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Eye-gaze behavior and emotional accuracy: a categorical and dimensional analysis
of youth with attention-deficit hyperactivity disorder and autism spectrum disorder

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College Honors Thesis

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Abstract

Differences in emotion recognition and dwell time in the eye region of static emotional faces were examined in an all-male sample of children (mean age 10.1 years) with comorbid Attention-Deficit/Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD), children with ADHD without ASD, and typically developing children. Correlations between the Attention Problems and Withdrawn/Depressed subscales of the Child Behavior Checklist, dwell time in the eye region of emotional faces, and emotion recognition scores were examined. We hypothesized that the ADHD/ASD group would exhibit less dwell time in the eye region and impaired emotion recognition relative to the ADHD and control groups. However, we found no significant differences between groups on dwell time in the eye region or in emotion recognition. We also hypothesized that there would be no correlation between Attention Problems and dwell time or emotion recognition, but that both variables would be negatively correlated with Withdrawn/Depressed scores. We found no correlation between either subscale with the dependent variables. Implications and future research directions are discussed.

Psychiatric disorders in children have received much attention in academic research and the media in recent years. Incidence of psychiatric disorders in children has risen over the last two decades, and it is estimated that between 13 and 20% of children in the United States are living with some psychiatric disorder (Perou et al., 2013). Attention-deficit/hyperactivity disorder (ADHD) is the most prevalent psychiatric disorder in children, characterized by inattention, hyperactivity and impulsivity that presents before 12 years of age and occurs in more than one setting (for example, at home and at school) (American Psychiatric Association, 2013; Perou et al., 2013). Another psychiatric disorder, Autism Spectrum Disorder (ASD), is defined by significant impairment in verbal and non-verbal communication and repetitive behaviors that emerge within the first few years of life (American Psychiatric Association, 2013). ASD occurs at a much lower rate than ADHD, though the number of children diagnosed with ASD has risen in recent years and it is a growing public health concern (King & Bearman, 2009). There is also significant comorbidity between the two disorders, with studies showing that approximately 6% of children with ADHD also have ASD, and 31% of children with ASD have comorbid ADHD (Gjevik, E., Eldevik, E., Fjæran-Granum, T., & Sponheim, E., 2011; Larson, Russ, Kahn, & Halfon, 2011).

ADHD and ASD: Social Difficulties

Both individuals with ADHD and ASD exhibit difficulties with social functioning. A 2005 study of children with ADHD and their same-sex peers asked them to confidentially rate those who they considered their closest friends, those they did not want to be friends with, and how likeable they found each classmate. Children with ADHD scored low on social preference, meaning that fewer children rated them as friends than rated them as someone they did not want to be friends with. In addition, children with ADHD had fewer dyadic friendships than their

peers, defined as a pair in which each child chose each other as one of their close friends (Hoza et al., 2005). There is also evidence that compared to controls, individuals with ADHD perceive their social interactions more positively than an objective rater in a laboratory setting, particularly in instances where the rater labeled the social interaction a “failure” (Hoza, Waschbusch, Pelham, Molina & Milich, 2000).

While there is evidence of social impairment in ADHD, abnormal social behavior is the hallmark manifestation of ASD. Children with ASD exhibit several atypical approaches to social behavior, including lack of initiation, odd or one-sided social interaction, and rejection of social overtures (Downs & Smith, 2004). Children with ASD also exhibit less age-appropriate play and imitative play (Bodison, 2015). This may be because children with ASD exhibit social anhedonia, where they enjoy social interaction less than typically developing children (Chevallier, Grèzes, Molesworth, Berthoz & Happé, 2012). However, another study found that children with ASD scored higher on a self-report measure of loneliness than control children, and had difficulty conceptualizing that friendship alleviated loneliness (Bauminger & Kasari, 2000). Another theory is that individuals with ASD lack social motivation. One study found that infants at high risk for ASD appeared to be less motivated to share positive emotions with others via bids for joint attention (Gangi, Ibanez & Messinger, 2014). Another study suggests a possible cause of this lack of social motivation. Ingersoll, Schreibman & Tran (2003) found that when children with ASD were asked to perform an action with a toy that was first modeled by an experimenter, they were more likely to correctly imitate the action if the toy provided immediate sensory feedback. The authors suggested that children with ASD may prefer sensory over social feedback. They may value social rewards less, which causes them to attempt social engagement

less frequently and impedes the development of normal social behaviors and communication skills.

