EMOTION PROCESSING AND WORKING MEMORY CONTRIBUTIONS TO ATTENTION-DEFICIT/HYPERACTIVITY DISORDER (ADHD)

by

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ABSTRACT

MARY CAITLIN COOK. Emotion processing and working memory contributions to Attention-Deficit/Hyperactivity Disorder (ADHD). (Under the direction of DR. SARA M. LEVENS)

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder characterized by a "persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development," according to the DSM-5, and its prevalence is on the rise in both children and adults. Deficits in executive functions, such as working memory and inhibition, and emotion processing domains, such as emotion recognition and regulation, have been well-documented among individuals diagnosed with ADHD. Less work, however, has been done on mechanisms that may underlie these observed deficits. The present studies sought to investigate one such possible mechanism, the updating of emotional stimuli in working memory. Participants completed an emotion n-back task, in which they were presented with a series of photos depicting faces of five different emotional expressions (happy, sad, neutral, angry, or fearful), and asked to determine whether the current face has the same expression as that presented two faces ago. In Study One, individuals who self-reported a diagnosis of ADHD were quicker to respond, and less accurate in responding to, the emotion n-back task, providing preliminary evidence to suggest the association of a speed-accuracy tradeoff with emotion updating in ADHD. In Study Two, individuals who met criteria for ADHD in childhood, as well as those who met criteria for a current diagnosis in adulthood, were less accurate than controls in disengaging from angry and happy emotional content in working memory. These findings provide preliminary evidence to suggest emotion-specific deficits in emotion updating associated with ADHD.

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INTRODUCTION

According to the fifth edition of the *Diagnostic and Statistical Manual of Mental* Disorders (DSM-5), Attention-Deficit/Hyperactivity Disorder (ADHD) is characterized by "a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development" (American Psychiatric Association, 2013). The disorder has its onset in childhood, and can be diagnosed as either a predominately inattentive presentation (e.g., difficulty with concentration, focus, and organization), predominately hyperactive-impulsive presentation (e.g., excessive motor activity, "hasty" acts made without thinking, difficulty delaying gratification), or a combined presentation. Evidence from population surveys suggests that ADHD is found in most cultures of the world, and is present in about 5% of children and 2.5% of adults. ADHD is often associated with a number of functional consequences, such as lower school performance and higher social rejection in children, which can lead to, in turn, poor occupational performance, higher likelihood of unemployment, and elevated levels of interpersonal conflict for these individuals as adults (American Psychiatric Association, 2013). Given the prevalence of ADHD, as well as consequences that may be associated with it, it is imperative to learn more about what cognitive and emotional processes underlie the disorder.

One of the most prominent ideas in the field is that ADHD is predominately characterized by deficits in executive function (Wilcutt et al., 2005). Executive functions are defined by Welsh and Pennington (1988, as cited in Wilcutt et al., 2005) as "neurocognitive processes that maintain an appropriate problem solving set to attain a future goal". Executive functions are regarded as "top-down" cognitive inputs that enable an individual to make a decision by maintaining information about potential choices in working memory, and then integrating this information with knowledge about a given current context to identify the best course of action in a given situation, as well as to inhibit inappropriate responses. In particular, deficits in working memory and inhibition are regarded as being associated with ADHD (Thissen et al., 2014). A wide array of research has provided evidence to support this idea, in both children and adults diagnosed with the disorder. Shallice and colleagues (2002), for instance, administered a battery of neuropsychological tests to 31 children diagnosed with ADHD, as well as a control group of 33 children who had not been diagnosed with the disorder. Tests encompassed within the battery were designed to assess executive function, particularly attentional and inhibitory processes, including: four subtests of the Wechsler Intelligence Scale for Children-Revised, a vigilance task, a number Stroop task, a sentence completion task, and a rule attainment test. Results indicated that children with ADHD performed significantly worse than controls on all tests in the battery, with the exception of letter fluency, where the performance of children with ADHD was not significantly different than the control group (Shallice et al., 2002).

Relatedly, results from a meta-analysis of 83 studies conducted by Wilcutt and colleagues (2005) indicated that individuals diagnosed with ADHD demonstrated significantly lower performance than controls on thirteen executive function tasks, including stop-signal reaction time, the Continuous Performance Test, Wisconsin Card Sorting Test, Trailmaking Test, and various working memory tasks. In particular, though fewer of the included studies investigated the relationship between ADHD and working memory, six of eight studies found significant differences in performance on spatial working memory tasks between individuals diagnosed with ADHD and those without the disorder. Several of the studies utilizing verbal working memory tasks also found significant group differences (Wilcutt et al., 2005). Thus, a pattern of findings from the literature points to the association of executive function deficits with ADHD.

Deficits associated with ADHD, however, have larger implications than impaired performance on simple cognitive tasks; other factors, such as emotion processing, may be implicated as well. An ability to selectively attend to emotional cues present in another person is arguably a central component of successful functioning in the daily social environment that all human beings navigate. Critically, there is a substantial body of evidence suggesting that, compared to those who do not have the disorder, individuals diagnosed with ADHD experience difficulties in attending to, and regulating their response to, emotional cues. Often, these difficulties manifest as decreased accuracy of identification, and, consequently, interpretation of emotional cues. According to Etcoff (1986, as cited in Corbett & Glidden, 2000), the three primary means by which people communicate emotions are facial expressions, gestures, and speech intonation; facial expressions and speech intonation, in particular, have been utilized in many studies on emotion processing in ADHD. Corbett and Glidden (2000), for instance, investigated the ability of 37 children diagnosed with ADHD between the ages of 7 and 12, compared with 37 control participants in the same age range, to perceive emotional stimuli, in the form of facial expressions and speech intonation. Results from this study suggested that, in comparison to the control group, children diagnosed with ADHD were significantly less accurate in identifying the emotion depicted in photos of facial expressions, as well as the emotion depicted in recordings of emotional sentences. Another study by Cadesky and colleagues (2000) found a similar pattern of findings with both facial expressions and recordings of voices, which led the authors to conclude that these deficits seen in ADHD result from an inability to "attend to the appropriate cues of affect." Other experimental paradigms have also provided evidence to support the notion that individuals with ADHD do not attend to emotional cues in the same manner as those who do not have the disorder. Pelc and colleagues (2006), for example, found that, during an emotional expression decoding procedure, children diagnosed with ADHD made significantly more emotional coding errors than the control group. Interestingly, decoding accuracy was lower in the ADHD group for faces with angry and sad expressions than for faces with happy and disgusted expressions (Pelc et al., 2006). These results suggest that rather than a global deficit in the identification of emotions and their interpretation, individuals with ADHD may have emotion specific deficits.

While there is a great deal of research on executive function and emotion processing in ADHD, there has been less attention placed on the interaction between executive processes and emotionally-salient cues in those with the disorder. A study by Marx and colleagues (2011) provides one first step toward understanding this interaction. In their investigation, the authors recruited individuals who had been treated for ADHD in the outpatient clinic at the university in which they worked, as well as a control group, and after verifying diagnosis, asked all participants to engage in an parametric emotion distractor n-back task. Participants completed 1-back and 2-back versions of the task in which they responded to whether the letter presented on the screen was the same as that presented 1 trial previously for the 1-back condition, or 2 trials previously for the 2-back condition. The emotional component of the task consisted of neutral and negative distractor pictures presented in the background of the letter presentation. Emotional distractor pictures varied in "emotional salience" and were either neutral, negative low arousing or negative high arousing. Participants were instructed to ignore the background pictures, and to respond to the n-back task as quickly as possible. Results were consistent with previous n-back findings, in that individuals with ADHD demonstrated lower response accuracy on a working memory task than the control group, suggesting the presence of a working memory deficit. In regards to the effect of distracting emotional content on task performance, individuals with ADHD were more distracted by the emotional stimuli than control participants. Specifically, while both controls and ADHD participants demonstrated lower accuracy in the high arousing negative condition, only ADHD participants were distracted by the low arousing negative photos, as indicated by significantly lower levels of accuracy on trials with low arousing negative emotional photos in the background (Marx et al., 2011). From the results of this study, there is preliminary evidence to suggest that individuals with ADHD may have a greater sensitivity or attention capture to irrelevant negative emotional content.

The existing literature presents a complex, and sometimes conflicting, picture of executive function and emotion in ADHD. Numerous studies support the notion of a general executive function deficit associated with the disorder, as manifested by significantly worse performance on working memory and inhibition tasks among individuals with ADHD, as compared to controls. In addition, a plethora of findings point to a broad deficit in emotion identification and regulation in this population. The emotion processing and executive control research that has been conducted to date suggests complex interactions between emotion and executive control. While Pelc and colleagues (2006) found that individuals with ADHD demonstrated lower accuracy in identifying negative emotions (such as anger and sadness), other findings, such as those obtained by Marx and colleagues (2011), suggest that negative emotion may be more likely to capture the attention of individuals with ADHD than those without the disorder. Taken together, this array of findings suggests that emotional content captures the attention of individuals with ADHD more easily, and consequently enters working memory more easily as well. This enhanced attention capture should suggest greater emotional accuracy in individuals with ADHD. However, once in working memory, difficulty appears to arise in regards to interpreting, integrating, and monitoring emotional content, particularly when it is negative, resulting in lower accuracy. While this hypothesis is supported by current empirical data, it has not been directly tested. The majority of research conducted to date has utilized 1) emotion identification tasks which require little to no executive function (e.g. Cadeskey et al., 2000; Corbett & Glidden, 2000; Pelc et al., 2006), *or* 2) executive function tasks, such as the n-back task, in which emotional content is not the focus of the task, but rather a distractor (e.g. Marx et al., 2011). The present study aims to address this gap in research and test whether individuals with ADHD are impaired at using executive control functions to integrate and monitor emotional content in working memory.

The present study, then, seeks to fill this gap in the literature by examining one possible executive function that may underlie difficulties with integrating and monitoring emotional content: updating. Updating as defined by Morris and Jones (1990), is an executive process that monitors incoming information for its relevance to a particular task, and replaces no-longer-relevant items in working memory with newer, more relevant information. Just like other information in working memory, emotional information needs to be constantly updated, and, thus, must be disengaged from when the appropriate time comes; a failure to do appropriately may lead to difficulties in emotion regulation. Emotion regulation difficulties have been repeatedly documented in ADHD populations, lending credence to the involvement of emotion updating dysfunction (Maedgen & Carson, 2000; Walcott & Landau, 2004). Emotion updating has been the subject of recent empirical study, such as by Levens and Gotlib (2010) in the context of depression. In their study, individuals who had recovered from depression, as well as a group of never-diagnosed controls, completed an emotion 2-back task using emotional facial expressions. Participants were presented with a series of happy, sad, and neutral faces and were asked to indicate whether the current face had the same emotional expression as that presented two faces earlier (which required that participants match set) or a different emotional expression as that presented two faces earlier (which required that participants integrate new content or break a previously matched set). Results from this investigation suggested that, compared to controls, individuals diagnosed with depression were faster to disengage from happy content in working memory, and slower to disengage from sad stimuli. The authors suggest that these findings may be a basis for maladaptive emotion and executive function biases that impair emotion regulation among individuals diagnosed with depression (Levens and Gotlib, 2010). While no studies have specifically investigated emotion updating in the context of ADHD, it is suggested that abnormalities in emotion updating, particularly with respect to negative emotion, may be a mechanism to explain the emotion regulation deficits observed among individuals with ADHD. Furthermore, investigating updating in this context may serve to shed light on how emotion-processing deficits may occur within working memory.

