https://doi.org/10.1177/1087054710372488.

Murnane, K. & Phelps, M. (1994). When does a different environmental context make a difference in recognition? A global activation model. *Memory & Cognition 22*(5), 584-590. https://doi.org/10.3758/BF03198397.

Murre, J. M. J. (2021). The Godden & Baddeley (1975) experiment on context-dependent memory on land and underwater: A replication. *Royal Society Open Science, 8*: 200724. https://doi.org/10.1098/rsos.200724.

Rappaport, S. J., Humphreys, G. W., & Riddoch, M. J. (2013). The attraction of yellow corn: Reduced attentional constraints on coding learned conjunctive relations. *Journal of Experimental Psychology: Human Perception and Performance, 39*(4), 1016-1031. https://doi.org/10.1037/a0032506.

Ruffman, T., Rustin, C., Garnham, W., & Parkin, A. J. (2001). Source monitoring and false memories in children: Relation to certainty and executive functioning. *Journal of Experimental Child Psychology, 80*(2)*,* 95-111. https://doi.org/10.1006/jecp.2001.2632.

Sakai, T., Isarida, T. K., & Isarida, T. (2010). Context-dependent effects of background colour in free recall with spatially grouped words. *Memory 18*(7), 743-753. doi: 10.1080/09658211.2010.508748.

Tanaka, J. W. & Presnell, L. M. (1999). Color diagnosticity in object recognition. *Perception & Psychophysics, 61*(6), 1140-1153. https://doi.org/10.3758/BF03207619.

Taylor, A., Deb, S., & Unwin, G. (2011). Scales for the identification of adults with attention deficit hyperactivity disorder (ADHD): A systematic review. *Research in Developmental Disabilities, 32*(3), 924-938. https://doi.org/10.1016/j.ridd.2010.12.036.

Therriault, D. J., Yaxley, R. H., & Zwaan, R. A. (2009). The role of color diagnosticity in object recognition and representation. *Cognitive Processing, 10,* 335. https://doi.org/10.1007/s10339-009-0260-4.

The World Health Organization. (2005). Adult ADHD Self-Report Scale (ASRS-v1.1) Symptom Checklist. National Comorbidity Survey. https://www.hcp.med.harvard.edu/ncs/asrs.php.

Weiss, W. & Margolius, G. (1954). The effect of context stimuli on learning and retention. *Journal of Experimental Psychology, 48*(5), 318-322. https://doi.org/10.1037/h0060746.

White, H. A. & Marks, W. (2004). Updating memory in list-method directed forgetting: Individual differences related to adult attention-deficit/hyperactivity disorder. *Personality and Individual Differences, 37*(7), 1453-1462. https://doi.org/10.1016/j.paid.2004.02.002.

Wichmann, F. A., Sharpe, L. T., & Gegenfurtner, K. R. (2002). The contributions of color to recognition memory for natural scenes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(3), 509-520. https://doi.org/10.1037/0278-7393.28.3.509.

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: A meta-analytic review. *Biological Psychiatry, 57*(11), 1336-1346. https://doi.org/10.1016/j.biopsych.2005.02.006.

Zhou, W., Deng, L., & Ding, J. (2021). Neural mechanism underlying the effects of object color on episodic memory. *Acta Psychologica Sinica, 53*(3), 229-243. https://dx.doi.org/10.3724/SP.J.1041.2021.00229.

**Figure 1**

*Mean Hits as a Function of Context and ADHD Symptomatology Level, Error Bars = 95% Confidence Intervals.*