ADHD and ASD: Etiology

Social impairment has always been considered the defining symptom of ASD. Children with ASD exhibit a marked deficit in theory of mind, the ability to conceptualize the mental states of others (Baron-Cohen, Leslie & Fritz, 1985). Theory of mind capability is thought to be a critical component of empathy (Vollm et al., 2006). Impairment in theory of mind may result in difficult conceptualizing the emotions of others and result in the abnormal social behavior and communication seen in ASD. In contrast, the social problems seen in children with ADHD are often considered a secondary symptom, and are thought to arise from the attentional problems themselves (Demopoulos, Hopkins & Davis, 2013). Attention is a domain of executive functioning, along with self-regulation. It is thought that impaired regulation of behavior in children with ADHD may be the cause of their social problems (Wheeler & Carlson, 1994).

Eye-Gaze Behavior in ADHD and ASD

One possible explanation underlying the social difficulty in children with ASD is abnormal processing of faces. Abnormal gaze behavior in children with ASD, specifically avoidance of eye contact, was documented in some of the earliest case studies (Kanner, 1943). It has been suggested that individuals with ASD avoid eye-contact because they have a stronger than typical amygdala response to eye-contact, which triggers an unpleasant sensation and causes them to look away (Kliemann et al., 2012). Another theory suggests that individuals with ASD display less regard for the eyes, nose and mouth as the “information-giving” features of the face, and attend more to non-essential features (Pelphrey et al., 2002). Given that individuals with ASD exhibit significantly poorer emotion recognition than typical individuals, it is plausible that

abnormal facial processing leads to poor emotion recognition, which then leads to difficulties in social interaction (Lozier, Vanmeter, & Marsh, 2014).

Several eye-tracking studies of individuals with ASD have examined the relationship between gaze behavior and the ability to recognize emotions. Klin and colleagues (2002) found that individuals who spent less time fixating on the eyes of people during the viewing of a video clip had a higher probability of ASD. Kirchner and colleagues (2011) found that poor performance on a Reading the Mind in the Eyes task, where subjects were asked to judge emotional states after viewing pairs of eyes, was associated with less fixation time on the eye region of emotional faces in a different task in individuals with ASD.

While there is less literature on gaze behavior and its relation to social competence in children with ADHD, several eye-tracking studies have examined patterns in judging emotional faces in this population. One study that displayed both a negative emotion and neutral face simultaneously found that typical children would preferentially gaze first at the negative emotion, but that children with ADHD did not exhibit this preference (Ahmadi, Judi, Khorrami, Mahmoudi-Gharaei & Tehrani-Doost, 2011). This may suggest that children with ADHD are less perceptive of negative emotions. Serrano, Owens and Hallowell (2015) found that compared to control children, children with ADHD spent less time fixating on the eyes and mouth when viewing emotional faces. Children with ADHD also had longer response times and were less accurate at judging emotions than control children, although the correlation between dwell time in the eye and mouth regions, accuracy and response time was found to be small and insignificant. However, Serrano and colleagues emphasized that gaze patterns were more similar than different between children with ADHD and control children. A 2008 study of children with comorbid diagnoses of ADHD and ASD found that emotional identification accuracy proceeded

highest to lowest in the following order: control children, ASD, ASD with ADHD, and ADHD (Sinzig, Morsch & Lemkuhl, 2008). Some research suggests that social difficulties in children with ADHD are not due to perception/processing abilities at all, but instead at level of behavioral response (Shapiro, Hughes, August & Bloomquist, 1993). We do not know if gaze behavior, or what types of gaze behavior, are affecting these accuracy rates across diagnoses and this is the primary objective of this study.

Previous Work

During the 2014-2015 academic year, I completed a five-credit undergraduate research project examining the relationship between eye-gaze behavior and emotional accuracy in children with the CBCL-ASD Profile (Ooi et al., 2011). The Child Behavior Checklist (CBCL) is a parental report measure of children's affective, cognitive and social functioning. Elevations on three syndrome scales (Withdrawn/Depressed, Social Problems, and Thought Problems) have been shown to reliably discriminate individuals with ASD from control children and children with other psychiatric disorders. The hypothesis was that children with elevations on the CBCL-ASD profile would exhibit a lower percentage of total fixations on the eye region compared to children who do not meet the profile when viewing emotional faces. We also predicted that a lower percentage of total fixations in the eye region would be negatively correlated with accurate emotion identification. There was a trend-level significant difference in fixations in the eye region between children with the ASD profile and control children, as well as significant difference in emotional accuracy between the two groups. A regression analysis revealed that the difference between the groups was accounted for by age instead of group status. However, there was significant positive correlation between emotional accuracy and fixations in the eye region. This independent study provided the basis for this current work and informed our hypotheses.