The present investigation was designed to examine emotion updating in ADHD within the context of an emotion n-back task. In Study One, individuals who self-reported a diagnosis of ADHD were compared to a group of age- and education- matched controls on the emotion n-back task. Consistent with previous findings from the literature, it was hypothesized that, in comparison to the control group, individuals with ADHD would demonstrate lower accuracy overall on the emotion n-back task. Additionally, it was hypothesized that, among individuals with ADHD, decreased accuracy on the emotion n-back task would be more pronounced in negative emotions, such as anger, sadness, and fear. In particular, this would be reflected by more difficulty engaging and disengaging from these negative facial expressions in working memory than those of other emotions. In Study Two, individuals who self-reported a diagnosis of ADHD were again compared to a group of age- and education-matched controls on the emotion n-back task, except in this study self-reported ADHD participants completed self-report clinical diagnostic measures to clarify ADHD diagnoses, based on childhood and current symptoms. Similar to Study One, we hypothesized that individuals in the ADHD group would demonstrate lower accuracy rates in comparison to controls, and those would be seen, in particular, with negative emotions. Additionally, it was hypothesized that deficits in emotion updating, particularly with attention to negative emotion, would be maximized in individuals who met criteria for the disorder in childhood, and still meet criteria currently.

STUDY ONE

Method

Participants:

Seventy-three undergraduate students (48 female and 25 male) were recruited through their participation in the UNCC Behavioral Genetics Project, a longitudinal study aimed at investigating adjustment to college life, through introductory courses in the Biology and Psychology departments. Students eligible for participation in the study included those enrolled in their freshman year at UNC Charlotte, at least 18 years of age, and fluent in English. Participants ranged in age from 18 to 25 years, (M = 18.42, SD = 0.98). 76.7% of the participants identified as Caucasian, 9.6% identified as African-American, 4.1% identified as Hispanic/Latino, 1.4% identified as Asian-American, 1.4% identified as Pacific Islander, and 6.8% identified as mixed race or other.

As part of their participation in the UNCC Behavioral Genetics Project, participants completed a Mental Health History Checklist, which asked them to indicate whether they had ever received a diagnosis of a number of mental health conditions. Based on their responses to the Mental Health History Checklist, those self-reporting a diagnosis of ADHD were placed into the ADHD diagnosis group, while those who did not self-report a diagnosis of ADHD were placed into the control group. Thirty-seven participants (24 female and 13 male) self-reported a diagnosis of ADHD, and were placed into the diagnostic group. Participants in this group ranged in age from 18 to 25 years (M = 18.62, SD = 1.28). Thirty-six participants (24 female and 12 male) from the UNCC Behavioral Genetics Project who did not indicate a diagnosis of ADHD were randomly chosen as the control group. Participants in this group ranged in age from 18-20 years ($M = 18.22$, $SD = 0.49$).

Materials:

Demographics questionnaire: This portion of the questionnaire asked participants for basic demographic questions, such as gender, age, and racial identity.

Mental Health History Checklist: The Mental Health History Checklist asked the participant to disclose whether or not they had received a diagnosis for a number of mental health conditions, including anxiety disorders, depression, and ADHD (Holman et al., 2008).

Emotion n-back task: This task was adapted from the emotion n-back task previously utilized by Levens and Gotlib (2010). Digital photos of faces were used as stimuli, and were of five facial expressions: happy, sad, neutral, angry, and fearful. Over the course of the task, participants viewed faces one at the time, presented for 2 seconds each, with 2.5 seconds in between each stimulus. The task consisted of 330 trials, separated into 6 blocks of 55 trials each, as well as an additional 10 un-scored practice trials. The modified emotion n-back task in the present study was a 2-back task, in which participants were asked to indicate whether the emotional expression of the face currently presented is the same as, or different than, the emotion of the face that was presented two faces earlier. Participants were instructed to press a key labeled "Same" if the facial expression was the same as that presented two faces before, or a key labeled "Diff" if the facial expression was different than that presented two faces earlier; these responses occurred from the third trial in each block on, as participants were told to view the first two faces presented without pressing any key, resulting in 53 useable trials per block.

Trial Types: Each trial required a complex set of cognitive demands on the part of the participant. In addition to simply processing the presented facial expression, a participant was required to add the current expression to a set of stimuli seen over the duration of the task, discard the expression of the face that was presented three faces earlier, compare the current expression to the one that was presented two faces earlier, and, from there, provide a response. Thus, three trial types resulted: "match-set" trials, "break-set" trials, and "no-set" trials. In "match-set" (or "Same" response) trials, the current facial expression was the same as that presented two faces earlier, which required the participant to identify the two expressions as stimuli belonging to the same category. A "Different" response, however, required a unique set of cognitive processes, reflected in two types of "Different" trials: "break-set" and "no-set." "Break-set" trials occurred after "match-set" trials, requiring the participant to "break" a response set they had endorsed in the previous trial. These trials, then, assessed a participant's ability to disconnect two paired stimuli and disengage the expression from working memory. On "no-set" trials, participants did not need to break a set of previously-paired facial expressions to respond, instead only needing to determine that no set exists. No-set trials, then, assessed a participant's ability to evaluate a given stimulus's relatedness to other stimuli present in working memory.

Procedure:

As part of their participation in the UNCC Behavioral Genetics Project, participants completed a survey conducted through the survey software Qualtrics. After each participant gave his or her consent, they completed the survey, consisting of basic demographic questions, as well as a Mental Health History Checklist. Upon completion of the survey, participants completed the emotion n-back task. Data was de-identified, and each participant was assigned a four-digit code.

Statistical Analysis:

Mean reaction times and accuracy rates were calculated for each trial of the emotion n-back task. Both accuracy rates and reaction times were considered as dependent variables for the purpose of analysis. Based on their responses to the Mental Health History Checklist, participants who reported a diagnosis of ADHD were sorted into the ADHD diagnosis group, while a sample of those who did not report a diagnosis of ADHD were sorted into the control group. For each trial type (match-set, break-set, and no-set), a separate two-way repeated measure analysis of variance (ANOVA) was conducted, with diagnostic status (ADHD vs. non-ADHD) as the between-group variable and emotion expression (happy, sad, neutral, angry, or fearful) as the within-subject repeated measures variable. Post-hoc tests were conducted to clarify any significant main effects observed in these analyses.

Results

Participant Characteristics:

Of the seventy-three participants recruited for Study One, seven were excluded from analyses due to obtaining a mean accuracy rate lower than 60% on the emotion n-back task. Overall, sixty-six participants were included in the final analyses (44 female and 22 male). Participants ranged in age from 18 to 25 years ($M = 18.379$, $SD = 0.957$). Race/ethnicity information, as well as diagnoses reported per the Mental Health History Checklist, are reported in Table 1.

Thirty participants (20 female and 10 male) who self-reported a diagnosis of ADHD on the Mental Health History Checklist were included in the final ADHD group in analyses. Participants ranged in age from 18 to 25 years (M = 18.57, SD = 1.31). 80% of participants identified as Caucasian, 6.7% identified as African-American, 3.3% identified as Asian-American, 3.3% identified as Pacific Islander, and 6.7% identified as mixed race or other. On the Mental Health History Checklist, 30% of participants self-reported a diagnosis of an anxiety disorder, 13.3% reported a diagnosis of an eating disorder, 23.3% reported a diagnosis of depression, 6.7% reported a diagnosis of post-traumatic stress disorder (PTSD), 13.3% reported a diagnosis of a learning disorder, 6.7% reported a diagnosis of a behavior disorder/conduct problem, 3.3% reported a diagnosis of an alcohol/substance use disorder, 3.3% reported insomnia, and 3.3% reported a diagnosis of an unspecified other disorder.

Thirty-six participants (24 female and 12 male) were included in the control group in final analyses. Participants ranged in age from 18-20 years (M = 18.22, SD = 0.49). Race/ethnicity information, as well as diagnoses reported per the Mental Health History Checklist, are reported in Table 1.

Results of Study One are presented in two sections. The first section presents results from the repeated measures ANOVA conducted on accuracy rates, while the second section presents results from the repeated measures ANOVA conducted on reaction times. Means and standard deviations of both accuracy rates and reaction times on the emotion n-back task can be found in Table 2. Means and standard deviations of accuracy rates and reaction times are graphically presented in Figures 2 and 3, respectively.

Accuracy Analysis:

To examine how accuracy on the emotion n-back task varied between ADHD diagnostic status, a Trial type (Match-set, Break-set, No-set) by Emotion (Happy, Sad, Neutral, Anger, Fear) repeated measures ANOVA was calculated on accuracy rates with Group (ADHD, Controls) entered as a between subject variable. Results revealed significant main effects for condition, $F(2, 128) = 35.790$, $p < 0.01$, and emotion, $F(4, 256) = 18.254$, $p < 0.01$, qualified by a condition by emotion interaction, $F(8, 512) = 18.085$, $p < 0.01$. Additionally, there was a trend main effect for diagnostic group, $F(1, 64) = 3.114$, $p < 0.10$. No other main effects or interactions were significant. To follow up on observed main effects, accuracy rates were averaged, and paired t-tests were conducted across condition and emotional expression. Results indicated that accuracy rates on match-set trials (M = 75%) were lower than those on break-set trials, $t(65) = 8.129$, $p < 0.01$, and those on no-set trials, $t(65) = 5.742$, $p < 0.01$; accuracy rates on break-set trials (M = 82%) and no-set trials (M = 81%) were not significantly different from each other. Results also indicated that differences in accuracy rates between emotions were all significantly different from each other, all *p*s < 0.05, with the exception of angry and sad, $t(65) = 0.200$, $p = 0.842$, and happy and neutral, $t(65) = 0.449$, $p = 0.655$; participants were least accurate in responding to sad trials (M = 76.8%), followed by angry (M = 77.0%), fearful (M = 79.2%), happy (M = 82.5%), and neutral (M = 82.8%). To examine the trend main effect between group, an independent sample t-test was conducted between diagnostic and control groups on average accuracy rates for the task. Differences in overall accuracy rates between the control group and ADHD group trended toward significance, $t(64) = 1.765$, $p < 0.10$, with the ADHD group overall less accurate (M = 77%) than the control group (M = 81%).

