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Characterizing attention deficit hyperactivity disorder with the slip induction task

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Attention deficit hyperactivity disorder (ADHD) is marked by increased distractibility and inhibitory deficits. This study sought to understand how individuals diagnosed with ADHD respond when required to inhibit a routine in response to unexpected stimuli. Ten young adults diagnosed with adult ADHD and ten controls completed the Slip Induction Task (SIT), a measure of attention and inhibition during a routine. The SIT involves participants repeatedly responding to a series of arrow cues, and then later adjusting their routine in response to unexpected stimuli. The findings of this study suggest that those with ADHD do not respond less accurately to novel stimuli within a routine. The data also indicate that when adults diagnosed with ADHD do respond correctly to novel stimuli, they do so more quickly than controls. This could imply that those with adult ADHD may be able to more quickly disengage a usual response pattern if a novel stimulus requires attention.

Keywords: Attention Deficit Hyperactivity Disorder, Inhibition, Distraction, Routine

Attention deficit hyperactivity disorder (ADHD) is defined by the Diagnostic and Statistical Manual V (American Psychological Association, 2013) as an inability to maintain attention during a variety of tasks, a propensity for careless mistakes, and general distractibility. In addition, some studies suggest that executive dysfunction could be a key symptom of the disorder (Kamradt, Ullsperger, & Nikolas, 2014; Nigg, Stavro, Ettenhofer, Hambrick, Miller, & Henderson, 2005). There are many definitions of executive function, but generally it has been described as a set of independent, but associated higher-order cognitive functions that are involved in goal-directed behaviors (Roberts and Pennington, 1996; Delis, 2012). Examples of these processes include attention, working memory, and inhibition and are ubiquitous throughout many daily activities such as cooking or shopping (Elliott, 2003).

There are multiple methods for assessing ADHD symptomology. Some of the most widely implemented include span tests, which are sensitive to lapses of attention by having participants immediately recall sequences of digits that progressively increase in size (Qian, Zhang, Yang, Du, & Wang, 2011), vigilance tests that require maintained attention for an extended period of time (Huang-Pollock, Karalunas, Tam, & Moore, 2012), and measures of inhibition, which index one's ability to occasionally withhold a response (Mcgee, Clark, & Symons, 2000). Despite the volume of research conducted on these types of measures, their utility remains equivocal when assessing symptoms related to ADHD, as they may not be specific enough (Loo et al., 2007; Rommelse et al., 2007).

However, Bédard, Trampush, Newcorn, and Halperin (2010) demonstrated that individuals with ADHD commit more errors and exhibit increased response times compared to controls. They accomplished this using a measure that required controlled attention and inhibition of a routine response whenever arrow cues pointed in a spatially incongruent direction. Norman and Shallice (1986, 2000) formulated a model of attentional control and willful action that could help to explain these deficits. This model posits that the amount of attention-related resources dedicated toward a specific task relates to how well the task is committed to habit. Tasks that are routine allow individuals to enter an "auto-pilot" state, which Norman and Shallice (1986, 2000) suggest is controlled by the contention scheduling system (CS). To contrast, unfamiliar tasks that require maintained focus of attention are controlled by the supervisory attention system (SAS). Importantly, when novel stimuli during routine tasks (under CS control) require a change in goal-directed behavior, inhibition of the routine response is necessary. So, inhibiting a well-learned, but incorrect, behavior requires reestablishing SAS control of attention.

According to this model, failure to maintain attention to a particular activity may occur through several means. Careless mistakes may occur when individuals enter into an autopilot state and fail to inhibit an expected, but inappropriate, behavior while involved in a routine activity. A common example might include incorrectly writing the wrong year after the New Year. Mistakes could also happen when attention is captured away from a primary task, such as being distracted by a phone alert while driving. Attention capture leaves fewer cognitive resources available for the accurate completion of the task (Manly, Robertson, Galloway & Hawkins, 1999).

