An investigation of attention biases to emotional faces in individuals with ADHD

Osly D. Galobardi[1] and Sara M. Levens[2]
[1]Eastern Kentucky University and [2]University of North Carolina at Charlotte

Abstract

The present studies aimed to examine attention capture biases in response to emotional stimuli in adults with Attention Deficit Hyperactivity Disorder (ADHD). Individuals with ADHD and matched controls completed an affective priming task with happy, sad, angry, disgust and neutral facial expressions as stimuli. In Study One, individuals who self-disclosed a diagnosis of ADHD showed greater attention capture for angry and happy expressions, though marginally less attention capture for disgusted expressions. In Study Two, individuals who met criteria for Child ADHD and/or current diagnosis of ADHD demonstrated greater attention capture for disgusted emotional expressions and less attention capture for angry emotional expressions. Different findings between study One and Two suggest different emotion processing patterns as individuals with ADHD develop into adulthood.

Key Words:
attention, emotion processing, ADHD

Rates of Attention Deficit Hyperactivity Disorder (ADHD) diagnosis have been increasing in recent years with parent-reported ADHD among children 4-17 years of age increasing by 22%, from 7.8% in 2003 to 9.5% in 2007 (Centers for Disease Control and Prevention [CDC], 2010). The rate of ADHD diagnosis increase among older teens is even more robust at 42% suggesting that young adults are struggling more with ADHD symptoms (CDC, 2010). Characteristics of ADHD include deficits in executive function and persistent hyperactivity-impulsivity behavior. According to the American Psychological Association, people with ADHD face difficulty staying organized, maintaining focus, planning for the future, and adapting to changing environments (2015). As a prominent issue in developmental health, a great deal of research has focused on identifying hallmark ADHD characteristics, such as attention deficits (Pritchard, Neumann, & Rucklidge, 2007) as well as specific deficits in emotion processing (Schulz et al., 2014). However, research examining how emotion processing and attention interact in individuals with ADHD is limited. As executive control processes are

necessary to manage thoughts and actions in order to achieve a goal, it may be that maladaptive interactions between emotion processing and attention could be mechanisms contributing to the development of ADHD. The goal of the present study is to investigate whether individuals with ADHD exhibit attentional biases in response to specific emotional stimuli.

Attention plays an important role not only in completing complex goal-oriented tasks, but also in simple everyday tasks, such as cooking a meal. Many people underestimate the influence attention has in completing goal-directed tasks as well as in perception and decision making. Attention enables us to process salient goal-oriented information while suppressing salient but extraneous information (Fenske and Raymond, 2006). While some aspects of attentional processing are involuntary, attention can be controlled. Individuals can allocate cognitive resources to voluntarily select what stimuli deserve attention resources and which do not (Chun and Turk-Browne, 2007). For example, a customer in a coffee shop can choose to focus on the book they are reading and ignore the talking people standing in line

and the loud espresso machine. With the idea that attention requires a range of cognitive resources, research has investigated the impact of attention on working memory. Working memory is a limited capacity system that maintains, manipulates and organizes relevant information from the environment and long-term memory in accordance with task demands and goals (Lindström and Bohlin, 2011). Attention and working memory work in tandem by providing a focus and a plan of action to complete a goal. However, a lack of control in attention or working memory, or possibly in both, results in performance decrements and goal pursuit issues (Rohlf et al., 2012). As processing goal-relevant information is a central focus of both attention and working memory, it may be that individuals with ADHD are less able to identify and or maintain attentional focus on goal-relevant information.

While what information is goal-relevant constantly varies as a function of an individual's current goal, emotional content based on its evolutionary significance continually captures attention (Ohman, Flykt, & Esteves, 2001). Recent research has revealed, for example, that emotion greatly affects attention in that emotion improves early visual processing of peripheral stimuli encountered in the environment to facilitate task performance (Phelps, Ling, & Carrasco, 2006). In addition, emotional content can capture attention to increase arousal, which in turn will facilitate a rapid behavioral response to environmental stimuli. For instance, when playing an alien invasion video game, your level of concentration increases when a scary alien captures your attention, generating quick finger dexterity on the controller to kill the alien just in time to complete that level of the video game. In essence, emotion focuses attention, which subsequently focuses working memory on relevant emotional content, which in turn influences decision-making and goal completion. In the context of ADHD, a dysfunction in emotion-attention capture may interfere with goal-directed capture of attention resulting in cognitive inflexibility and impaired goal pursuit. Understanding how individuals with ADHD attend to emotional content is therefore important for identifying the mechanisms involved in ADHD behavior.

Although multiple research studies have found that children with ADHD perform worse on

emotion recognition tasks than children without ADHD (Da Fonseca, Seguier, Santos, Poinso, and Deruelle, 2009), identifying emotion-attention biases in ADHD has been more challenging with studies reporting contrasting results. For example, research by Weissman, Chu, Reddy, & Molhman (2012) evaluated and compared attention mechanisms in adolescents 8-16 years old ($M = 11.57$ years) with anxiety disorders and children with ADHD. The participants completed a Faces Dot Probe task, which assessed reaction time to the dot probe after viewing emotional faces (happy, angry, or sad). Results revealed that in comparison to children with ADHD, children with anxiety disorder exhibited a greater selective processing bias towards threat (negative) cues. Children with ADHD showed no significant attentional bias towards any emotion, rather they exhibited a generalized attention deficit. The study suggests that a generalized attention deficit may be contributing to ADHD symptoms as opposed to a heightened attention capture by emotional content.