To follow up on the observed condition by emotion interaction, paired t-tests were conducted on the accuracy rates observed for trials of each emotional expression in each condition. Results indicated that in the match-set condition, accuracy rates for each emotion were all significantly different from each other, all *p*s < 0.01, with the exception of angry and sad, $t(65) = 1.935$, $p < 0.10$, which trended toward significance; participants were least accurate in responding to sad trials (M = 66%), followed by angry (M = 69.4%), fearful (M = 75%), neutral (M = 80.5%), and happy (M = 85%). In the break-set condition, results indicated that participants were more accurate in responding to neutral stimuli (M = 87.2%) than to angry stimuli, $t(65) = 4.059$, $p < 0.01$, happy stimuli, $t(65) = 4.800$, $p < 0.01$, fearful stimuli, $t(65) = 4.279$, $p < 0.01$, and sad stimuli, $t(65) = 5.086$, $p < 0.01$; participants were least accurate in disengaging from happy stimuli (M = 79.8%), followed by sad (M = 81.2%), fearful (M = 81.5%), and angry (M = 82.1%). In the no-set condition, significant differences were only observed between angry and happy trials, $t(65) = 2.236$, $p < 0.05$, and angry and sad trials, $t(65) = 2.419$, $p < 0.05$; participants were least accurate in responding to angry trials (M = 79.4%), followed by neutral (M = 80.8%), fearful (M = 81.1%), happy (M = 82.7%), and sad (M = 83.1%).

Reaction Time Analysis:

To examine how participants varied in their response times on the emotion n-back task by diagnostic status, a Trial type (Match-set, Break-set, No-set) by Emotion (Happy, Sad, Neutral, Anger, Fear) repeated measures ANOVA was calculated on reaction times with Group (ADHD, Controls) entered as a between subject variable. Results revealed significant main effects for condition, $F(2, 128) = 78.339$, $p < 0.01$, and emotion, $F(4, 256) = 31.981$, $p < 0.01$, qualified by a condition by emotion interaction, $F(8,512) = 22.494$, $p < 0.01$. Additionally, there was a trend main effect for diagnostic group, $F(1, 64) = 3.346$, $p < 0.10$. No other main effects or interactions were significant. To follow up on observed main effects, mean reaction times were calculated for each participant, and paired t-tests were conducted between conditions and emotional expressions. Results indicated that reaction times between conditions were all significantly different from each other, all *p*s < 0.01, with participants responding the fastest to match-set trials (M = 1193.40 ms), followed by break-set trials (M = 1294.52 ms), and no-set trials (M = 1328.63 ms). Results also indicated that reaction times between emotions were all significantly different, all *p*s < 0.05, with the exception of angry and neutral, $t(65) = 1.538$, $p = 0.129$, and fearful and sad, $t(65) = 0.283$, $p = 0.778$; participants responded the fastest to happy stimuli (M = 1199.92 ms), followed by neutral (M = 1266.14 ms), angry (M = 1280.25), sad (M = 1305.60 ms), and fearful (M = 1309 ms). To examine the trend main effect between group, an independent sample t-test was conducted between diagnostic and control groups on average reaction times for the task. Overall differences in reaction time between the ADHD and control groups tended toward significance, $t(64) = 1.829$, $p < 0.10$, with participants in the ADHD group overall responding faster (M = 1229.45 ms) than the control group (M = 1307.80 ms).

To follow up on the condition by emotion interaction, paired t-tests were conducted on the mean reaction times observed between the diagnostic and control groups for trials of each emotional expression in each condition. In the match-set condition, results indicated that reaction times were all significantly different between each emotion, all *p*s < 0.01, with the exception of angry and neutral $t(65) = 0.832$, $p = 0.408$, and fearful and sad, $t(65) = 0.848$, $p = 0.399$; participants responded most quickly to happy stimuli (M = 1011.15 ms), followed by neutral (M = 1196.40 ms), angry (M = 1212.85 ms), fearful (M = 1265.38 ms), and sad (M = 1281.23 ms). In the break-set condition, the results indicated that only reaction times between happy and neutral stimuli were significantly different, $t(65) = 2.264$, $p < 0.05$; participants responded most quickly to neutral stimuli (M = 1274.74 ms), followed by angry (M = 1292.95 ms), sad (M = 1293.48 ms), fearful (M = 1303.05 ms), and happy (M = 1308.38 ms). In the no-set condition, results indicated that reaction times were significantly different between happy stimuli and angry, $t(65) = 2.785$, $p < 0.01$, neutral, $t(65) = 2.592$, $p < 0.05$, fearful, $t(65) = 3.869$, $p < 0.01$, and sad stimuli $t(65) = 2.827$, $p < 0.01$; participants responded most quickly to happy stimuli (M = 1280.23 ms), followed by neutral (M = 1327.29 ms), angry (M = 1334.96 ms), sad (M = 1342.09 ms), and fearful (M = 1358.57 ms).

Summary of Study One Findings

Study One compared performance on the emotion n-back task, in terms of accuracy rates and reaction times, between individuals self-reporting a previous diagnosis of ADHD and a group of age- and education-matched controls in a larger longitudinal study. Results from Study One indicated that, overall, participants responded least accurately to match-set trials and most accurately to break-set trials, and to sad trials and most accurately to neutral trials. Participants were least accurate in engaging with sad content and most accurate in engaging with happy content, least accurate in breaking from happy content and most accurate in breaking from neutral content, and were least accurate in responding to angry content and most accurate responding to sad content in the no-set condition. In terms of reaction time, participants responded the fastest to match-set trials and the slowest to no-set trials, and the fastest to happy content and the slowest to fearful content. Participants were fastest to engage with happy content and slowest to engage with sad content, fastest to break from neutral content and slowest to break from sad content, and were quickest to respond to happy content and slowest to respond to fearful content in the no-set condition. There were no group effects observed between the ADHD diagnosis and control groups, apart from a trend effect in both overall accuracy rates and reaction times; participants were overall faster and less accurate in their responses to the emotion n-back task. This may suggest the presence of a speed-accuracy tradeoff, in which individuals with ADHD process emotional information from the environment more quickly than those without the disorder, but at the cost of accuracy.

STUDY TWO

Method

Participants:

Ninety-six participants (63 female and 33 male) were recruited through SONA, the psychology department online subject pool, after responding to a SONA prescreen questionnaire. Participants ranged in age from 18 to 60 years (M = 21.29, SD = 5.48). Race/ethnicity data was collected for 86 participants in the sample, and of this number, 65.6% identified as Caucasian, 12.5% identified as African-American, 1% identified as Hispanic/Latino, 5.2% identified as Asian American, and 5.2% identified as mixed race or other.

As part of the SONA prescreen, participants responded to the Mental Health History Checklist, which asked them to indicate whether they had received a previous diagnosis of a number of mental health conditions. Based on their responses to the Mental Health History Checklist, those who reported a diagnosis of ADHD were eligible to participate as a member of the ADHD diagnostic group, while those who reported no diagnosis of ADHD were eligible to participate as a member of the control group. Of the eligible diagnosis group participants, forty-nine participants (34 female, 15 male) who reported a diagnosis of ADHD signed up to participate in the experiment. Participants ranged in age from 18 to 60 years (M = 21.47, SD = 6.51). Of the eligible control group participants, forty-seven participants (29 female, 18 male) who reported no diagnosis of ADHD signed up to participate in the experiment. Participants ranged in age from 18 to 41 years (M = 21.11, SD = 4.22).

Materials:

Mental Health History Checklist: As used in Study One, the Mental Health History Checklist asked participants to identify whether they had received a previous diagnosis of a number of mental health conditions, such as anxiety, depression, and ADHD (Holman et al., 2008).

Adult ADHD Self-Report Scale (ASRS): Current ADHD symptoms in adulthood were evaluated through the Adult ADHD Self-Report Scale (ASRS), which assesses the frequency that DSM-IV ADHD symptoms have been present for the respondent over the past six months (World Health Organization, 2003). The ASRS, which consists of 18 items, is the official ADHD screening measure of the World Health Organization (WHO), and proves to be useful for this purpose due to its short length (Rosler et al., 2006). As done in previous studies (e.g., Das et al., 2014), scoring was conducted based on the first six items of the questionnaire, which are considered to be the screening items. The items of the ASRS asked participants to rate the frequency with which they experienced a number of symptoms over the past six months on a 0 to 4 scale, with 0 equating to "never" and 4 equating to "very often" (World Health Organization, 2003). Kessler and colleagues (2005) estimate the sensitivity of the measure to be 68.7%, while the specificity is estimated to be 99.5%. Based on optimal empirical cutoffs established by Kessler and colleagues (2007), individuals who gained a sum score of 14 or higher based on the screening items were considered to meet criteria for current ADHD symptomatology in adulthood.

Wender Utah Rating Scale (WURS): Childhood recall of ADHD symptoms, a crucial component of ADHD diagnosis, was ascertained through the short version of the

Wender Utah Rating Scale (WURS; Ward et al., 1993). In a previous study conducted by Ward and colleagues (1993), these 25 items were shown to be endorsed more frequently by individuals who had been diagnosed with ADHD, and assess for the childhood presence of symptoms such as concentration problems and distractibility, inattentiveness, and impulsivity. Items of the WURS asked participants to rate the frequency with which they experienced a number of symptoms in childhood on a 0 to 4 scale, with 0 equating to "not much or very slightly" and 4 equating to "very much". Based on an empirical cutoff with 96% sensitivity, individuals who obtained a sum score of 36 on the 25 items were considered to meet criteria for the presence of ADHD symptoms in childhood (Ward et al., 1993). Previous studies (Ginsberg, Hirvikoski, and Lindefors, 2010; Jahangard et al., 2013; Daigre et al., 2015) have utilized the ASRS and WURS in concert to clarify a current ADHD diagnosis, based on the presence of both childhood and current symptoms.

Emotion n-back task: As in Study One, participants completed the emotion n-back task, in which they were asked to indicate whether a photograph of a facial expression currently being presented was the same as, or different than, the expression of the face presented two faces earlier. The trial types and number of trials were identical to Study One.

Procedure: Students were recruited for participation through SONA, the psychology department's online subject pool, after completing the SONA prescreen, which included the Mental Health History Checklist. Those reporting a diagnosis of ADHD on the Mental Health History Checklist, as well as non-diagnosed controls, were recruited to participate in an in-person laboratory session. Participants completed a survey through the online survey software Qualtrics, and afterward completed the emotion n-back task. As part of their survey participation, individuals who reported a diagnosis of ADHD on the Mental Health History Checklist indicated how they received their diagnosis of ADHD (e.g. via psychological evaluation, a primary care physician, etc.), and completed the ASRS and WURS. Data was de-identified, and each participant was given a three-digit code.

Statistical Analyses:

Participants meeting eligibility criteria were sorted into three groups for analysis. Participants who did not report a diagnosis of ADHD were sorted into the control group. Those who self-reported a diagnosis of ADHD on the Mental Health History Checklist and obtained a score of 36 or higher on the WURS were included in the childhood ADHD diagnosis group. Of those participants, those who also obtained a score of 14 or higher on the ASRS were included in the adult ADHD diagnosis group. Those participants who self reported a diagnosis of ADHD but did not meet criteria on the WURS were not included in the final statistical analyses. After groups were established, mean reaction times and accuracy rates were calculated for each trial of the emotion n-back task, as done in Study 1. Both accuracy rates and reaction times were considered as dependent variables for the purpose of analysis. For each trial type (match-set, break-set, and no-set), a separate two-way repeated measure analysis of variance (ANOVA) was conducted, with diagnostic status (ADHD vs. non-ADHD) as the between-group variable and emotion expression (happy, sad, neutral, angry, or fearful) as the within-subject repeated measures variable. Post-hoc tests were conducted to clarify any significant main effects observed in these analyses.