Significance

ADHD and ASD affect a significant portion of the population (Perou et al., 2013). With psychiatric and neurodevelopmental disorders, early intervention can improve social functioning in affected individuals (Jones, Daley, Hutchings, Bywater & Eames, 2007; McFadden, Kamps & Heitzman-Powell, 2014). Research on the underlying causes of social difficulties in ADHD and ASD allow for more targeted therapies. One major limitation of my previous independent study work was that children in the ASD-profile group were selected using a parental report measure (CBCL) rather than diagnosis of ASD. It was unknown, in fact, if any of those children carried a diagnosis of ASD. In this new study, every child participating has either been diagnosed with or without ASD. In addition, this study also incorporates data from children with ASD and ADHD to examine their similarities and differences in emotion processing. I will compare eye-tracking and emotion recognition performance between the two groups, which few studies have done. In addition, I will assess the effect of attention problems and withdrawn behavior on gaze and emotional accuracy. This will complement the between-group analysis and give a fuller picture of which symptoms and behaviors are correlated with alternative facial processing and impaired emotional judgment. To my knowledge, this type of simultaneous categorical and dimensional analysis has not been conducted in eye-tracking research on children with ASD and ADHD.

The purpose of this study was to investigate how gaze behavior and emotion recognition capability differ between children with ASD and ADHD, ADHD only, and children without any psychiatric diagnoses. We compared the time spent gazing in the eye region of faces, as well as accuracy at judging four basic emotions: happiness, anger, disgust and fear. We hypothesized that children with comorbid ASD and ADHD would exhibit less dwell time in the eye region, and perform worse at emotion recognition, than children with ADHD. Additionally, we sought to

perform regression analyses of dwell time in the eye region and emotional recognition with the Attention Problems and Withdrawn/Depressed syndrome scales from Child Behavior Checklist (CBCL) (Achenbach & Rescola, 2001). The Withdrawn/Depressed syndrome scale has been shown to be elevated in children with ASD, and together with the subscales Social Problems and Thought Problems, comprises the CBCL-ASD profile (Ooi et al., 2011). For the regression analyses, we hypothesized that there would be no significant correlation between the Attention problems subscale and dwell time or emotion recognition. Further, we hypothesized that the Withdrawn/Depressed syndrome scales would be negatively correlated with dwell time and emotion recognition. We hoped that these regression analyses would provide a more nuanced description of the effects of specific constructs that underlie eye-gaze behavior and emotional judgments.

Methods

The data for this analysis is from one completed study and two ongoing studies, all conducted at the Vermont Center for Children, Youth and Families. All studies were approved by the UVM Research Protections Office. Participants were recruited from VCCYF child psychiatry clinic and from the community using flyers and community forum announcements. All children in the study were between the ages of 4-17. To be included in the ADHD/ASD or ASD group, the child must have a previous diagnosis of ASD or ADHD from a health professional. Medication status was not controlled for. Children were eligible controls if they received no psychiatric diagnoses on the clinician-administered interview Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime version (K-SADS-PL), which was administered to each family as part of the study protocol.

Procedure

Prior to data collection, informed consent was obtained from all participants. During the study visit, the child's parent/guardian completed questionnaires about their child's behavior, social, emotional, and adaptive functioning including our survey measure of interest, the Child Behavior Checklist (Achenbach & Rescola, 2001). The child was either administered the Kaufman Brief Intelligence Test-2 (K-BIT 2) or the Wechsler Abbreviated Scale of Intelligence (WASI) (Kaufman & Kaufman, 2004; Wechsler, 1999). The WASI has four subtests, two verbal and two non-verbal, while the KBIT has three subtests, two of which measure verbal intelligence and the third non-verbal intelligence. The WASI and the KBIT have been shown to have significant convergent validity (Hays, Reas & Shaw, 2002). Neither intelligence test requires literacy. The child then completed several computer tasks, including the Emotional Faces task (described below), while undergoing eye-tracking and heart-rate monitoring.