In contrast, research by Pishyareh, Tehrani-Doost, Mahmoodi-Gharaie, Khorrami, & Rahmdar (2015) found that male children with ADHD ages 6-11 years old *do* exhibit an increased attentional bias to emotional images. Sustained attention was measured with an eye-tracking task in which the participants viewed paired pictures of faces categorized as "neutral," "pleasant," or "unpleasant." Results revealed that the ADHD group focused on unpleasant images for a significantly longer period than pleasant and neutral images. The finding suggests that negative emotional stimuli may capture the attention of individuals with ADHD in a manner that causes a disruptive attentional shift away from task relevant information toward negative emotional stimuli in the environment.

Taken together, findings from these studies illustrate how research on emotion biases in individuals with ADHD has been contradictory and warrants further investigation. In addition, ADHD is a developmental disorder whose symptoms changes as the individual matures. The majority of research on ADHD investigating emotion biases in attention had been conducted on children or young adults (Da Fonseca et al., 2009; Pishyareh et al., 2015; Pritchard et al., 2007). The attention deficits and challenges an individual with ADHD experiences as a child or

young adolescent may be qualitatively different than those experienced by an adolescent who is older and entering young adulthood. Adolescence is a critical time period of development in which aspects of executive function such as, affective and cognitive coordination, and long-term planning, improves increasingly via synaptic pruning (Steinberg, 2005). According to de Luca et al. (2003), strategic planning and organization of goal-directed behavior reaches optimum level between the ages 20-29 years old. As individuals with ADHD develop into adulthood, a lag in the development of the prefrontal cortex could interfere with the cognitive processes that enable goal completion. Rates of diagnosis are increasing dramatically, particularly in teens (CDC, 2010) highlighting the importance of research examining emotion biases in attention in older adolescents and young adults. For example, it is not known if increases in ADHD diagnoses are genuine (reflecting increases in stimulation in the environment), or if rates of ADHD are increasing because of over-diagnosis and demand for stimulant medications. If the latter is true then emotion bias research could help reduce false positive ADHD diagnosis. If for example, research is able to identify emotional biases that are associated with ADHD status, then alternate forms of testing could be developed that are not solely based on self-report which could help reduce false-positive diagnoses and prevent false diagnoses aimed at gaining access to stimulant medications.

The goal of the present study is to resolve contrasting emotion-attention bias findings in a sample of young ADHD adults who are developmentally older than many childhood and adolescent ADHD samples. Using the affective priming task, this study will examine whether emotional stimuli in individuals with ADHD capture attention or facilitate rapid processing of emotional content. The affective priming task involves viewing a prime and a target consecutively and then indicating the valence (negative or positive) of the target as quickly as possible. The primes and targets consist of happy, sad, angry, disgust, or neutral faces. A positive prime score represents faster target response and emotion facilitation whereas a negative prime score represents target response delay and prime attention capture. In Study One, undergraduates who self-disclosed a diagnosis of ADHD were compared with age, gender and education matched controls on the affective priming task. Since previous literature has found that children with ADHD tend to hold their attention longer on negative faces (Pishyareh et al., 2015), we hypothesized that young adults with ADHD will have greater negative priming scores to negative faces, reflecting greater attention capture, than will age, gender and education matched controls. Similarly, in Study Two a different sample of undergraduates who endorsed a diagnosis of ADHD was compared to age, gender and education matched controls on the affective priming task. However, self-disclosed ADHD participants additionally completed a set of clinical diagnostic questionnaires regarding childhood and current ADHD symptoms. Just as in Study One, we hypothesized that adults who met criteria for child and/or adult ADHD would reflect greater attention capture to negative faces as expressed by greater negative priming scores in comparison to age, gender and education matched controls.

Study One

Method

Participants

Participants were a sample of 76 college undergraduates, aged 18-47 years ($M = 18.93$, $SD = 2.99$), who participated in a longitudinal study in the Levens Emotion and Cognition Lab. Thirty-three individuals (20 females) who indicated a diagnosis of ADHD on the Mental Health History Checklist were included in the present study. Of the 33 participants who indicated a diagnosis of ADHD, 7 reported a diagnosis of an anxiety disorder (4 of which also reported depression), 2 indicated a diagnosis of a learning disability, 1 reported an eating disorder and depression, 1 reported an anxiety disorder, depression and an eating disorder, 1 reported a diagnosis of a behavior disorder and 1 reported a diagnosis of Post Traumatic Stress Disorder. Forty-three age and gender matched controls (21 female) who endorsed no history of mental health diagnoses were also included in the study. 68.4% of the participants reported their race as White, 13.2% African American, 1.3% Native American, 1.3% Pacific Islander, and 15.8% Other.

Materials

Mental Health History Checklist. The 9-item questionnaire asked the participant to report if they have been diagnosed with specific mental health disorders, such as anxiety disorders, eating disorders, and depression. The current study focused on participants who endorsed a diagnosis of ADHD.