Results

Participant Characteristics:

Of the 96 participants recruited for Study Two, 27 were excluded from analyses due to obtaining a mean accuracy rate below 60% on the emotion n-back task (14 in the control group, 13 in the ADHD diagnosis group). An additional 11 participants in the ADHD diagnosis group were excluded from analysis due to not meeting the cutoff score of 36 on the WURS. Overall, 55 participants (31 female and 24 male) were included in the final analyses. Participants ranged in age from 18 to 38 years (M = 20.82, SD = 3.48). Participants were divided into three groups for analysis. Those who obtained the cutoff score of 36 or higher on the WURS were sorted into the childhood ADHD diagnosis group. Of those twenty-two participants, those who also obtained the cutoff score of 14 or higher on the ASRS were sorted into the adult ADHD diagnosis group, as done by Ginsberg and colleagues (2010). Those who did not self-report a diagnosis of ADHD were sorted into the control group.

Twenty-two participants (12 female and 10 male) met the cutoff score of 36 on the WURS, and were included in the childhood ADHD diagnosis group. Participants ranged in age from 18 to 38 years (M = 20.91, SD = 4.36). Race/ethnicity data, as well as mental diagnoses reported per the Mental Health History Checklist, are reported in Table 3. Of the participants in this group, 1 reported receiving a diagnosis of ADHD through disability services, 10 reported receiving an ADHD diagnosis through another psychological evaluation, and 11 reported receiving the diagnosis through a primary care physician. 15 participants in this group reported currently taking medication to address their ADHD symptoms, with Adderall and Vyvanse the most commonly-reported medications.

Eleven participants (7 female and 4 male) who met the cutoff of score of 36 on the WURS also met the cutoff score of14 on the ASRS, and were included in the adult ADHD diagnosis group. Participants ranged in age from 18 to 38 years (M = 21.45, SD = 5.80). Race/ethnicity data, as well as mental diagnoses reported per the Mental Health History Checklist, are reported in Table 3.

Thirty-three participants (19 female and 14 male) were included in the control group. Participants ranged in age from 18 to 32 years (M = 20.76, SD = 2.82). Race/ethnicity data, as well as mental diagnoses reported per the Mental Health History Checklist, are reported in Table 3.

Results of Study Two are presented in two sections. The first section presents results from repeated measures ANOVAs conducted on accuracy rates and reaction times for the childhood ADHD diagnosis group versus controls. The second section presents results from repeated measures ANOVAs conducted on accuracy rates and reaction times for the adultADHD diagnosis group versus controls. Means and standard deviations of both accuracy rates and reaction times across all three groups are presented in Table 4. Means and standard deviations of accuracy rates and reaction times are graphically presented in Figures 4 and 5, respectively.

Childhood ADHD

Accuracy Analyses:

To examine how accuracy on the emotion n-back task varied by the presence of ADHD symptoms in childhood, a Trial type (Match-set, Break-set, No-set) by Emotion

(Happy, Sad, Neutral, Anger, Fear) repeated measures ANOVA was calculated on accuracy rates. Results revealed significant main effects for condition, $F(2, 112) = 15.549$, $p < 0.01$, and emotion, $F(4, 224) = 14.835$, $p < 0.01$, qualified by a condition by emotion interaction, $F(8, 448) = 20.586$, $p < 0.01$, and a condition by emotion by diagnostic group interaction, $F(8, 448) = 3.661$, p = 0.001. No other main effects or interactions were significant. To follow up on observed main effects, accuracy rates were averaged, and paired t-tests were conducted between conditions and emotional expressions. Results indicated that differences in accuracy rates were significant for all conditions, all *p*s < 0.01, with participants responding least accurately to match-set trials (M = 75.5%), followed by no-set trials (M = 82.3%), and break-set trials (M = 82.5%). Results also indicated that differences in accuracy rates were significant between all emotions, all *p*s < 0.01, with the exception of angry and sad, $t(54) = 1.635$, $p = 0.108$, and happy and neutral, $t(54) = 0.266$, $p = 0.791$; participants responded least accurately to sad content (M = 75.8%), followed by angry (M = 77.5%), fearful (M = 80.1%), neutral (M = 83.4%), and happy content (M = 83.6%).

To follow up on the observed condition by emotion interaction, paired t-tests were conducted comparing accuracy rates for across emotion expression for each condition. In the match-set condition, results indicated that all differences in accuracy rates between emotional expressions were significant, all *p*s < 0.05, with the exception of angry and sad, $t(54) = 1.376$, $p = 0.174$; participants responded least accurately to sad stimuli (M = 65.9%), followed by angry (M = 68.8%), fearful (M = 75.9%), neutral (M = 80.4%), and happy (M = 86.4%). In the break-set condition, results indicated that significant differences in accuracy rates were present between neutral and angry, $t(54) = 2.632$, $p <$

0.05, happy, $t(54) = 3.606$, $p < 0.01$, fearful, $t(54) = 2.821$, $p < 0.01$, and sad stimuli, $t(54) = 4.758$, $p < 0.01$; participants responded least accurately to sad stimuli (M = 80.0%), then happy (M = 81.0%), fearful (M = 82.5%), angry (M = 82.7%), and neutral (M = 86.4%). In the no-set condition, results indicated that no differences between emotional expressions were significant.

To investigate the observed three-way interaction between condition, emotion and diagnostic group status, independent t-tests were conducted between controls and childhood ADHD participants for each trial type. Results revealed that participants meeting criteria for childhood ADHD were less accurate than the control group in breaking from happy content, $t(56) = 1.245$, $p < 0.01$, and angry content, $t(56) = 0.638$, $p < 0.05$. No other differences were significant.

Reaction Time Analyses:

To examine how participants varied in their response times on the emotion n-back task by the presence of ADHD symptoms in childhood (individuals who met WURS criteria versus controls), a Trial type (Match-set, Break-set, No-set) by Emotion (Happy, Sad, Neutral, Anger, Fear) repeated measures ANOVA was calculated on reaction times. Results revealed significant main effects for condition, $F(2, 112) = 39.197$, $p < 0.01$, and emotion, $F(4, 224) = 28.415$, $p < 0.01$, qualified by a condition by emotion interaction, $F(8, 448) = 17.506$, $p < 0.01$. No other main effects or interactions were significant. To follow up on observed main effects, mean reaction times were calculated for each participant, and paired t-tests were conducted between conditions and emotional expressions. Results indicated that differences in reaction times between conditions were all significant, all *p*s < 0.01, with participants responding most quickly to match-set trials

(M = 1152.7 ms), followed by break-set trials (M = 1217.8 ms), and no-set trials (M = 1253.1 ms). Results also indicated that differences in reaction times between emotions were all significant, all *p*s < 0.05, with the exception of angry and neutral, $t(54) = 0.937$, $p = 0.353$, angry and fear, $t(54) = 1.876$, $p = 0.07$, and fear and sad, $t(54) = 0.036$, $p = 0.971$; participants responded most quickly to happy content (M = 1132.7 ms), followed by neutral (M = 1207.1 ms), angry (M = 1216.6 ms), sad (M = 1241.3 ms), and fearful content (M = 1241.8 ms).

To follow up on the observed condition by emotion interaction, paired t-tests were conducted on the mean reaction times observed between the childhood ADHD and control groups for trials of each emotional expression in each condition. Results indicated that in the match-set condition, all differences in mean reaction times between emotions were significant, all *p*s < 0.05, with the exception of angry and neutral, $t(54) = 0.481$, $p = 0.633$, and fearful and sad, $t(54) = 1.287$, $p = 0.204$; participants responded the fastest to happy content (M = 964 ms), followed by neutral (M = 1160.9 ms), angry (M = 1171.8 ms), fearful (M = 1218.5 ms), and sad content (M = 1248.4 ms). In the break-set condition, in contrast, no differences in mean reaction times were significant. Finally, in the no-set condition, mean reaction times in response to happy content (M = 1201 ms) were significantly faster than to angry, $t(54) = 3.622$, $p < 0.01$, neutral, $t(54) = 2.269$, $p < 0.05$, and fearful content, $t(54) = 4.916$, $p < 0.01$; participants also responded more quickly to happy content than to sad content in a difference that trended toward significance, $t(54) = 1.787$, $p < 0.10$. Participants also responded significantly more quickly to neutral content than to fearful content, $t(54) = 2.801$, $p < 0.05$, and responded significantly more quickly to sad content than to fearful content, $t(54) = 2.393$, $p < 0.05$.

Childhood ADHD Findings Summary:

This analysis compared performance on the emotion n-back task, in terms of accuracy rates and reaction times, between individuals meeting criteria for an ADHD diagnosis in childhood, as measured by the WURS, and the control group. Participants were overall least accurate in responding to match-set trials and most accurate for break-set trials, and responded most quickly to match-set trials and least quickly to no-set trials. In terms of emotion, participants were overall least accurate in responding to sad content and most accurate in responding to happy content, and responded most quickly to happy content and most slowly to fearful content. Participants were least accurate in responding to sad content and most accurate in responding to sad content in the match-set condition, with similar accuracy rates seen for angry and sad content. Participants responded most quickly to happy content and slowest to sad content in this condition, with similar reaction times for angry and neutral content, and fearful and sad content. In the break-set condition, participants were least accurate in responding to sad content and most accurate in responding to neutral content; no significant differences in reaction time were observed. In the no-set condition, no significant differences were observed in accuracy rates between emotional expressions; participants responded more quickly to happy content than angry, neutral, and fearful content, more quickly to neutral than fearful content, and more quickly to sad content than fearful content.

With respect to group differences, individuals in the childhood ADHD group disengaged from happy and angry content significantly less accurately than the control group. No group differences in reaction times were observed.

Adult ADHD Diagnosis

Accuracy Analyses:

To examine how accuracy on the emotion n-back task varied by diagnostic status (individuals who met criteria for ADHD on the WURS and ASRS versus controls), a Trial type (Match-set, Break-set, No-set) by Emotion (Happy, Sad, Neutral, Anger, Fear) repeated measures ANOVA was calculated on accuracy rates. Results revealed significant main effects for condition, $F(2, 90) = 12.111$, $p < 0.01$, and emotion, $F(4, 180) = 8.154$, $p < 0.01$, qualified by a condition by emotion interaction, $F(8, 360) = 11.464$, $p < 0.01$, and a condition by emotion by diagnostic group interaction, $F(8, 360) = 3.174$, $p = 0.002$. To follow up on observed main effects, accuracy rates were averaged, and paired t-tests were conducted between conditions and emotional expressions. Results indicated that participants responded less accurately to match-set trials than to break-set, $t(43) = 5.297$, $p< 0.01$, and no-set trials, $t(43) =4.214$, $p < 0.01$. Differences in accuracy rates between emotions were all significant, all *p*s < 0.01, except for those between angry and fearful content, $t(43) = 1.759$, $p = 0.086$, and angry and sad content, $t(43) = 1.862$, $p = 0.069$, which trended toward significance, and happy and neutral content, $t(43) = 0.540$, $p = 0.592$; participants responded least accurately to sad content (M = 75.2%), followed by angry (M = 77.4%), fearful (M = 79.2%), neutral (M = 82.9%), and happy content (M = 83.4%).