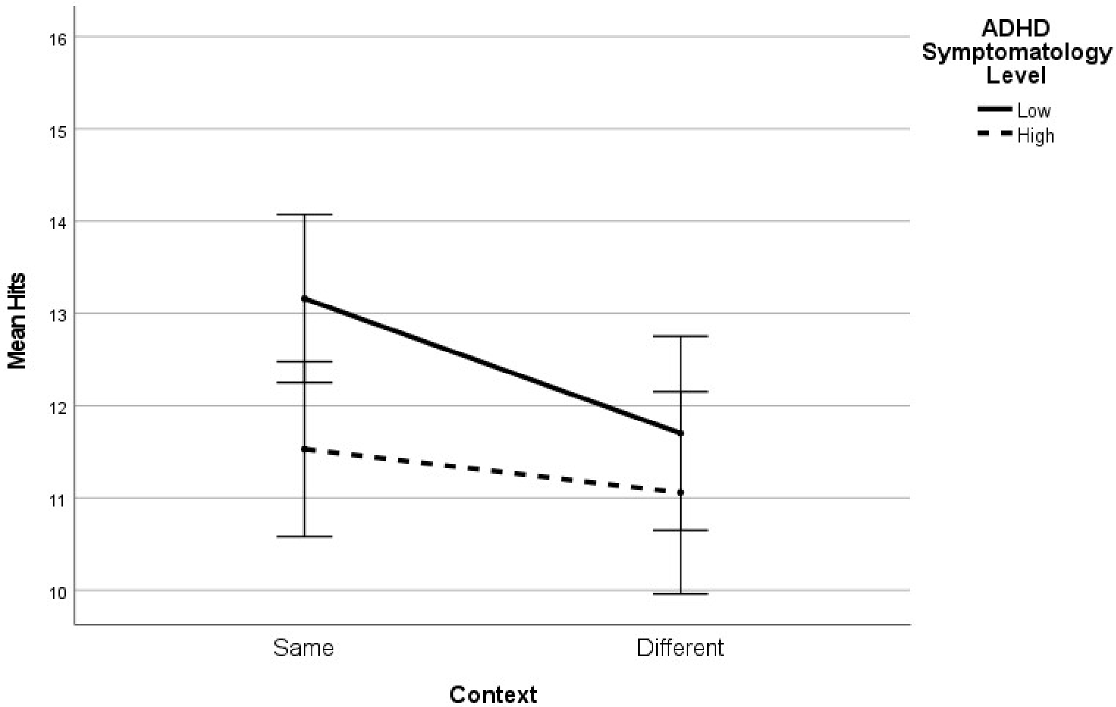
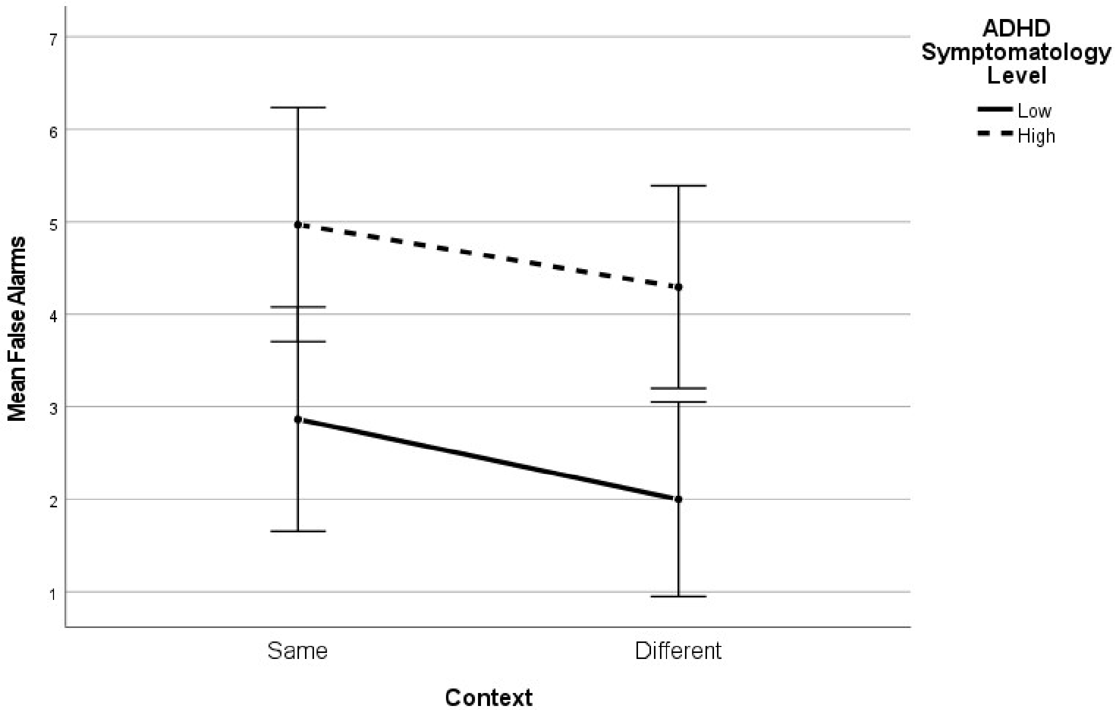


**Figure 2**

*Mean False Alarms as a Function of Context and ADHD Symptomatology Level, Error Bars = 95% Confidence Intervals.*



# Appendix

List Words and Distractor Words

List words:

| | | |
|---|---|---|
| flamingo | lobster | fire |
| barn | blood | glacier |
| ocean | chocolate | basketball |
| turtle | cheetos | brain |
| fork | mustard | mud |
| fox | salmon | koala |
| veins | broccoli | sapphire |
| banana | ladybug | smoke |
| violin | shrimp | grass |
| tractor | sun | elephant |
| pinecone | lemon | |

Distractor Words:

| | | |
|---|---|---|
| cactus | sky | worm |
| lime | corn | watermelon |
| frog | chick | cement |
| pickle | taxi | rhinoceros |
| brick | dandelion | nickel |
| cardinal | orangutan | wrench |
| tomato | carrot | cardboard |
| cherry | goldfish | football |
| jeans | pumpkin | deer |
| whale | piglet | moose |
| denim | tongue | |