Affective Priming Task. We employed the same affective priming task used by LeMoult, Joormann, & Lira (2012) to assess emotion processing, specifically, how emotional stimuli affect attention capture. Each trial in the task involved viewing facial expressions in consecutive pairs on a computer screen. Facial expressions were either happy, sad, angry, neutral, or disgust. At the start of a trial, the participant saw "Ready" presented on the computer screen for 500 ms followed by the first facial expression (the prime) for 500 ms. Participants were instructed to attend to the photo, but no action was required. Then immediately after the first photo left the screen, a second facial expression (the target) was presented in the center of the computer screen. The target remained displayed on the screen until the participant indicated the valence (positive or negative) of the photo by pressing the 1 key for negative and the 2 key for positive on the keyboard. On the keyboard, there were labels over the 1 and 2 keys denoting 'N' for negative and 'P' for positive. Participants were instructed to indicate the valence of the photo as quickly as possible using the labeled keys on the keyboard.

To certify that participants were consciously processing both the prime and target emotional expressions, participants were asked a follow-up question, "Which picture was friendlier?" Using the 1 and 2 keys, the participant indicated whether the first face or the second face was friendlier. The 1 key indicated the first face was friendlier and the 2 key indicated the second face was friendlier. Participants completed 10 practice trials before moving on to complete a total of 240 experimental trials.

Trial Types. There were two trial types, emotion-congruent trials and neutral-incongruent trials, that were used for analysis. A third trial type, emotion-incongruent, was used as a filler trial during the task. As a filler trial, emotion-incongruent trials

were included in the task so that emotional primes would not lead to participants anticipating a target of congruent valence. For each facial expression (happy, sad, angry, neutral, and disgust), 20 trials were emotion-congruent, 20 trials were neutral-incongruent, and 20 trials were emotion-incongruent. Emotion-congruent trials have the prime and the target of the same valence (i.e. the prime and the target are both angry). Neutral-incongruent trails have a neutral prime and the target is an emotional expression (i.e. a neutral prime appears first followed by a target with a happy expression). Emotion-incongruent trails consist of a prime and a target of two different emotional expressions (i.e. the prime is a happy expression followed by a target with a sad expression). Trials were presented pseudorandomly to prevent participants from predicting facial expressions and responses.

Procedure

Participants from this study were part of a longitudinal behavioral study in the Levens Emotion and Cognition Lab in the Department of Psychology at UNCC. Participants were recruited through the subject pool in the Psychology Department at UNCC to participate in a longitudinal study. Upon arrival for the study participants were consented and completed demographic questions as well as battery of questionnaires that included the Mental Health History Checklist. After completing the questionnaires participants completed a series of cognitive tasks with emotional content, including the affective priming task. After completing both the questionnaires and cognitive tasks an experimenter debriefed the participant and indicated that they would be contacted to participate in future studies.

Statistical Analysis

Mean reaction times and responses were recorded for each trial. To check if the participant was consciously attending to the prime and target facial expressions, an accuracy measure was created that assessed how accurately the participant judged which face was friendlier. An accuracy cut-off of 60% was used to make sure that participants understood the task and were performing above chance (50%). Accuracy rates for neutral-

incongruent trials were entered into a two-way group (ADHD, Control) by emotion (happy, sad, angry, and disgust) repeated measures ANOVA. T-tests were to follow-up on any main effects or interactions.

To assess attention capture of each emotion expression, a priming score was calculated for each emotional expression for each participant. The following equation was used to calculate a priming score for each participant for each facial expression: Priming Score = (Neutral incongruent RT) – (Emotion congruent RT). Neutral incongruent RT represents the mean reaction time to identify the valence of the target expression when the prime expression is neutral. Emotion congruent RT

average of 60% resulting in 24 ADHD (14 female) and 35 (18 female) controls for final analyses. There were no significant differences between groups in the number of participants who were excluded. The age distribution for the ADHD group and the control group were 18-47 years ($M = 19.34$, $SD = 5.17$) and 18-25 years ($M = 18.63$, $SD = 1.44$) respectively.

Accuracy Scores

Accuracy scores for the task were measured by how efficient the participant judged which face was friendlier in the neutral-incongruent trials. A two-way group (ADHD, Control) by emotion (happy, sad, angry, and disgust) repeated measures

Table 1

Mean Priming Scores and Percent Accuracy Scores

	Control		ADHD	
	Accuracy	Priming Score	Accuracy	Priming Score
Happy	91 (9)	-108.20 (396.96)	89 (17)	-460.41 (767.92)
Angry	96 (7)	-74.13 (332.15)	95 (9)	-276.62 (267.18)
Sad	96 (7)	-216.63 (1062.80)	94 (8)	-6.61 (215.54)
Disgust	95 (5)	49.39 (348.83)	95 (6)	209.50 (294.97)

Note: Standard deviations in parentheses.
Priming Score = (Neutral incongruent RT) – (Emotion congruent RT)

represents the mean reaction time to identify the valence of the target expression when the prime has the same emotional expression as the target. A positive prime score indicates a faster response when prime-target pairs are valence congruent. A negative prime score indicates that the prime captured attention capture and delayed responding to the target. Once priming scores were calculated for each participant for each expression they were entered into a two-way group (ADHD, Control) by emotion (happy, sad, angry, and disgust) repeated measures ANOVA. Main effects and interactions were examined using independent sample t-tests or paired-sample t-tests.