To follow up on the observed condition by emotion interaction, paired t-tests were conducted on the mean accuracy rates for trials of each emotional expression in each condition. Results indicated that in the match-set condition, accuracy rates between emotional expressions were all significantly different from each other, all *p*s < 0.05, with participants responding least accurately to sad content (M = 64.3%), followed by angry content (M = 69%), fearful (M = 74.5%), neutral (M = 80.4%), and happy content (M = 86.2%). In the break-set condition, participants responded significantly more accurately to neutral content than angry content, $t(43) = 2.505$, $p < 0.05$, and happy content, $t(43) = 3.167$, $p < 0.01$, but significantly less accurately to neutral content than fearful, $t(43) = 3.101$, $p < 0.01$, and sad content, $t(43) = 4.622$, $p < 0.01$. Participants also responded significantly more accurately to angry content than to sad content, $t(43) = 2.014$, $p < 0.05$. No significant differences in accuracy rates were observed in the no-set condition.

To investigate the three-way interaction between condition, emotion and group, independent t-tests were conducted between controls and ADHD participants for each trial type. Results revealed that participants meeting criteria for adult ADHD diagnosis were significantly less accurate than the control group in breaking from angry emotional content, $t(45) = 2.420$, $p < 0.05$, and in breaking away from happy emotional content, $t(45) = 2.427$, $p < 0.05$.

Reaction Time Analyses:

To examine how accuracy on the emotion n-back task varied by diagnostic status (individuals who met criteria for ADHD on the WURS and ASRS versus controls), a Trial type (Match-set, Break-set, No-set) by Emotion (Happy, Sad, Neutral, Anger, Fear) repeated measures ANOVA was calculated on accuracy rates. Results revealed a significant main effect for condition, $F(2, 90) = 20.539$, $p < 0.01$, and emotion, $F(4, 180) = 17.672$, $p < 0.01$, qualified by a condition by emotion interaction, $F(8, 360) = 10.031$, $p < 0.01$. To follow up on observed main effects, mean reaction times were calculated for each participant, and paired t-tests were conducted between conditions and emotional expressions. Results indicated that differences in reaction time were significant for all conditions, all *p*s < 0.01, with participants responding most quickly to match-set trials (M = 1158 ms), followed by break-set trials (M = 1218 ms), and no-set trials (M = 1257.7 ms). Differences in reaction times were significant for all emotions, all *p*s < 0.05, except for angry and neutral, $t(43) = 0.182$, $p = 0.856$, angry and sad, $t(43) = 2.006$, $p = 0.051$, and fearful and sad, $t(43) = 0.259$, $p = 0.797$. Participants responded most quickly to happy content (M = 1134.3 ms), followed by neutral (M = 1213.5 ms), angry (M = 1215.7 ms), sad (M = 1244.3 ms), and fearful content (M = 1248.2 ms).

To follow up on the observed condition by emotion interaction, paired t-tests were conducted on the mean reaction times for trials of each emotional expression in each condition. Results indicated that in the match-set condition, all differences in reaction time between emotions were significant, all *p*s < 0.05, except for angry and neutral, $t(43) = 0.231$, $p = 0.818$, neutral and fearful, $t(43) = 1.731$, $p = 0.091$, and fearful and sad, $t(43) = 0.879$, $p = 0.384$. Participants responded most quickly to happy content (M = 969.5 ms), followed by angry (M = 1171.6 ms), neutral (M = 1177.5 ms), fearful (M = 1224 ms), and sad content (M = 1247.2 ms). In the break-set condition, participants responded significantly more quickly to angry content than sad content, $t(43) = -2.881$, $p < 0.01$. In the no-set condition, participants responded significantly more quickly to happy content than angry, $t(43) = 3.324$, $p < 0.01$, neutral, $t(43) = 2.08$, $p < 0.05$, and fearful content, $t(43) = 5.074$, $p < 0.01$. Participants also responded significantly more slowly to fearful content than to neutral, $t(43) = 2.340$, $p < 0.05$, and sad content, $t(43) = 2.638$, $p < 0.05$.

Adult ADHD Findings Summary:

This analysis compared performance on the emotion n-back task, in terms of accuracy rates and reaction times, between individuals meeting criteria for an adult ADHD diagnosis, as measured by the WURS and ASRS, and the control group. Participants were overall less accurate in responding to match-set trials than to no-set or break-set trials, and were quickest to respond to match-set trials and slowest to respond to no-set trials. In terms of emotion, participants were least accurate in responding to sad content and most accurate in responding to happy content, and were quickest to respond to happy content and slowest to respond to fearful content, with similar reaction times for angry and fearful content, angry and sad content, and happy and neutral content. In the match-set condition, participants responded least accurately to sad content and most accurately to happy content, and responded quickest to happy stimuli and slowest to sad stimuli. In the break-set condition, participants responded more accurately to neutral content than angry and happy content, but less accurately than fearful content, and responded more accurately to angry content than sad content. Participants responded more quickly to angry than sad content in this condition. In the no-set condition, no significant differences in accuracy rates were observed. Participants responded more quickly to happy content than angry, neutral, and fearful content. Participants also responded more slowly to fearful content than neutral and sad content. With respect to group differences, individuals in the adult ADHD group disengaged from happy and angry content significantly less accurately than the control group. No group differences in reaction times were observed.

Summary of Study Two Findings

Study Two compared performance on the emotion n-back task, in terms of accuracy rates and reaction times, between individuals meeting criteria for the presence of childhood ADHD symptoms and a group of controls, and individuals meeting criteria for an adult ADHD diagnosis, and a group of controls. Results from Study Two indicated that participants were overall less accurate in responding to match-set trials than other conditions, and were least accurate in their responses to sad content and most accurate in their responses to happy content. Participants responded most quickly to trials in the match-set condition, and slowest to trials in the no-set condition. Similar accuracy rates were observed for angry and sad content, as well as happy and neutral content, across both analyses. Similar patterns of findings emerged between emotions in each condition, with respect to accuracy and reaction time, across both analyses.

With respect to group differences, ADHD diagnosis groups in both the childhood symptoms analysis and adult ADHD diagnosis analysis were significantly less accurate than controls in disengaging from angry and happy emotional content. These differences in accuracy rates, in comparison to controls, were more pronounced in the adult ADHD diagnosis group than in individuals who only met criteria for childhood ADHD. Relative to controls (M = 85.1%), the adult ADHD diagnosis group was more impaired (M = 75.8%) than the childhood ADHD group (M = 79.4%) in disengaging from angry emotional content. Similarly, relative to controls (M = 83.9%), the current, continual ADHD diagnosis group was more impaired (M = 74.1%) in disengaging from happy emotional content than those who met criteria for childhood symptoms only (M = 77.4%). While the number of participants in each group as well as overlap across groups prevents direct comparisons between the ADHD groups, the present findings suggest the presence of a pattern of emotion-specific updating deficits that persists into adulthood, but the deficits appear to be more pronounced in individuals who continue to meet criteria for an ADHD diagnosis in adulthood. No group differences in reaction time were found in either analysis.

DISCUSSION

The present study sought to investigate the interaction between emotion processing and executive function in ADHD by examining one particular mechanism, emotion updating. In Study One, 66 undergraduate students, 30 self-identified as having been diagnosed with ADHD and 36 controls, as part of a larger longitudinal investigation on adjustment to college life, completed an emotion n-back task at an in-person experimental session, in which they were instructed to indicate whether each face that was presented on a computer screen contained the same or different emotional expression than the face presented two faces earlier. In Study Two, 47 undergraduate students completed the same task as in in Study One, with those identifying an ADHD diagnosis completing self-report ADHD measures designed to determine the presence of childhood and current symptomatology to clarify a continual diagnosis of ADHD. Findings from Study One indicated that individuals with ADHD are overall faster to respond to trials on the emotion n-back task, but less accurate in their responses; however, these findings were not replicated in Study Two. Findings from Study Two indicated that individuals with ADHD, both those meeting criteria for a childhood diagnosis of the disorder and those meeting criteria for an adult diagnosis, were less accurate than the control group in disengaging from angry and happy emotional content in working memory. These findings provide preliminary evidence to suggest that individuals with ADHD process emotional information in working memory differently than those without the disorder, and that emotion-specific emotion updating deficits may be associated with ADHD. Furthermore, a similar pattern of findings was observed across individuals who met criteria for ADHD in childhood and those who meet criteria for an adult ADHD diagnosis, suggesting that this profile of emotion updating deficits persists into adulthood.

It was originally hypothesized in both Study One and Study Two that individuals with ADHD would be less accurate than controls on the emotion n-back task, pointing to a general deficit in emotion updating. Such a finding was observed in Study One, in which participants in the ADHD group demonstrated significantly lower accuracy rates on the emotion n-back task across the board. These findings are in line with previous studies, which have reported broadband deficits in accurately identifying emotional facial expressions associated with ADHD (Cadeskey et al., 2000; Corbett & Glidden, 2000). Interestingly, in Study One, participants in the ADHD group also demonstrated lower reaction times than the control group on the emotion n-back task, suggesting that individuals with ADHD process emotional information in working memory more quickly than those without the disorder. It is postulated, then, that a speed-accuracy tradeoff may be associated with emotion updating in ADHD; by this idea, individuals with ADHD process and update emotional information more quickly than those without the disorder, but at the cost of doing so in an accurate fashion. This is consistent with ideas presented in the original hypothesis of this investigation, which posited that, in individuals with ADHD, while emotional information enters working memory more easily, difficulties in processing arise once the information is there. Findings from this study, however, are the first to suggest the presence of a speed-accuracy tradeoff, and come into conflict with previous findings in the literature. In an event-related potential study that used photos of emotional faces as stimuli, Raz and Dan (2015) found that individuals with ADHD exhibited slower reaction times on the task than the control group. Such findings also come into conflict with those obtained in Study Two. Indeed, neither lower accuracy rates in individuals with ADHD, nor evidence of a speed-accuracy tradeoff, was obtained in Study Two. While this lack of replication across studies in the present investigation may be a function of difference in sample size between Study One and Study Two, the picture remains unclear, and further study is needed.