The VU-AMS heart-rate monitor was used to record each subject's heartbeat. For this process, seven electrodes were affixed to the participant's torso. They then completed the "Emotional Faces" task. In this task, participants viewed three slideshows of human faces depicting four emotions: anger, fear, happiness, and disgust, as well as neutral faces. While the participants were shown faces with a range of emotion (40-100% of each emotion) only faces with 80%-100% valence were included in the task. The order of the slideshows and images within each slideshow were counterbalanced. Each slideshow contained 15-17 static images presented individually and consecutively. The subjects were instructed to press the trigger button on a video game controller once they had identified the emotion on the face. At this time four words appeared on the screen: anger, fear, and happiness and disgust. Subjects were asked

to select the word that best describes the emotion depicted in the image. The maximum time of stimulus presentation was 10.65 seconds.

During this task, an EyeLink 1000 was used to monitor pupillary movements. Subjects were seated approximately 17 inches from the eye-tracker. A chin rest was used to keep the head in place. The EyeLink 100 uses corneal reflection to detect pupillary movements. The EyeLink technology can measure the amount, duration and location of fixations (gaze directed at a specific area), as well as saccades (rapid movements of both eyes in a single direction). This eyetracker samples data from the eye every 1 ms and has an accuracy of approximately 0.5 degrees of visual angle. Interest areas were defined and fitted to each image. For this analysis, the areas of interest were the left and right eyes – which were separated, on average, by approximately 4.9 degrees of visual angle on the display.

Measures

The CBCL is a 113-item parent report that measures children's behavior, affect, and activity in and outside the home. Items are endorsed on a 3-point Likert scale of "0=Not true, "1= Somewhat or Sometimes True," "2= Very True or Often True." Items that comprise the Attention Problems subscale are: "Acts young," "fails to finish things he/she starts," "can't concentrate," "can't sit still," "confused or in a fog," "daydreams," "impulsive," "poor school work," "inattentive," and "stares blankly." Items that comprise the Withdrawn/Depressed subscale are: "Enjoys little," "prefers to be alone," "won't talk," "secretive," "shy," "lacks energy," "sad," and "withdrawn." Elevations on various combinations of syndrome scales have been shown to classify children with psychiatric disorders including ASD (Ooi et al., 2011).

Statistical Analyses

All statistical analyses were conducted with the program SPSS Statistics, Version 21. One-way ANOVAs were performed to compare dwell time in the eye region of emotional faces and emotion recognition between the ADHD/ASD, ASD, and control groups. Second, we performed correlation analyses examining how the CBCL Attention Problems and Withdrawn/Depressed subscales (Achenbach & Rescorla, 2001) related to emotion recognition and dwell time in the eye region. Independent-samples T-tests were also performed for dwell time and emotion recognition after individuals were categorized as “elevated” or “non-elevated” on the CBCL subscales. Finally, because these hypotheses were based on results from my previous independent study that showed a significant positive correlation between dwell time in the eye region and emotional accuracy, a correlation between those same variables was run again.

Results

Descriptives

The group sizes for the ADHD/ASD, ADHD, and control groups were 7, 12, and 14 individuals, respectively. Groups were matched on age (ADHD/ASD $M = 9.71$, $SD = 1.80$, ADHD $M = 9.83$, $SD = 1.64$, control $M = 10.69$, $SD = 2.29$) and IQ (ADHD/ASD $M = 106.33$, $SD = 21.46$, ADHD $M = 106.75$, $SD = 18.36$, control $M = 112.00$, $SD = 12.86$); no significant differences on age or IQ emerged from group comparisons. The sample was entirely male (Table 1).

ANOVAs for Dwell Time and Emotion Recognition

One-way ANOVAs revealed no significant differences between groups in dwell time in the eye region of emotional faces [$F(2, 28) = 1.64$, $p = .212$] or in emotion recognition [$F(2, 29)$

= 1.99 , $p = .155$] (Figures 1 and 2). For dwell time, we did note a non-significant pattern in the means, where controls and the ADHD group displayed higher amounts of dwell time on the eyes ($M = 2512.82$, $SD = 708.95$, $M = 2589.62$, $SD = 703.41$) relative to the ADHD/ASD group ($M = 2008.48$, $SD = 703.57$).

Correlation Analyses

Due to significant collinearity between CBCL scales, correlations were examined instead of multiple linear regression models. Correlations between Attention Problems, Withdrawn/Depressed, dwell time, and emotion recognition were considered. There was not a significant correlation between Attention Problems and dwell time in the eye region $r(31) = .24$, $p = .185$, or Attention Problems and emotion recognition $r(31) = .08$, $p = .659$. There was also no significant correlation between Withdrawn/Depressed scores and dwell time in the eye region, $r(31) = -.08$, $p = .678$ or emotion recognition $r(31) = .04$, $p = .849$ (Table 2).