To our knowledge, Norman and Shallice's (1986; 2000) model has only been applied to an ADHD population by Bayliss and Roodenrys (2000), who used a child-specific measure called the Star Counting Test (SCT; de Jong, & Das-Smaal, 1990). They found that children with ADHD committed more errors compared to typically developing children when they were required to inhibit a routine. Given these findings and Bédard et al.'s (2010) suggestion that ADHD symptomology changes with age, it remains prudent to apply this model to an adult sample.

One such task that would allow for the assessment of inhibition is the Slip Induction Task (SIT; Clark, Parakh, Smilek, & Roy, 2012). The SIT is an assessment designed to investigate the type of cognitive control described in Norman and Shallice's (1986; 2000) model of attention during routines. Therefore, this task may be useful in examining attention and inhibition in ADHD. The SIT is a computer-based measure that theoretically establishes CS control of participants' actions as they learn a routine sequence of movements to visually presented arrow cues. After repeating the movement sequence many times, participants occasionally encounter an unexpected cue and must recruit SAS control to inhibit a routine response. Clark et al. (2012) have demonstrated that even healthy young adults make considerable errors on this task and when they are accurate, such SAS recruitment requires considerable time.

Consequently, the purpose of this study is to elucidate attention and inhibition-related symptomology in a young adult population diagnosed with ADHD using the SIT. We hypothesize that if those diagnosed with ADHD have greater difficulty switching to SAS control of attention, they will display worse accuracy on the SIT when required to inhibit a well-learned response. If instead young adults with ADHD display greater propensity to attention capture, and therefore easier or swifter switches to SAS control it is expected that they will perform just as accurately or perhaps, even more accurately, than controls when cued to adjust a habitual response.

Method

Participants

The experimental group consisted of ten young adult volunteers who had a reported

ADHD diagnosis on file at The University of Tennessee at Chattanooga's Disability Resource Center (6 females, 4 males M_{age} = 19.7 years, range: 18 – 22 years, $M_{years\ education}$ = 14.2). All volunteers abstained from any medications prescribed to treat ADHD for 24 hours prior to testing. Ten demographically similar control volunteers (10 females, M_{age} = 20.5 years, range: 18 – 23 years, $M_{years\ education}$ = 14.7) were also recruited from various psychology classes at the University of Tennessee at Chattanooga. All participants were right handed and had normal or corrected-to-normal vision. None of the participants were currently being treated for depression or anxiety, and no participants reported any history of traumatic brain injury or brain surgery. All participants were compensated $25 for their time and effort.

Materials and Procedure

Upon arrival to the testing center, informed consent and a general health and demographics questionnaire were administered. Subsequently, participants completed the Word Choice Test (WCT; Pearson Clinical Assessments, 2009), which is a measure of sub-optimal effort. This test was included because there has been concern about whether college-aged adults diagnosed with ADHD feign the severity of ADHD symptomology (Sullivan, May, & Galbally, 2007). Subsequently, participants completed the SIT.

The Slip Induction Task (SIT). The SIT is a computer-based measure of inhibition and attention that involves two phases. First, in the practice phase, participants are presented with a sequence of seven arrow cues that they repeat for 120 trials. During this phase, each arrow within each sequence appears in a location on the computer screen that corresponds to the direction it is pointing. Each sequence is separated by a fixation cross which is presented for a variable period: 500, 1000, 1500, or 2000ms. Participants are instructed to respond to each arrow cue as quickly and as accurately as possible, using a five-key response pad where the response keys are congruent with the possible arrow cue locations (above, below, to the right, and to the left of a center response key).

The second phase involves completing the same sequence of responses (prompted by arrow cues) for 150 trials. However, in this phase, an arrow cue that points in an unexpected direction, and therefore an unexpected target button, is presented in 24% of the sequences. Before beginning this phase the participant is instructed that unexpected cues will be presented and that he/she should respond based on the pointed direction of the cue (if the arrow points rightward, press the response key on the right). Like in the first phase, the participants were instructed to respond as quickly and as accurately as possible.