Unlike Study One, findings from Study Two suggest the presence of emotion-specific emotion updating deficits in ADHD. Contrary to the original hypotheses and to previous research (e.g., Pelc et al., 2006; Marx et al., 2011), the identified emotion-specific effects were not confined to negative emotion. Instead, decreased accuracy in disengaging from angry and happy emotional content was observed in individuals with ADHD as compared to those without the disorder; these differences were not observed for any other condition or emotion on the emotion n-back task. Current theories of emotion, which allow for emotional dimensions beyond valence, may provide insight into the mechanisms driving these observations. In particular, Rolls (2013) describes a motivational approach to emotion, in which emotions are conceptualized as being created by reinforcers in the environment (rewards or punishments), and are designed to facilitate either an individual's approach toward a particular stimulus in that environment, or their avoidance of that stimulus. By this framework, emotions such as fear and sadness are considered *avoidance* emotions; these emotions create states that are designed to motivate an individual to withdraw from an unpleasant or potentially harmful stimulus in the environment. Anger and happiness, on the other hand, are considered *approach* emotions; these emotions create states which encourage an individual to approach a pleasant stimulus in the environment, or confront a threat (Rolls, 2013). Findings, then, appear to point to a deficit in disengaging from approach emotions in working memory associated with ADHD. The present pattern of findings may be particularly relevant for understanding a key characteristic of ADHD, impulsivity. Individuals with ADHD often demonstrate heightened impulsivity, reflected by behaviors such as difficulty in delaying gratification and acting quickly without considering consequences (American Psychiatric Association, 2013). One may conjecture, then, that difficulty in disengaging from emotional content designed to facilitate approach behavior, may contribute to the impulsivity that is characteristic of the disorder, although this idea is largely speculative based on Study Two's limited findings.

The accuracy findings from Study Two were largely consistent across both ADHD diagnosis groups in Study Two, with individuals meeting criteria for childhood ADHD symptoms, as well as those meeting criteria for an adult diagnosis of ADHD, demonstrating significantly lower accuracy in disengaging from happy and angry emotional content relative to controls. The observed differences are more pronounced in the adult ADHD diagnosis group, with those individuals obtaining lower accuracy rates, relative to controls, than those meeting criteria for childhood ADHD symptoms only. Such findings are consistent with the original hypothesis that observed deficits in emotion updating would be exacerbated in individuals who continue to meet criteria for an ADHD diagnosis in adulthood, and provide preliminary evidence to support this idea. Perhaps more critically, however, these findings suggest that though individuals who no longer meet criteria for ADHD in adulthood are less impaired than their counterparts who continue to meet diagnostic criteria, they are still significantly impaired in emotion updating in comparison to controls and these deficits persist into adulthood. Such a pattern is consistent with the profile of impairments in social and emotional functioning associated with ADHD across the lifespan. Young and Gudjonsson (2008), for instance, found that, in comparison to individuals who continued to meet criteria for ADHD in adulthood, those in remission or partial remission from their symptoms demonstrated significant improvement in a number of psychosocial domains, including anxiety, drug use, and police contact; however, problems in other psychosocial domains, such as friendship, continue to persist into adulthood even with remission of ADHD symptoms. It is possible that the deficits in processing emotional information observed in the current investigation are a similar persistent emotional effect that could have implications for an individual's emotional and social functioning, even if diagnostic criteria for ADHD are no longer met. While the relationship between decreased emotion updating impairment, along with other domains of social and emotional functioning, and no longer meeting criteria for an ADHD diagnosis in adulthood remains unclear, these findings provide an exciting first step toward demystifying this relationship.

Though this investigation does put forth potentially exciting preliminary findings regarding emotion updating in ADHD, there are a number of limitations present that may have influenced the results. Fundamentally, findings from the present investigation, particularly for Study One, were limited by reliance on self-report for identification of ADHD diagnosis. Student constraints, as well as constraints on resources, prevented the use of more thorough diagnostic measures, such as structured clinical interviews. Self-report alone may not provide a wholly accurate picture of diagnosing the disorder, and supplemental measures should be used in subsequent studies to confirm ADHD diagnoses. For example, while the ASRS screening measure is one of the most widelyused self-report measures of current ADHD symptomatology in adults, its sensitivity is only estimated at 68.7%, meaning that the measure correctly identifies 68.7% of adults with an ADHD diagnosis as having the disorder; it is possible, then, that more individuals in the sample met criteria for an adult ADHD diagnosis than the measure was able to identify (Kessler et al., 2005).

Finding in the present study may have also been impacted by the high rates of comorbidity present in the ADHD groups in both Study One and Study Two. In Study One, for instance, 30% of the sample in the ADHD group indicated a previous diagnosis of an anxiety disorder, and 23.3% indicated a previous diagnosis of depression; these disorders are frequently comorbid with ADHD. Findings from the National Comorbidity Survey estimate that in adults diagnosed with ADHD, 38.3% were diagnosed with a mood disorder, 47.1% with an anxiety disorder, and 15.2% with an alcohol or substance use disorder (Kessler et al., 2006). While the comorbidity rates in Study One were lower than those reported in the National Comorbidity Survey, the ADHD group samples in Study Two saw even higher rates of comorbidity, with 63.6% of both the childhood ADHD diagnosis and adult ADHD diagnosis samples reporting a previous diagnosis of depression, much higher than population comorbidity estimates, such as those observed by Kessler and colleagues (2006). Such a high degree of coexisting psychiatric disorders present in the sample could have influenced the results obtained in these studies. Crawford, Kaplan, and Dewey (2006), for instance, found that more impairment on working memory and visual-motor skills tests was associated with a higher number coexisting disorders in children with ADHD. While the impact of comorbidity on emotion updating in ADHD is unknown, such findings from existing cognitive studies may suggest that the deficits found in Study Two may not be related to ADHD alone. Furthermore, previous findings on the emotion n-back task in individuals with depression have pointed to deficits in disengaging from happy emotional content, relative to those without the disorder (Levens & Gotlib, 2010). While these deficits were observed in reaction times, rather than accuracy rates, it is possible that comorbid depression could have driven the present investigation's observed deficits in disengaging from happy content, rather than these deficits being characteristic of ADHD. Further investigation will be required to clarify this relationship, in particular future research should recruit ADHD participants with and without comorbid depression and anxiety to resolve this open question.

Another limitation of note is that the majority of participants recruited for this investigation were young adults between the ages of 18 and 25 attending college, and thus the samples obtained may not be representative of the general population. While a goal of the study was to examine the persistence of ADHD symptoms into the beginning of adulthood, suggesting a focus on young adults in the 18 to 25 year range, additional research is needed to replicate Study Two’s findings and determine if the pattern persists further into adulthood. Small sample sizes, particularly in Study Two, are another potential limitation of the results obtained in this investigation. It is possible that with larger numbers, more effects could have been obtained in analyses, pointing to further group differences between individuals with ADHD and those without the disorder, as well as emotion-specific deficits in emotion updating. Additionally, consistent findings across both analyses in Study Two may not be the function of persistent deficits in processing emotional information in ADHD, but rather a function of the fact that the samples for the two analyses largely overlapped; half of the participants in the childhood ADHD symptoms analysis (N = 22) were included in the adult diagnosis analysis (N = 11).

Small sample sizes also did not allow for ADHD groups to be separated by diagnostic subtype in analysis. Previous studies have pointed to differing deficits in emotional functioning and regulation by diagnostic subtype; Maedgen and Carson (2000), for instance, found that children diagnosed with ADHD, combined type, which includes symptoms associated with the predominately hyperactive-impulsive presentation of the disorder, demonstrated more problems with emotion reactivity and regulation than those diagnosed with ADHD, inattentive type. It is possible that results obtained in the current investigation may have a link to impulsivity, and may therefore differ by whether an individual meets criteria for the predominately inattentive presentation, versus the predominately hyperactive-impulsive presentation. Creating further separation between the two samples in future studies, then, would allow researchers to be more confident in their interpretation of observed effects.

The current investigation provides preliminary evidence that informs how individuals with ADHD process emotional information, which may have wide-reaching behavioral, social, and emotional implications for those who have the disorder. The finding that ADHD individuals are less accurate at disengaging from approach related emotional content (i.e. happiness and anger), begin to paint a picture of how difficulties in processing emotional information in working memory may be contributing to behavior. Difficulty disengaging from emotional content designed to facilitate approach behavior, may contribute to the impulsivity that is characteristic of the disorder. This knowledge may potentially be useful in building targeted interventions designed to teach individuals with ADHD, both children and adults, skills to improve emotion recognition and regulation, as well as social functioning. Such interventions could provide focused instruction on the distinctions between not only discrete emotions, but also the categories into which emotions fall in the approach and avoidance framework. Armed with this knowledge, individuals could learn emotion regulation skills that would assist them with identifying situations in which difficulty disengaging from emotions facilitating approach might lead to negative consequences, and thus better cope with them. A combination of psychoeducation and applied skills could potentially provide utility in reducing the negative outcomes associated with the disorder, and provide opportunities for maximum success in our complex, fast-paced social environment. While research in this area is just beginning, and more work must be done to replicate and extend the present findings, this study offers a first step in elucidating the role of emotion and executive function interactions in ADHD.

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APPENDIX A: TABLES

Table 1: Study One demographic information for the final sample included in analyses (N = 36 Controls, N = 30 ADHD).

	Controls		ADHD	
	N	%	N	%
Gender				
Female	24	66.7	20	66.7
Male	12	33.3	10	33.3
Race/Ethnicity				
Caucasian	27	75	24	80
African-American	4	11.1	2	6.7
Hispanic/Latino	2	5.6	0	0
Asian-American	0	0	1	3.3
Pacific Islander	0	0	1	3.3
Mixed Race/Other	3	8.3	2	6.7
Diagnoses				
Anxiety disorder	5	13.9	9	30
Eating disorder	1	2.8	4	13.3
Depression	3	8.3	7	23.3
PTSD	0	0	2	6.7
Learning disorder	1	2.8	4	13.3
Behavior disorder	0	0	2	6.7
Alcohol/substance use	0	0	1	3.3
Insomnia	0	0	1	3.3
Other	0	0	1	3.3

Table 2: Study One reaction times and accuracy rates.