Results

Of the original sample of 76 participants, 59 participants ages 18-47 years ($M = 19.05$, $SD = 4.07$) met the minimum accuracy requirement of an

ANOVA was conducted on the neutral-incongruent trials. Accuracy rates for each emotion for each group are presented in Table 1. The ANOVA yielded a significant main effect of emotion, $F (3, 171) = 7.14$, $p < .001$. No other main effects or interactions were significant. To investigate the main effect of emotion a series of paired t-tests were conducted comparing the various neutral-incongruent emotion trials. Results revealed that happy expressions were judged the least accurately in comparison to angry, $t (58) = 3.15$, $p < .01$, sad, $t (38) = 2.79$, $p < .01$, and disgust, $t (58) = 3.54$, $p < .01$, expressions.

Priming Scores

To test our main hypothesis in regard to attention capture biases in response to emotional stimuli in individuals with ADHD, a two-way group (ADHD, Control) by emotion (happy, sad, angry, and disgust) repeated measures ANOVA was

conducted on priming scores. Priming scores for each emotion for each condition are presented in Table 1 and variability is displayed graphically in Figure 1. The ANOVA yielded a significant main effect of emotion, $F(3,171) = 5.79, p < .001$ qualified by a significant group by emotion interaction, $F(3,171) = 3.56, p < .05$. There was no significant main effect of group. Independent sample t-tests were conducted on each priming score to investigate the group by emotion interaction. Results revealed that ADHD participants demonstrated significantly greater

accuracy scores, negative valences seem to be easier to identify as friendlier when preceded by a neutral prime. There may be some ambiguity with the faces used for the neutral primes, making it more difficult to identify which is friendlier when the target is a happy expression. Findings regarding priming scores revealed that participants with self-disclosed ADHD showed greater attention capture for angry expressions and happy expressions, yet marginally less attention capture for disgust expressions. Greater attention capture (higher prime score) indicates that the participant took longer to identify the emotional
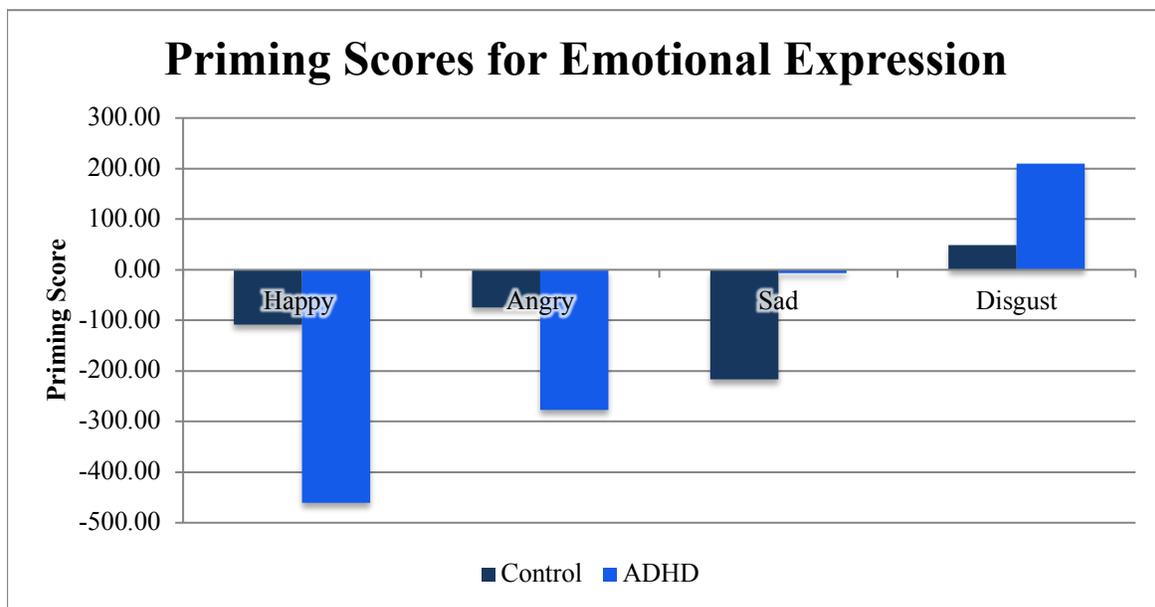
Figure 1.

Figure 1. Mean priming scores for each emotion for ADHD and Control groups.

attention capture for angry expressions, $t(57) = 2.48$, $p < .05$ and happy expressions, $t(57) = 2.31, p < .05$. Additionally, findings revealed marginally less attention capture for disgust expressions $t(57) = 1.84, p = .071$. There was no significant difference between ADHD participants and the control group for sad expressions.