Participant performance on the SIT is measured by examining both accuracy and response times to expected and unexpected arrow cue trials during the second phase. Response times are measured by the amount of time it takes for the participant to respond to an arrow cue. Response times are subdivided by whether the response was correct or incorrect and whether the cue was unexpected or expected.

Results

One participant within the experimental group did not meet the criteria to be included in any statistical analysis due to unsatisfactory effort (<49/50) as measured by the Word Choice Test (Pearson Clinical Assessments, 2001). Therefore, the final sample of young adults diagnosed with ADHD included five females and four males ($M_{age=}$ 19.8, $M_{years\ education}$= 14.33).

First, to ensure that all of the participants had learned the sequence of arrow cues during the SIT, a repeated measures one-way analysis of variance (ANOVA) was conducted to compare mean response times during the first 20 trials and mean response times during the last 20 trials of the practice phase. There was a main effect of response time, $F(1, 17) = 53.560, p<.001$, and there were no between subjects effects observed, $F(1, 17) = .361, p>.556$, nor was there an interaction, $F(1, 17) = .446, p>.513$.

Turning now to the results from the second phase, we assessed distraction effects between groups. Accuracy on trials that contained an unexpected arrow cue was analyzed using an independent samples t-test. As can be seen in Figure 1, those with ADHD did not commit more errors ($M= .45, SD = .25$) than controls ($M= .30, SD= .23$) on trials where unexpected arrow cues occurred, $t(17)=1.42, p >.17, d = 0.87$. If anything, participants with ADHD were more accurate on these trials, though this difference was not statistically significant.

Interestingly, while an independent samples t-test revealed no group differences in how quickly either group responded to expected trials, $t(17) = 1.35, p > .195, d=.51$, a repeated measures ANOVA, (group) X (correct vs. incorrect response times), was used to measure how quickly participants responded to unexpected trials. As can be seen in Figure 2, there was an interaction between group and response times for correct response times to unexpected arrow cues, $F(1,17) = 5.37, p < .05$, with the ADHD group responding faster, $F(1,17) = 68.63 , p < .001$.

Discussion

This study sought to examine how individuals diagnosed with ADHD react to unexpected stimuli during routine scenarios as routines may elicit a lower level of willful cognitive control. The findings of this study suggest that those diagnosed with ADHD are as capable of maintaining directed attention during routines as a typically developing control group. When administered the SIT, a test designed to place a repetitive behavior under CS control of attention, participants diagnosed with ADHD demonstrated similar accuracy and response times as controls. During the SIT, accuracy was lower on trials wherein unexpected cues were encountered. This means participants pressed the key that was expected, rather than the key that would be accurate. Low accuracy under these circumstances appears to indicate a decreased ability to inhibit a routine response. Though some might have predicted worse inhibition skills in those with ADHD (Bedard et al, 2010), we found that accuracy was comparable in both groups.

Similarly, our results revealed no group differences with respect to speed of responding on the routine trials. However, an interesting finding was observed when comparing the speed with which participants were able to achieve accurate responding on unexpected trials. We found that those with ADHD did so significantly faster than the control group. Faster response times to accurately executed unexpected trials might indicate faster attention capture, while slower response times might indicate slower attention capture. In the terms of Norman and Shallice's (1986, 2000) model of attentional control, our data suggests that individuals with ADHD do not have greater difficulty inhibiting CS control of attention but instead, are quicker at noticing novel stimuli, and were faster to transition into SAS control of attention.

Quicker transitions between Norman and Shallice's (1986, 2000) theoretical attention control systems appears to have been beneficial for those diagnosed with ADHD with respect to SIT performance as individuals diagnosed with ADHD were faster at correctly responding to unexpected stimuli. This could also be beneficial in real-world scenarios where an individual must react quickly in response to potentially dangerous and unexpected situations, such as avoiding a collision with a driver running a red light. Conversely though, this benefit might not carryover into all real-world situations, especially with the widespread use of mobile phones and other devices with communication alerts such as text messages and email. For example, an individual with ADHD may be more distracted by a text message while driving a usual route to work than one who does not experience ADHD.