	Controls		ADHD	
	RT	Acc	RT	Acc
Match-set				
Angry	1259 (201)	70% (14%)	1158 (203)	69% (17%)
Happy	1031 (142)	86% (12%)	987 (180)	84% (12%)
Neutral	1229 (182)	83% (10%)	1157 (205)	78% (11%)
Fear	1289 (177)	76% (13%)	1237 (234)	73% (16%)
Sad	1322 (167)	66% (15%)	1232 (204)	66% (15%)
Break-set				
Angry	1322 (190)	85% (9%)	1258 (219)	79% (15%)
Happy	1348 (171)	81% (12%)	1261 (219)	78% (12%)
Neutral	1320 (187)	89% (10%)	1220 (229)	85% (11%)
Fear	1328 (185)	85% (11%)	1273 (216)	77% (13%)
Sad	1339 (195)	83% (11%)	1239 (232)	79% (8%)
No-set				
Angry	1372 (198)	82% (13%)	1290 (210)	76% (11%)
Happy	1310 (189)	87% (12%)	1245 (209)	78% (13%)
Neutral	1370 (205)	82% (15%)	1276 (238)	79% (18%)
Fear	1390 (200)	83% (13%)	1321 (245)	79% (12%)
Sad	1388 (192)	83% (14%)	1287 (264)	83% (14%)

Note: Standard deviations are shown in parenthesis; RT = reaction time; Acc = Accuracy

Table 3: Study Two demographic information for final sample included in analyses (N = 33 Controls, N = 22 Childhood ADHD, N = 11 Adult ADHD)

	Controls		Childhood		Adult	
	N	%	N	%	N	%
Gender						
Female	19	57.6	12	54.5	7	63.6
Male	14	42.4	10	45.5	4	36.4
Race/Ethnicity						
Caucasian	17	51.5	20	90.9	9	81.8
African-American	5	15.2	0	0	0	0
Hispanic/Latino	0	0	0	0	0	0
Asian-American	3	9.1	0	0	0	0
Pacific Islander	0	0	0	0	0	0
Mixed Race/Other	1	3	1	4.5	1	9.1
Not Identified	5	15.2	1	4.5	1	9.1
Diagnoses						
Anxiety disorder	2	6.1	13	59.1	7	63.6
Eating disorder	0	0	5	22.7	4	36.4
Depression	3	9.1	14	63.6	7	63.6
PTSD	0	0	0	0	0	0
Learning disorder	1	3	5	22.7	3	27.3
Behavior disorder	0	0	0	0	0	0
Alcohol/substance use	0	0	4	18.2	3	27.3
Bipolar disorder	1	3	0	0	0	0
Other	0	0	0	0	0	0

Table 4: Study Two reaction time and accuracy rates.

	Controls		Childhood		Adult	
	RT	Acc	RT	Acc	RT	Acc
Match-set						
Angry	1183(177)	70%(13%)	1154(195)	68%(18%)	1136(242)	68%(16%)
Happy	967(134)	87%(12%)	942(130)	86%(14%)	941 (119)	86%(13%)
Neutral	1179(129)	80%(12%)	1137(202)	81%(12%)	1183(269)	81%(12%)
Fear	1243(193)	74%(15%)	1180(174)	79%(14%)	1163(188)	76%(10%)
Sad	1250(179)	63%(15%)	1241(180)	72%(16%)	1228(192)	72%(16%)
Break-set						
Angry	1194(156)	85%(9%)	1208(222)	79%(15%)	1178(263)	76%(18%)
Happy	1238(165)	84%(9%)	1220(199)	77%(16%)	1200(207)	74%(18%)
Neutral	1205(126)	87%(9%)	1207(208)	86%(8%)	1203(257)	86%(9%)
Fear	1216(171)	83%(11%)	1214(177)	82%(12%)	1217(226)	78%(10%)
Sad	1250(167)	81%(12%)	1199(158)	79%(12%)	1209(181)	75%(14%)
No-set						
Angry	1277(184)	82%(13%)	1264(197)	79%(16%)	1276(227)	76%(18%)
Happy	1227(163)	83%(13%)	1164(169)	85%(13%)	1132(186)	84%(12%)
Neutral	1263(204)	82%(13%)	1219(246)	86%(13%)	1201(276)	82%(16%)
Fear	1321(173)	82%(15%)	1237(220)	82%(18%)	1234(285)	78%(20%)
Sad	1249(191)	84%(12%)	1246(231)	78%(16%)	1244(318)	76%(19%)

Note: Standard deviations are shown in parenthesis; RT = reaction time; Acc = Accuracy

APPENDIX B: FIGURES

Figure 1

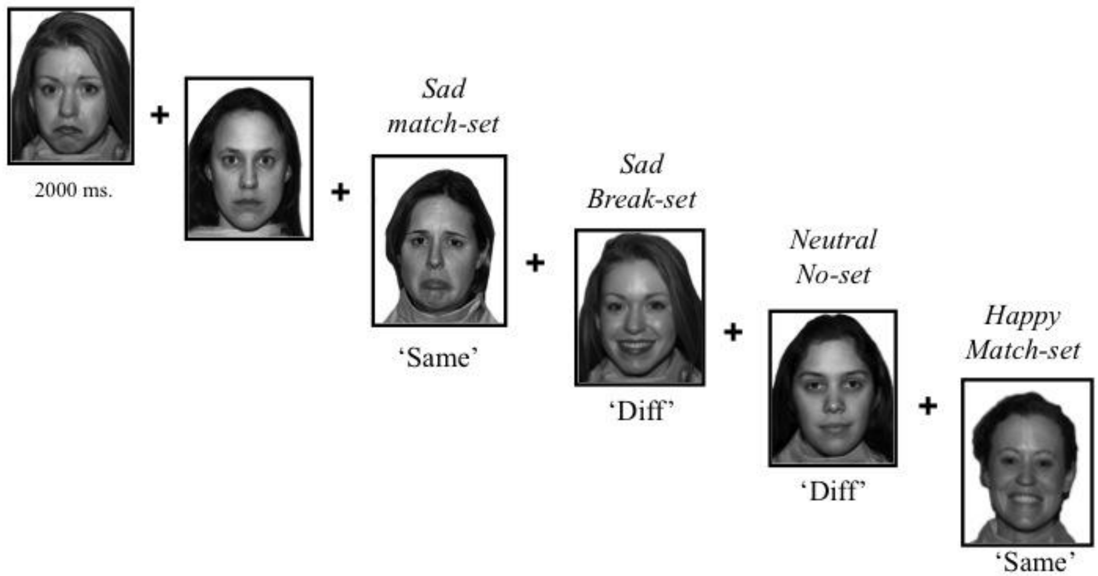

Figure 1: Emotion n-back task sample trials. Participants viewed each face for 2000 ms. with an interval of 2500 ms between stimuli. Participants are instructed not to respond to the first two trials, and to just remember the facial expressions presented; from the third trial onward, participants are instructed to indicate whether the current facial expression is the same as, or different than, the facial expression viewed two expressions earlier. Two initial trials, followed by four trials with correct responses, are displayed in this figure.

Figure 2

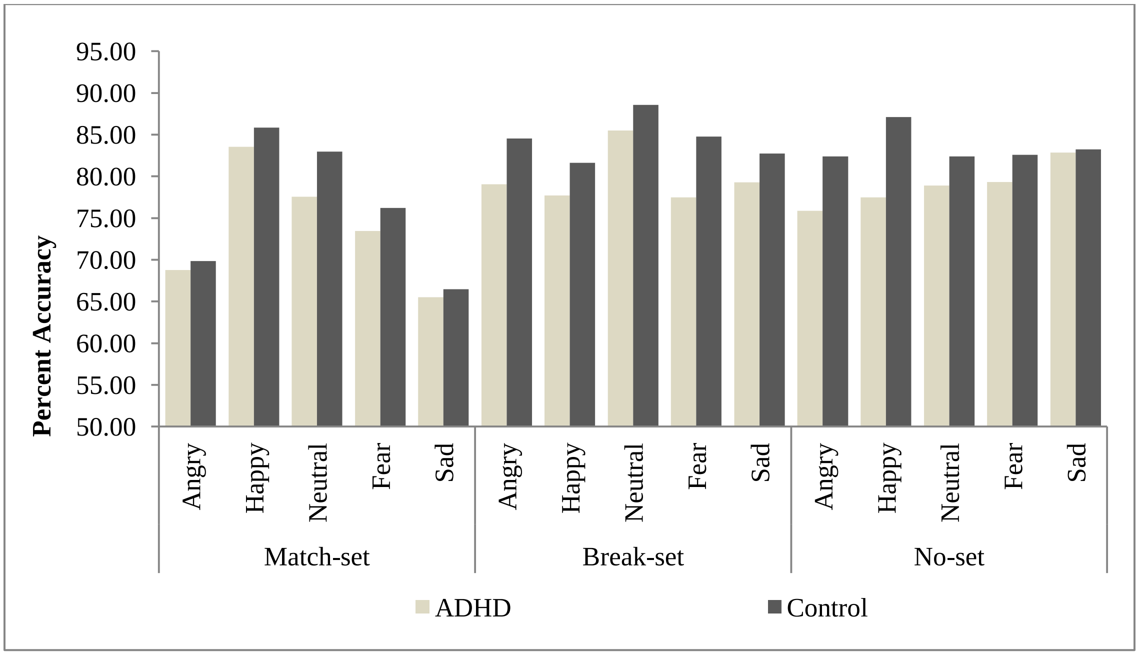

Figure 2: Study One accuracy findings. Participants self-reporting a diagnosis of ADHD were overall less accurate in responding to the emotion n-back task in a difference that trended toward significance, $F(1, 64) = 3.114$, $p < 0.10$.

Figure 3

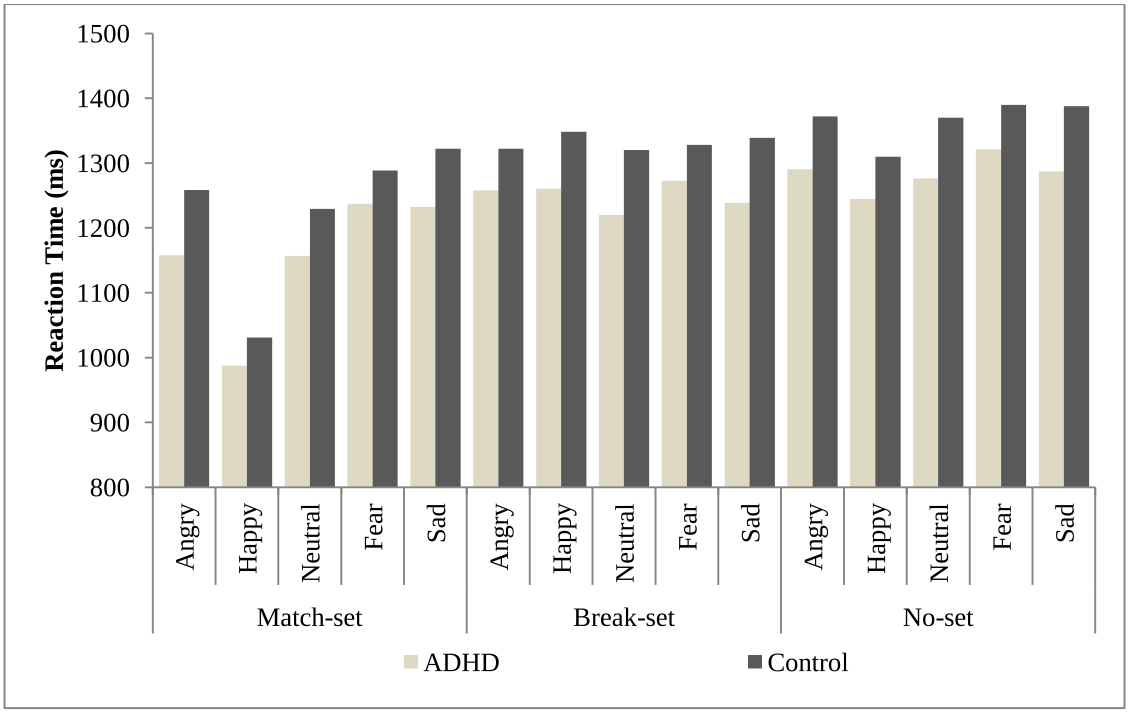

Figure 3: Study One reaction time findings. Participants self-reporting an ADHD diagnosis were overall faster in responding to the emotion n-back task in a difference that trended toward significance, $F(1, 64) = 3.346$, $p < 0.10$.