Summary of Study One Findings

The goal of the study was to examine attention capture in response to emotional stimuli in adults with self-disclosed ADHD. In the case of

expression of the target because they were engaging in more elaborative processing of the emotional prime. Given that angry and happy are considered approach-oriented emotions and disgust is considered a withdrawal emotion (Davidson, 1994), it may be that individuals with ADHD experience attentional difficulties due to a dysregulation in approach-avoidance attention mechanisms. Spending cognitive resources elaborating upon irrelevant approach-related emotional content may be interfering with the ability to plan and complete an action or goal. To replicate this finding a second study was conducted in which ADHD diagnosis was determined using clinical

diagnostic questionnaires, namely a modified version of the Wender Utah Rating Scale (WURS; Ward, Wender, & Reimherr, 1993) and the Adult ADHD Self-Report Scale (ASRS-v1.1; World Health Organization, 2003).

Study Two

This study aimed to replicate the results of Study One and used refined methods for diagnosis of ADHD. A new sample of participants was recruited to address this question. Participants who indicated a diagnosis of ADHD on a prescreen questionnaire were asked to complete additional surveys regarding child and adult diagnosis of ADHD. Analyses of accuracy rates and priming scores were conducted for each set of ADHD criteria resulting in 3 ADHD groups: Child ADHD, Adult ADHD, and Combined ADHD. We hypothesized that a sample that met clinically diagnosed criteria for diagnosis of ADHD would show stronger and more pronounced emotion-attention biases than controls as compared to the sample of self-disclosed ADHD participants and controls from Study One.

Method

Participants

A sample size of 57 undergraduates aged 18-60 years ($M = 20.21$, $SD = 5.99$) were recruited through SONA, an online psychology research system from the University of North Carolina at Charlotte (UNCC). A sample of 25 (16 female) undergraduates who endorsed a diagnosis of ADHD on a SONA prescreen questionnaire were invited to participate in the study. Of the 25 participants who indicated a diagnosis of ADHD, 1 reported a diagnosis of an eating disorder. Thirty two (17 female) students with reported no history of mental health diagnoses were also included in the study. 73.7% of participants reported their race as White, 19.3% African-American, 1.8% East Indian, 1.8% Pacific Islander, and 3.5% Other.

Materials

ADHD Diagnosis Questionnaire. This questionnaire asked participants who endorsed "yes"

to an ADHD diagnosis in the Mental Health History Checklist specific items regarding their ADHD diagnosis, such as "How were you diagnosed with ADHD?," and "Do you take any medication to address your ADHD?"

Adult ADHD Self-Report scale (ASRS). The 18-item Adult ADHD Self-Report Scale (ASRS-v1.1; World Health Organization, 2003) served as a checklist for ADHD symptoms following DSM-IV-TR criteria. Items included questions regarding ADHD symptomatology over the last 6 months. For example, when asked, "How often do you have problems remembering appointments or obligations?" the participant answered with the following Likert scale: "Never" to "Very Often." Only the first 6 items were scored. Using the 0-24 scoring approach, a cutoff score of 14 indicated a diagnosis of adult ADHD (Kessler et al., 2007).

Wender Utah Rating Scale (WURS). A modified version of the Wender Utah Rating Scale (WURS; Ward, Wender, & Reimherr, 1993) assessed childhood recall of ADHD symptoms. The 25-item questionnaire focused on childhood ADHD symptoms including concentration, impulsivity, and temper in which the participant indicated the extent the item is true with the following Likert scale: "Not at all or very slightly" to "Very Much." Using a 0-100 scoring approach, a cutoff score of 36 indicated a diagnosis of childhood ADHD.

Affective Priming Task. Participants completed the same affective priming task as the participants in Study One with the same trial types and emotional faces.

Procedure

Similar to Study One, participants were recruited through SONA, they were consented and completed demographic questions. In addition participants completed the Adult ADHD Self-Report scale (ASRS) and Wender Utah Rating Scale (WURS). After completing the questionnaires participants completed the affective priming task. At the conclusion of the experiment session the experimenter debriefed the participant.

Statistical Analyses

Just as in Study One, an accuracy measure was created that assessed how accurately the participant judged which face was friendlier to check if the participant was consciously attending the prime and target facial expressions. Mean reaction times and accuracy rates were calculated for each trial type. Accuracy rates for neutral-incongruent trials were entered into a two-way group (ADHD, Control) by emotion (happy, sad, angry, and disgust) repeated measures ANOVA. T-tests were used to analyze any main effects or interactions. A priming score was calculated for each emotional expression for each participant to assess attention capture of each emotional expression. The priming scores were calculated for each participant for each expression and they were entered into a two-way group (ADHD, Control) by emotion (happy, sad, angry, and disgust) repeated measures ANOVA. Additional independent sample t-tests and paired-sample t-tests were used to analyze main effects and interactions.

Results

Of the original sample of 57 participants, 53 participants ages 18-31 ($M = 19. 49$, $SD = 2.75$) met the minimum accuracy requirement of an average of 60% resulting in 23 ADHD (14 female) and 30 controls (17 females) for final analyses. There were no significant differences between groups in the number of participants who were excluded. The age distribution for the ADHD group and the control group were 18-31 years ($M = 20.74$, $SD = 3.37$) and 18-27 years ($M = 18.53$, $SD = 1.66$), respectively.