T-test for CBCL scales

We ran independent samples T-tests after categorizing participants as “elevated” (T-score of 65 or greater) or “non-elevated” (T-score below 65) on both the Attention and Withdrawn/Depressed Syndrome scales. For the Attention Problems scale, there was no significant difference between elevated and non-elevated groups on dwell time, $t(29) = 1.59$, $p = .123$, or emotion recognition, $t(29) = -.53$, $p = .604$. For the Withdrawn/Depressed scale, there was no significant difference between the elevated and non-elevated groups on dwell time, $t(29) = .99$, $p = .332$, or emotion recognition $t(29) = .42$, $p = .674$.

Finally, since our hypotheses were based on my previous undergraduate work that found a positive correlation between fixations in the eye region and emotion recognition, we ran a correlation analysis between dwell time in the eye region and emotion recognition. Surprisingly,

we found no significant correlation between dwell time and emotion recognition, $r(30) = -.07$, $p = .696$.

Discussion

Many studies have sought to understand how children with ASD process faces, and whether ASD is associated with impairment in emotion recognition. A recent study suggested that children with ADHD may also display abnormal gaze behavior and difficulty judging emotions (Serrano, Owens & Hallowell, 2015). However, conflicting studies cite that social problems in ADHD arise from broad executive functioning problems, including self-regulation of behavior, in contrast to the lack of attention to salient social stimuli found in ASD (Demopoulos, Hopkins & Davis, 2013). The present study sought to examine differences in dwell time in the eye region of faces and emotion recognition between children with comorbid ADHD and ASD, ADHD, and children without psychiatric diagnoses. We hypothesized that children with ADHD and ASD would display less dwell time in the eye region of faces and impairment in emotion recognition relative to children with either ADHD or control children. There were significant differences in dwell time or emotion recognition in the eye region between the ADHD/ASD, ADHD, and control groups. For dwell time, there was a non-significant pattern where control children and children with ADHD exhibited greater dwell time in the eye region than children with comorbid ADHD and ASD.

Dwell Time

While these results do not support our hypothesis, the means for dwell time in the eye region displayed a pattern consistent with what was predicted (Figure 1). There are several possible factors that may have influenced these results. First, this study may have been underpowered, as discussed further in the limitations section. Second, interventions for ASD,

including peer-mediated pivotal response training and joint attention training, have been shown to increase eye contact (Pierce & Schreibman, 1995; Whalen & Schreibman, 2003). Studies have shown that the median age for diagnosis of ASD ranges from 3.1 to 7.2 years of age, depending on how high functioning the individuals are (Mandell, Novak, & Zubritsky, 2005). Since the mean age of children in our ADHD/ASD group was 9.71 years, it is possible that our subjects could have undergone years of interventions that may have increased dwell time beyond what you might see in someone who had not been subject to intervention. Unfortunately detailed information regarding subjects' treatments/interventions was not collected, so this can only be speculated. Treatment may also be related to socioeconomic status, for which we did not control.

Emotion Recognition

The results did not show any group differences in emotion recognition, which did not support our hypothesis (Figure 2). The emotion recognition findings are not supported by many studies that suggest that children with ASD are less accurate at judging emotions (Lozier, Vanmeter, & Marsh, 2014). Emotions are generally classified as basic or complex, where there are thought to be six basic emotions: happiness, sadness, fear, anger, surprise and disgust (Ekman & Friesen, 1971). Complex emotions are also known as "self-conscious" emotions, and include emotions such as guilt and embarrassment. While some studies have suggested that individuals with ASD are selectively impaired in complex emotion recognition (Heerey, Keltner & Capps, 2003), many studies have found differences in recognition of the same emotions used in this study (Enticott et al., 2014; Sinzig, Morsch & Lemkuhl, 2008). However, our paradigm uses static images of emotional faces, which may fail to mimic real-life social situations. Other studies that have used video clips, or stills of neutral faces slowly transitioning to emotional images, have repeatedly found that children with ASD are impaired in emotion recognition

relative to controls for at least some emotions (Bal et al., 2010; Enticott et al., 2014). Another study reported a larger effect size for emotion recognition for images of faces with contextual cues, compared to stand-alone images of emotional faces (Serrano, Owens & Hallowell, 2015). For our study, it is possible that the combination of small group size and the lack of contextual cues may have limited ability to find effect deficits in emotion recognition, although this paradigm is still currently in use (Crehan, Ametti, Hudziak, Rettew & Althoff, 2015).