Figure 4

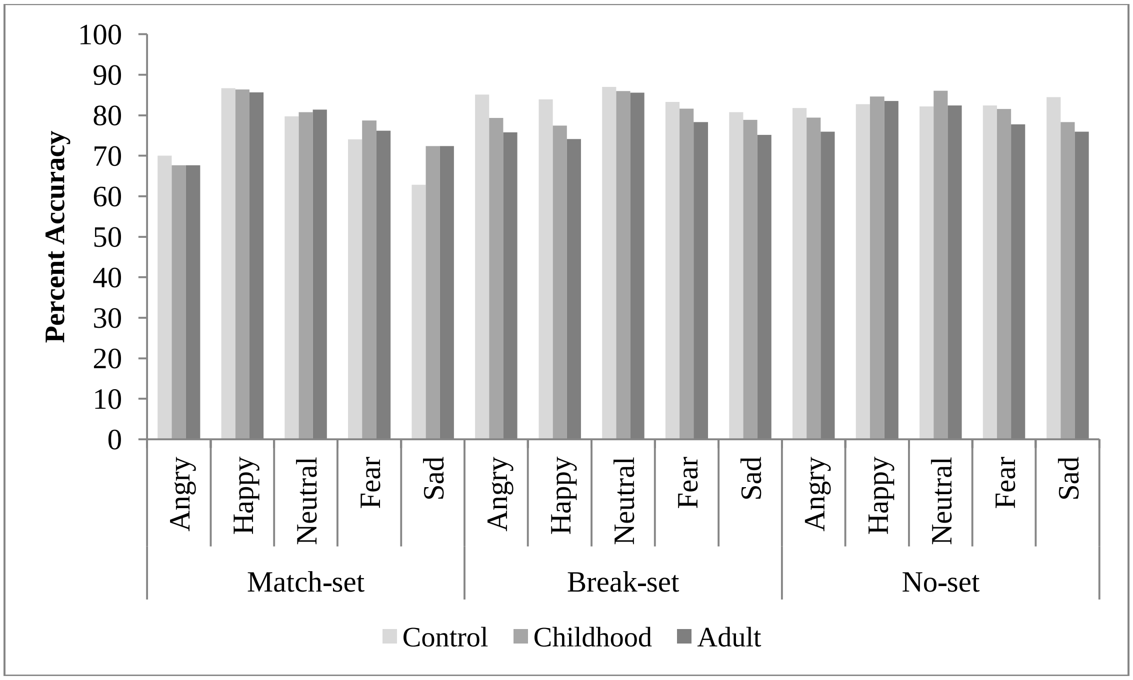

Figure 4. Study Two accuracy findings. Results indicated that participants were overall less accurate in responding to match-set trials than other conditions, and were least accurate in their responses to sad content and most accurate in their responses to happy content. Individuals with ADHD were significantly less accurate than the control group in disengaging from angry emotional content in both the childhood ADHD group, $t(56) = 0.638$, $p < 0.05$, and the adult diagnosis group, $t(45) = 2.420$, $p < 0.05$. Individuals with ADHD were also significantly less accurate than the control group in disengaging from happy emotional content in both the childhood ADHD group, $t(56) = 1.245$, $p < 0.01$, and the adult diagnosis group, $t(45) = 2.427$, $p < 0.05$.

Figure 5

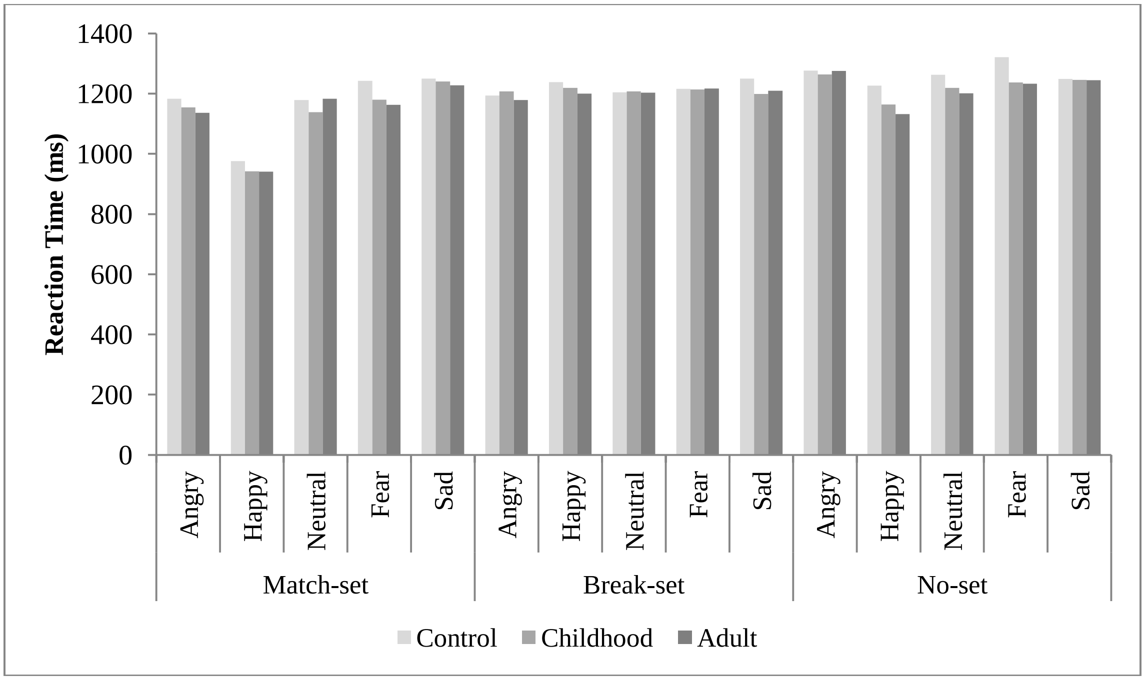

Figure 5. Study Two reaction time findings. Participants overall responded most quickly to trials in the match-set condition, and slowest to trials in the no-set condition. Participants responded most quickly to happy content, and more slowly to sad and fearful content. No significant group differences in reaction time emerged between controls and either the childhood ADHD or adult ADHD groups.

APPENDIX C: DEMOGRAPHICS QUESTIONNAIRE

1. Please select. Are you: "Male" or "Female"
2. What is your major? (please write undeclared if you have not yet decided on a major) ________________________
3. What was your SAT score: ____________. If you took a test other than the SATs, what was the test and what was your score: ____.
4. Has an immediate family member (mother, father, sister, brother) ever been diagnosed with depression? Y / N
5. What best describes your racial identity: ____.
6. How old are you in years? ____.
7. How many times a day do you brush your teeth?
8. Do you live with parents at home, in a dorm, or in an apartment?
9. Do you drink alcohol? If so, what kind and how often?
10. How many different kinds of fruits and vegetables do you eat per day?
11. How many minutes of exercise do you get a day (include walking to classes, dining hall, etc)?
12. Do you routinely take prescription medication? If so, which medication(s), and how frequently do you take them?
13. Approximately how many 'friends' do you have on facebook?
14. How often do you post updates to your facebook page?
15. How often do you check for comments to your facebook posts?
16. How were you diagnosed with ADHD?
    - Disability Services
    - Other Psychological Evaluation
    - Primary Care Physician
    - Other

APPENDIX D: MENTAL HEALTH HISTORY CHECKLIST

Has a medical doctor or psychologist ever diagnosed you as suffering from any of the following conditions?

Diagnosis	**NO**	**YES**
Anxiety disorders (e.g., anxiety disorder, panic disorder, phobias, etc.)	0	1
Eating disorder (e.g., bulimia, anorexia)	0	1
Depression (e.g., major depression, dysthymia, etc.)	0	1
Posttraumatic Stress Disorder (PTSD)	0	1
Learning disability	0	1
Attention-Deficit/Hyperactivity Disorder (ADHD/ADD)	0	1
Behavior Disorder (e.g., Conduct disorder, oppositional defiant disorder)	0	1
An alcohol or substance abuse problem/disorder	0	1
Other condition. Specify ______________________________	0	1

APPENDIX E: WENDER UTAH RATING SCALE (WURS)

Please indicate the extent to which each item was true for you *in childhood*.
As a child, I was (or had):
Not at all or very slightly Mildly Moderately Quite a bit Very much

1. Concentration problems, easily distracted
2. Anxious, worrying
3. Nervous, fidgety
4. Inattentive, daydreaming
5. Hot- or short-tempered, low boiling point
6. Temper outbursts, tantrums
7. Trouble with stick-to-it-tiveness
8. Stubborn, strong-willed
9. Sad or blue, depressed, unhappy
10. Disobedient, rebellious, sassy
11. Low opinion of myself
12. Irritable
13. Moody, ups and downs
14. Angry
15. Trouble seeing things from someone else's point of view
16. Acting without thinking, impulsive
17. Tendency to be immature
18. Guilty feelings, regretful
19. Losing control of myself
20. Tendency to be or act irrational
21. Unpopular with other children
22. Trouble with authorities, trouble with school, visits to principal's office
23. Overall a poor student, slow learner
24. Trouble with mathematics or numbers
25. Not achieving up to potential

APPENDIX F: ADULT ADHD SELF-REPORT SCALE (ASRS)

For each item, please indicate the option that best describes how you have felt or acted over *the past 6 months*.

Never Rarely Sometimes Often Very Often

1. How often do you have trouble wrapping up the final details of a project, once the challenging parts have been done?
2. How often do you have difficulty getting things in order when you have to do a task that requires organization?
3. How often do you have problems remembering appointments or obligations?
4. When you have a task that requires a lot of thought, how often do you avoid or delay getting started?
5. How often do you fidget or squirm with your hands or feet when you have to sit down for a long time?
6. How often do you feel overly active and compelled to do things, like you were driven by a motor?
7. How often do you make careless mistakes when you have to work on a boring or difficult project?
8. How often do you have difficulty keeping your attention when you are doing boring or repetitive work?
9. How often do you have difficulty concentrating on what people say to you, even when they are speaking to you directly?
10. How often do you misplace or have difficulty finding things at home or at work?
11. How often are you distracted by activity or noise around you?
12. How often do you leave your seat in meetings or other situations in which you are expected to remain seated?
13. How often do you feel restless or fidgety?
14. How often do you have difficulty unwinding or relaxing when you have time to yourself?
15. How often do you find yourself talking too much when you are in social situations?
16. When you're in a conversation, how often do you find yourself finishing the sentences of people you are talking to, before they can finish them themselves?
17. How often do you have difficulty waiting your turn in situations when turn taking is required?
18. How often do you interrupt others when they are busy?