The 23 ADHD participants were organized into 3 groups based on who met criteria for Child, Adult, or Combined (child and adult) ADHD. Depending on which criteria was met, some ADHD participants were included in just one group, two groups or in all three groups. For example, if a participant met criteria for child and adult ADHD, then the participant would be included in all the groups: Child ADHD, Adult ADHD and Combined ADHD. Of the original sample of 23 ADHD participants, 15 (8 female) participants ages 18-27 ($M = 21.67$, $SD = 3.87$) met criteria for Child ADHD ($M = 53.33$, $SD = 12.30$), 14 (8 female) participants ages 18-31 ($M = 20.93$, $SD = 3.73$) met criteria for Adult ADHD ($M = 17.14$, $SD = 2.66$), and 10 (5 female) participants ages 18-31 ($M = 21.80$, $SD =$

4.13) met criteria for both ($M = 50.30$, $SD = 12.37$ for WURS and $M = 17.10$, $SD = 2.88$ for ASRS).

Just as in Study One, accuracy scores for the task were measured by how efficiently the participant judged which face was friendlier in the neutral-incongruent trials. Three separate two-way group (ADHD, Control) by emotion (happy, sad, angry, and disgust) repeated measures ANOVA were conducted on the neutral-incongruent trials based on Child, Adult, and Combined ADHD criteria (i.e. in one ANOVA grouped based on Child ADHD, another ANOVA grouped based on Adult ADHD, another ANOVA grouped based on Combined ADHD). Accuracy rates for each emotion for each group are presented in Table 2. To investigate the main effect of emotion a series of paired t-tests were conducted comparing the various neutral-incongruent emotion trials for each ADHD group.

Similar to Study One, to test our main hypothesis in regard to attention capture biases in response to emotional stimuli in individuals with ADHD, a two-way group (ADHD, Control) by emotion (happy, sad, angry, and disgust) repeated measures ANOVA was conducted on priming scores, except three repeated measures ANOVAs were run for each ADHD group. Priming scores for each emotion for each condition are presented in Table 2 and variability is displayed graphically in Figure 2. Independent sample t-tests were conducted on each priming score to investigate the group by emotion interaction.

Child ADHD and Control

Accuracy Scores. The ANOVA yielded a significant main effect of emotion, $F (3, 129) = 3.47$, $p < .05$. No other main effects or interactions were significant. Paired t-tests revealed angry expressions were judged the most accurately in comparison to happy, $t (44) = 2.83$, $p < .01$ and sad, $t (44) = 2.54$, $p < .05$ expressions. Happy expressions were judged less accurately in comparison to disgust expressions, $t (44) = 2.53$, $p < .05$.

Priming Scores. The ANOVA yielded a significant main effect of emotion, $F (3,129) = 3.74$, $p < .05$; however, there was not a significant group by emotion interaction. Planned independent sample t-tests revealed no significant differences between Child ADHD and the control group for any of the

Table 2

	Control		Child ADHD		Adult ADHD		Combined ADHD	
	Accuracy	Priming Score	Accuracy	Priming Score	Accuracy	Priming Score	Accuracy	Priming Score
Happy	91(9)	-141.87 (390.2)	93 (16)	-107.27 (365.64)	94 (6)	-134.00 (369.51)	96 (7)	-76.38 (352.32)
Angry	97 (4)	-299.86 (805.01)	95 (6)	-213.08 (293.06)	94 (8)	-253.48 (283.31)	95 (6)	-231.45 (334.85)
Sad	95 (8)	-69.47 (283.78)	91 (12)	54.31 (272.29)	90 (13)	-12.14 (213.62)	90 (14)	28.92 (202.84)
Disgust	96 (5)	94.08 (224.69)	96 (5)	-21.49 (336.04)	93 (8)	-28.03 (349.24)	95 (6)	-69.53 (316.94)

emotional expressions. The priming scores seem to reflect greater attention capture for disgust expressions and less attention capture for happy, angry, and sad expressions for Child ADHD participants.

Combined ADHD and Control

Accuracy Scores. The ANOVA yielded a significant group by emotion interaction, $F (3, 114) = 4.62$, $p < .01$. Just as in the paired t-tests for the Child ADHD and Adult ADHD groups, angry expressions were judged the most accurately in comparison to happy, $t (39) = 3.25, p < .01$, and sad, $t (39) = 2.19, p < .05$ expressions. Happy was judged less accurately than disgust expressions, $t (39) = 2.60, p < .05$.

Priming Scores. The ANOVA yielded a marginal main effect of emotion, $F (3, 114) = 2.38$, $p = .074$. There were no other significant main effects or interactions. The planned independent sample t-tests revealed no significant differences between controls and Combined ADHD participants for any of the emotional expressions. Although not significant, there was a marginal difference for disgust faces, $t (38) = 1.80, p = .081$. The Adult ADHD group exhibited greater attention capture for disgust expressions, but less attention capture for happy, angry, and sad expressions (See Table 2).

Summary of Study Two Findings

The aim of the study was to examine attention capture in response to emotional stimuli in adults that met criteria for child, adult or both child and adult ADHD diagnosis. While no group effects were significant, there were trending differences between the ADHD group and the control group that are worth discussion. Interestingly, the results of this study did not align with the results from Study One as expected. Findings for Study Two contrasted sharply with Study One, revealing a near reversal of findings. Instead of showing greater attention capture for happy and angry expressions as was found in Study One, Study Two yielded a pattern indicating decreased attention capture for happy and angry expressions as well as greater attention capture for disgust expressions. Greater attention capture for disgust expressions (more negative priming scores) implies more time spent processing the target. These conflicting results suggest that a dysregulation in approach-avoidance attention mechanisms could distinguish adults who have matured out of ADHD from those who still report ADHD associated dysfunction.