A second possible explanation is the fact that individuals were asked to choose the appropriate emotion after the four options appeared on the screen. The use of a multiple choice paradigm lends itself to guessing, so this might conceal deficits in emotion recognition that would be more apparent if subjects were asked to generate an answer themselves. Our study attempts to control for this effect by delaying the presentation of the choices until the subject has pressed the trigger button, which they were instructed to do once they believed they knew the emotion being presented. However, the task did advance after a fixed period of time, so even if subjects had no idea what the emotion was, they were always presented with choices.

Additionally, at least one study has shown that children with ASD have a longer latency to respond in emotion recognition tasks, so it may take children with ASD more time to even make a judgment (Bal et al., 2010). If the task advances faster than they can make a choice, choosing from one of four options may inflate their emotion recognition abilities.

Additionally, there may be real neurological differences in processing in children with ASD between how they process a multiple-choice emotion recognition task versus how they would process a true social interaction. A 2014 study showed that individuals with ASD that were presented with both visual and auditory stimuli in an emotion recognition test showed increased activation of the categorization part of the brain, the right anterior temporal pole (Hall,

Szechtman & Nahmias, 2003). The task in the study was also a free-response (non-multiple choice.) This task more closely approximates a social situation, and experimenters expected that this would improve emotion recognition. Yet they found that this task produced activation of the part of the brain that controls heuristics, and that individuals with autism still had reduced emotion recognition scores compared to controls. It is possible that in a task like ours, which only minimally approximates a true social dynamic, individuals with ASD are less likely to use heuristics when making judgments. Perhaps with less competing social stimuli, they actually attempt to process stimuli holistically, but would revert to systematic, bottom-up processing in a real-life social situation.

Finally, age and IQ may have influenced emotion recognition capabilities. IQ has been shown to be a predictor of better performance on emotion recognition tasks among children with and without ASD (Buitelaar et al., 1999). With regards to age, one study showed that individuals with ASD display a “catch-up” period in emotion recognition compared to typically developing peers between the ages of 8-12. Before age 8, children with ASD are comparatively impaired in emotion recognition, and do not appear to acquire any skill in emotion recognition through adolescence and adulthood. While typically developing children may perform no differentially than children with ASD during this late childhood window, they continue to develop emotion recognition skills during teenage years that children with ASD do not (Rump et al., 2009). Since all three of our groups fall within the 8-12 age range, this may explain why we did not find differences in emotion recognition.

Dimensional Analyses

The effect of attention problems and withdrawn behavior on dwell time in the eye region and emotion recognition was also examined. We hypothesized that there would be no significant

correlation between Attention Problems scores and dwell time in the eye region or emotion recognition. Further, we hypothesized that there would be a negatively correlation between Withdrawn/Depression syndrome scale scores and dwell time in the eye region, as well as emotion recognition. There was no significant correlation between either subscale and dwell time or emotion recognition. We predicted that there would be no correlation between attention problems and dwell time or emotion recognition, and these results support this hypothesis. However, the possibility that this null result is due to the effect of small sample size cannot be excluded.

We also predicted that there would be a significant negative correlation between withdrawn behavior and dwell time and emotion recognition, but our results did not support this. Although dwell time and withdrawn behavior were negatively correlated, this correlation was not significant. It is possible that the Withdrawn Behavior subscale does not adequately capture the features of ASD that are linked to facial processing and emotion recognition. Withdrawn behavior is typically used along with the Social Problems and Thought problems subscales to classify children with ASD from the general population (Ooi et al., 2011). The Withdrawn subscale on its own may not capture enough of the features of ASD for the correlation analysis. Further, it may be that the Withdrawn subscale does not capture the salient features of ASD that are related to gaze behavior and emotion recognition. The Withdrawn subscale contains mostly questions about social isolation. The Theory of Mind Inventory, which was dropped from the analysis due to a low response rate, would likely have been more closely related to emotion recognition. One current hypothesis suggests that theory of the mind, the ability to understand mental states of others, underlies the capacity for empathy. Individuals are able to create mental representations of an observed emotion, which in turn activates limbic structures that produce an

emotional response (Vollm et al., 2006). Thus, we would have expected low scores on ToM to be associated with impaired emotion recognition because that capacity for mental representations would have been limited.