There are a number of possible limitations of this study. First, the sample size was quite small, and therefore, it is possible some group effects went undetected. Specifically, we suspect that with larger sample sizes, adults with ADHD would actually outperform a control group on both unexpected trial accuracy. Second, 56% of the experimental group and 100% of the control group were female. One study suggests that ADHD is predominantly diagnosed in males at a ratio of to 2:1 (Ramtekkar, Reiersen Todorov, & Todd, 2011). In addition, another study by Skogli, Teicher, Andersen, Hovik, and Øie (2013) suggests that symptoms might manifest differently in males and females. Therefore, the present study's findings could be biased toward female characteristics of the disorder.

Despite these limitations, this study has provided intriguing information that should help guide future studies seeking to examine how individuals with ADHD direct attention when required to inhibit routine scenarios. Apart from addressing the limitations discussed, future research should continue to examine response speed to extraneous stimuli as a possible facet of symptoms associated with distractibility reported by those diagnosed.

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Appendix

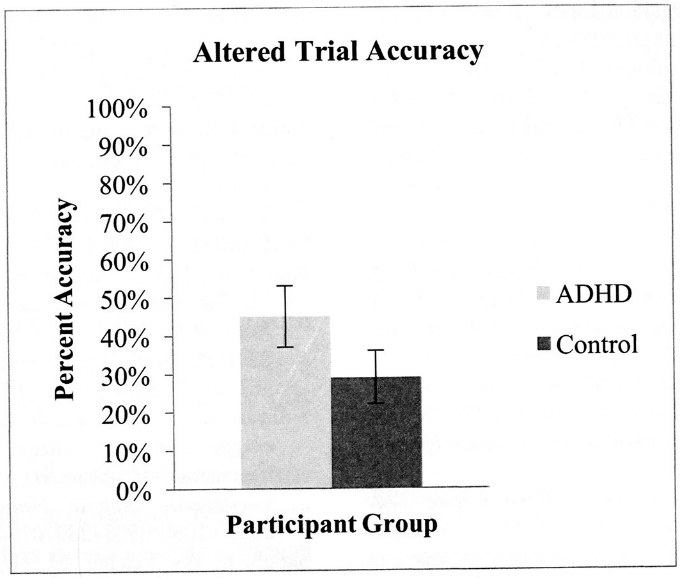

Figure 1. Accuracy of responses to unexpected arrow cues.

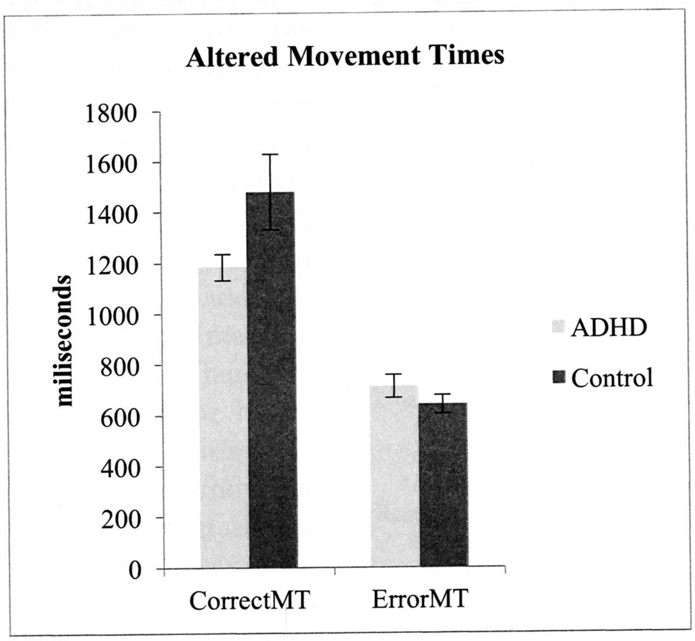

Figure 2. Comparison of movement times for during correct and incorrect response to unexpected trials.