General Discussion

The current study aimed to resolve contrasting emotion-attention bias findings in a sample of adults with ADHD. Both Study One and Study Two, examine whether attention capture for
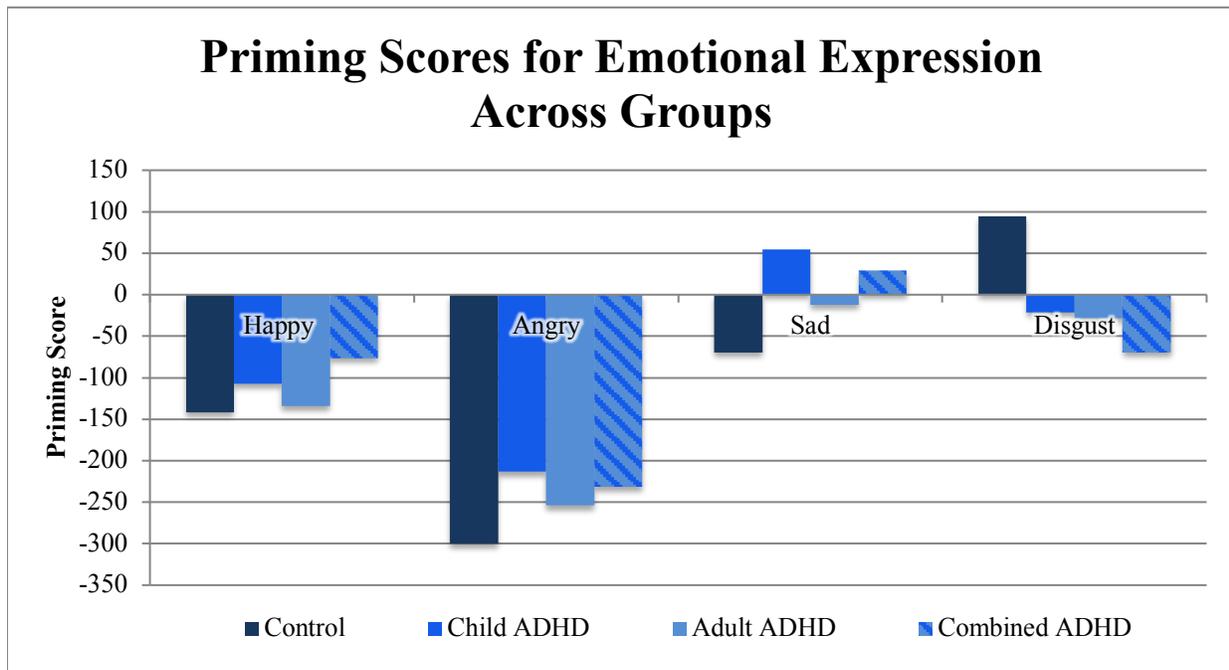
Figure 2.

Figure 2. Mean priming scores for each emotion across all groups.

emotional stimuli differs in adults with ADHD compared with adults without ADHD. The main difference between Study One and Study Two was the way participants endorsed a diagnosis for ADHD. Participants in Study One self-disclosed their diagnosis of ADHD, while participants in Study Two completed a set of clinical diagnostic questionnaires to indicate diagnosis of ADHD. In both studies we analyzed emotion processing in individuals diagnosed with ADHD using the affective priming task, focusing on emotional stimuli that generated greater attention capture or facilitated rapid processing of emotional content. The results of neither study supported our original hypothesis that young adults with ADHD will have greater negative priming scores to negative faces, reflecting greater attention capture, than will age, gender and education matched controls.

The outcome of Study One revealed greater attention capture for the approach emotions, happy and angry, and less attention capture for the withdrawal emotion, disgust. As discussed in the summary of findings for Study One, these results suggest that individuals with ADHD may exhibit a dysregulation in approach-avoidance attention mechanisms. When analyzing forms of motivational

behaviors in relation to emotional stimuli, most studies focus on the approach-withdrawal system theory. The approach system enables appetitive behavior that generates the motivation to achieve a desired goal whereas the withdrawal system enables the individual to avoid/withdraw from aversive stimulation (Davidson and Irwin, 1999). In the context of ADHD, greater attention capture for approach related content could contribute to some of the hyperactive/impulsive behaviors demonstrated in individuals with ADHD that may interfere with focused goal pursuit. Greater attention capture to approach related emotional content may hinder focused goal pursuit as ADHD individuals may be impulsively drawn to approach related content that is not necessarily consistent with their current goal or activity.