Limitations and Future Directions

One significant limitation of this study was a small sample size. A post-study G*Power analysis revealed that with a total sample size of only 32 individuals, we only had the power to detect effect sizes greater than or equal to .73. Klin and colleagues (2002) examined differences in dwell time between children with ASD and controls, and found that dwell time in the eye region predicted diagnostic status beyond any other variable, with an effect size of 3.19. However, another study that examined differences in total fixations in the eye and mouth region between children with ADHD and control children found a small effect size of only -.21 (Serrano, Owens & Hallowell, 2015). Given that our sample was children with comorbid ASD and ADHD, it is possible that we were underpowered, and that a larger sample size may have rendered the mean patterns in dwell time significant. Additionally, Klin's study used images of video clips, while ours used static images of emotional faces. It is possible that since static images less closely approximate a social setting, the effect size for dwell time in the eye region might be smaller simply to due the experimental paradigm.

A larger sample size would also allow for comparisons between emotions. There is some evidence that individuals with autism may be impaired only on certain emotions (such as anger, fear and surprise) (Lozier, Vanmeter, & Marsh, 2014). Emotions are also often categorized as "top" or "bottom" emotions, meaning they mostly involve the either the eye region and mouth region, respectively (Evers, Kerkhof, Steyaert, Noens, & Wagemans, 2014). Since individuals with autism avoid eye contact, it is possible that we would see less gaze time in the eye region

and perhaps less accurate emotion identification for top-heavy emotions only. Another limitation of this study was that only emotional faces of 80 and 100% valence were used. In my previous independent study work, emotional faces ranging from 40% to 100% valence were included in the analysis. The faces were excluded in order to shorten the task, since this study used children of younger ages than previous work. This exclusion may explain why a positive correlation emerged between fixations in the eye region and emotion recognition in my previous work, but not in this study. Studies have shown this type of selective impairment for other features of ASD. For example, one study found that children with ASD were only impaired on tasks that required higher levels of theory of mind (Downs & Smith, 2004). It is possible that differences in dwell time and emotion recognition only appear when emotions are less obvious.

In addition to potentially increasing effect size, naturalistic paradigms that more closely approximate social settings could provide a more accurate assessment of emotion recognition, as discussed above. Future studies would benefit from the use of video clips depicting social interactions (Klin et al., 2002), paradigms where a face displaying one emotion slowly transitions to another (Enticott et al., 2014), or even videotaped analyses of interactions between children. Additionally, future studies should focus on expanding sample size, possibly by adding a group of individuals with ASD only. This would help to elucidate differences in facial processing and emotion recognition in the two conditions. This will likely prove difficult, as some studies suggest there is up to a 78% rate of comorbidity (Lee & Ousley, 2006). It would also be interesting to examine possible differences between the two subtypes of ADHD. The symptoms of the Inattentive subtype (difficulty sustaining attention, does not follow instructions) seem to lend themselves to worse performance on a multiple choice task and to less gaze time at the faces altogether, while symptoms of the Hyperactive subtype (acts without thinking, difficulty waiting

his or her turn) would likely be more related to real-life social impairment (American Psychiatric Association, 2013). Finally, other survey measures should be examined in the dimensional analyses, including the Social Responsiveness Scale (SRS) and Social Communication Questionnaire (SCQ). The SCQ measures three areas associated with ASD: reciprocal social interaction, communication, and restricted, stereotyped patterns of behavior (Rutter, Bailey, & Lord, 2003). Subscores on the first two domains could be examined in relation to dwell time and emotion recognition. The SRS represents a way of looking at autistic traits along a continuum, and may be particularly useful for correlational analyses (Constantino & Gruber, 2005). Finally, experimental tasks measure first and second order theory of mind, in place of parental report, should be considered.

In summary, we did not find a significant difference in dwell time in the eye region or in emotion recognition between children with both ADHD and ASD, ADHD, and children with no psychiatric disorders. However, we did observe a mean pattern, where dwell time in the eye region was lower for children with ADHD/ASD than the other groups, which was consistent with our hypothesis. Further, as we hypothesized, we found no correlation between Attention Problems and dwell time or emotion recognition. However, we did not find support for a significant negative correlation between Withdrawn behavior and dwell time or emotion recognition. It is difficult to draw any conclusions from our analysis towards whether abnormal facial processing is implicated only in individuals with ASD, and if so, how this affects emotion recognition. These questions will best be tested in a larger population of individuals with categorical and dimensional measures.