Although the idea of a dysregulation of approach-avoidance attention mechanisms seems probable, the results from Study Two suggest a more complicated picture. Study Two yielded a different pattern of emotion processing. Despite no significant difference in priming scores for each emotion, all three ADHD groups demonstrated greater attention capture for disgust emotional expressions and less attention capture for angry emotional expressions, a

pattern opposite that of Study One. As Study Two uses diagnostic measures to confirm ADHD diagnosis, the findings raise questions about how disgust and angry expressions are processed. The processing of disgust faces was marginally different between ADHD and control participants. It may be that individuals with ADHD experience difficulty identifying disgust faces due to ambiguous or overlapping features. Or there may be a deeper meaning behind how disgust faces are processed in individuals with ADHD. According to the Circumplex Model of Affect, all affective states emanate from two independent neurophysiological systems: valence and arousal (Posner, Russell, & Peterson, 2005). Instead of viewing greater attention capture for disgust, as a withdrawal emotion, maybe disgust should be viewed as a negative and high intensity emotion. However, because there were no significant differences in priming scores for happy and angry or a trend suggesting greater attention capture for happy and angry emotional expressions, it is uncertain if the Circumplex Model of Affect is the best explanation for emotion-attention biases in adults with ADHD.

As noted by the conflicting results of each study there are some limitations to take into consideration. Both Study One, but especially Study Two were impacted by low sample size. Specifically in the case of Study Two, a larger ADHD group might have resulted in significant findings. A larger sample size of ADHD participants might have produced an accurate generalization of emotion-attention biases in individuals with ADHD. Second, the diagnostic measures for endorsement of ADHD could have contributed to confounding results. Given that Study One used participants who self-disclosed a diagnosis of ADHD, it may be that some of the participants falsely reported a diagnosis of ADHD as a way to potentially explain poor academic performance. However, as we did not use any confirmatory diagnostic tests in Study One (a limitation we addressed in Study Two) there is no way to determine if the different findings between Study One and Study Two could be explained by false ADHD diagnosis declaration. Another potential confounding difference between Study One and Study Two is that Study One may have included participants who 'matured out' of ADHD. Roughly 25% of self-diagnosed ADHD participants who

completed Study Two did not meet criteria for either childhood or adult ADHD, suggesting that Study One could have similar rates of people who do not meet ADHD diagnostic criteria. While Study Two excludes individuals who do not meet criteria, Study One did not and could have therefore included a large percentage of individuals who 'matured out' of ADHD.

Taken together, the opposing outcomes from Study One and Study Two raises the question: Is there a difference in emotion processing for adults who mature out of ADHD? As shown by Figure 2, priming scores patterns for happy, angry, and disgust expressions are similar across the ADHD groups, but there is a shift in the pattern for sad expressions. The priming scores for both Child ADHD and Combined ADHD were positive while the priming scores for Adult ADHD was negative. The inconsistent pattern suggests emotion facilitation (positive priming score) for sad expressions are evident during childhood, but seems to shift to greater attention capture in adulthood. Considering that the Combined ADHD group also showed emotion facilitation for sad expressions suggests a shift in emotion processing from childhood ADHD to adult ADHD. Interestingly, as seen in Figure 1, the self-disclosed ADHD group had a negative priming score for sad expressions, which is consistent with the Adult ADHD group. Given that we did not know who in the self-disclosed ADHD group actually did meet criteria with ADHD diagnosis, it may be that the majority of the ADHD participants in Study One thought they had ADHD at one point in their lives, but are now in remission.

Studies have shown evidence of childhood ADHD symptomatology persisting into adulthood (Halmøy, Fasmer, Gillberg, & Haavik, 2009; Semeijn et al., 2016; Walker, Venter, Van, & Esterhuyse, 2011). However other studies report adults growing out of ADHD (Gustafsson, Holmström, Besjakov, & Karlsson, 2010; Karam, et al., 2015). Young and Gudjonsson (2008) found that full remission of ADHD was associated with improvement in psychosocial functioning, while under partial remission signs of antisocial behavior are still present. In the present study, we did not measure for full or partial remission of ADHD, which adds an additional variable that could explain our conflicting findings. Building on the idea that as

individuals with ADHD mature into adulthood hyperactive-impulsive behavior becomes less prominent and inattentive symptoms remain prevalent (Walker, et al., 2011), it could be that as individuals with ADHD develop some may continue to use the same emotion processing patterns as when they were a child while others who might have matured out of ADHD may use emotion processing patterns similar to individuals without ADHD.

In summary, the results from this investigation suggest a shift in emotion processing patterns as individuals with ADHD develop into adulthood. Future studies will be needed to clarify emotion processing patterns in adults with partial remission and full remission of ADHD. Findings from this study provide insight on the challenges of assessing emotion-attention biases in adults with ADHD due to possible changes of symptomology across development. It is difficult to say if an individual just has ADHD in adulthood since ADHD is considered a developmental disorder. However, different individuals may use different compensatory strategies to overcome ADHD symptoms during childhood. As an exploratory study, the results may have captured a different type of symptom progression of ADHD where the symptoms of ADHD appear more prominent in adulthood to an individual that would never have noticed as a child. The information presented highlights the importance of appropriately evaluating ADHD symptoms not just in children but also in adults. Understanding differences in ADHD symptoms as one develops is critical for providing the best services for individuals who legitimately need them as they progress in their academic and professional careers. Specifically, assessing differences in emotion-attention biases during the development of ADHD is essential for identifying changes in psychosocial functioning given that well-founded social skills are important for transitioning into adulthood.

Acknowledgments

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