Table 1. Group Descriptives

	Age (M)	Age (SD)	IQ (M)	IQ (SD)
ADHD/ASD	9.71	1.80	106.33	21.46
ADHD	9.83	1.64	106.75	18.36
Control	10.69	2.29	112.00	12.86

Table 2. Correlation Analyses with CBCL Syndrome Scales

	Attention Problems	Withdrawn/Depressed	Emotion Recognition	Dwell Time in Eye Region
Attention Problems	1	.74**	.08	.24
Withdrawn/Depressed	.74**	1	.04	-.08
Emotion Recognition	.08	.04	1	-.07
Dwell Time in Eye Region	.24	-.08	-.07	1

** significant at the .01 level

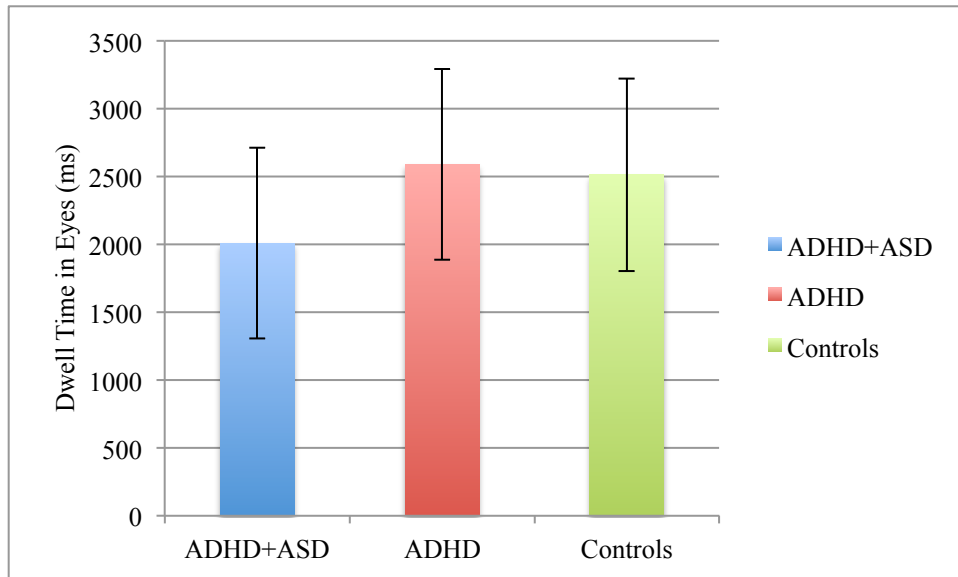
Figure 1.

Figure 1. Comparison of dwell time in the eye region (ms) between ADHD/ASD, ADHD, and control groups.

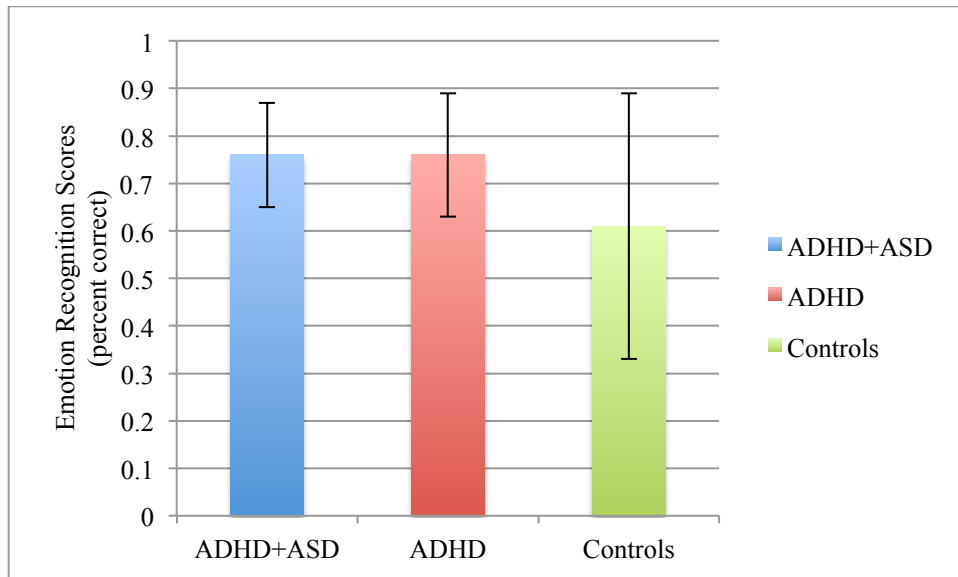
Figure 2.

Figure 2. Comparison of emotion recognition scores between ADHD/ASD, ADHD and control groups.

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