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The Stare-In-The-Crowd Effect: Phenomenology, Psychophysiology, And Relations To Psychopathology

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THE STARE-IN-THE-CROWD EFFECT: PHENOMENOLOGY, PSYCHOPHYSIOLOGY, AND RELATIONS TO PSYCHOPATHOLOGY

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ABSTRACT

The eyes are a valuable source of information for a range of social processes. The stare-in-the-crowd effect describes the ability to detect self-directed gaze. Impairment in gaze detection mechanisms, such as the stare-in-the-crowd effect, has implications for social interactions and development of social relationships. Given the frequency with which humans utilize gaze detection in interactions, there is a need to better characterize the stare-in-the-crowd effect. This study utilized a previously validated dynamic visual paradigm to capture the stare-in-the-crowd effect. We compared typically-developing (TD) young adults and young adults with Autism Spectrum Disorder (ASD) on multiple measures of psychophysiology, including eye tracking and heart rate monitoring. Four conditions of visual stimuli were presented: averted gaze, mutual gaze, catching another staring, and getting caught staring. Eye tracking outcomes and arousal (pupil size and heart rate variability) were compared by diagnosis (TD or ASD) and condition (averted, mutual, catching another staring, getting caught staring) using repeated measure ANOVA. Significant interaction of diagnosis and condition was found for IA dwell time, IA fixation count, and IA second fixation duration. Hierarchical regression was used to assess how dimensional behavioral measures predicted eye tracking outcomes and arousal; only two models with advanced theory of mind as a predictor were significant. Overall, we demonstrated that individuals with ASD do respond differently to various gaze conditions in similar patterns to TD individuals, but to a lesser extent. This offers potential targets to social interventions to capitalize on this present but underdeveloped response to gaze. Implications and future directions are discussed.

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CHAPTER 1: INTRODUCTION

1.1. Background and Significance

Humans are particularly adept at detecting if someone is looking at them in a crowd of other faces. This "stare-in-the-crowd effect" is implicated in numerous moment-to-moment interactions yet relatively little is known about its characteristics. Properly detecting and reacting to gaze informs social interactions in a unique way. Deficits in this perceptual system cause an individual to miss out on large amounts of social information. Thus, study of the stare-in-the-crowd effect is necessary to more completely map social interactions, and to help identify impairments in those interactions which will inform intervention development.

The stare-in-the-crowd effect is likely a familiar experience to readers; for instance, think of a time when you were sitting on a bus and looking up because you "had a feeling" that someone was looking at you. Your ability to quickly pick out this self-directed gaze in a sea of faces is an experience of the stare-in-the-crowd effect. Face scanning experiences occur across age groups and settings. At work, we determine when to participate in water cooler conversations by initiating eye contact or following the gaze of others. We glean if someone is referring to a nearby object or person by following and interpreting their gaze. During recess, the direction of a ringleader's gaze indicates whether they are inviting you to play or if you are being excluded.

Both humans and non-human primates are sensitive to this effect. In fact, it has been posited that the low sclera-iris ratio that is unique to human and non-human primates evolved expressly to enable quick gaze detection. Why would this be a selective trait? There is a substantial amount of information conveyed through the eyes which, if not noticed quickly enough or observed long enough, will be lost. In advanced social societies, it is imperative to use this nonverbal communication to fully engage and reciprocate in an interaction. Gaze provides categorical information about a potential conversational partner, their investment in continuing the interaction, extraneous people or objects referenced in the conversation, and clues about their emotional state (for review, see Kleinke, 1986). Lack of eye contact in autism spectrum disorder, for instance, clearly has negative implications for social interactions, partially because abnormal gaze detection results in missed social information.

1.1.2 Gaze in Social Interactions

Historically, quick identification of self-directed gaze was necessary to assess whether an approaching human was a friend or foe (Kobayashi & Kohshima, 2001). In modern times, gaze serves a vital role in quickly accessing social information about others and identifying their emotions. Due to the large quantity of information coming from a face, looking at the eye is highly adaptive. Self-directed gaze attracts our own gaze (Senju & Hasegawa, 2005) and has repeatedly been shown to be more interesting (as measured by longer looking times) than gaze directed elsewhere (Macrae, Hood, Milne, Rowe, & Mason, 2002). Humans also assess others on their use of eye contact. Maintaining eye contact during social interactions results in being perceived as more attentive (Breed, 1972; Kelly, 1978), intelligent (Wheeler, Baron, Michell, & Ginsburg, 1979), and pleasant (Cook & Smith, 1975). These relations are not simply a one-to-one-correlation, however. In most cases, both inconsistent and constant eye contact result in negative perceptions while well-modulated and frequent eye contact results in positive perceptions.

The duration of eye contact is full of social information as well. Eye contact is the mechanism through which next steps in a social interaction are conveyed. In the passing back and forth of the proverbial "talking stick" during a conversation, longer gazes are used to convey that a speaker has finished what he/she is saying and is waiting for someone else to respond (Kendon, 1967; Levine & Sutton-Smith, 1973). Breaking eye contact has been shown to indicate the end of a social interaction (Knapp, Hart, Friedrich, & Shulman, 1973). The impact of gaze on social interaction also generalizes to other broader settings, such as the classroom. For instance, it has been found that learning is enhanced when taught by a teacher initiating frequent gaze and that seating arrangements in which mutual gaze is encouraged facilitate more cooperative interactions (Jellison & Ickes, 1974; Otteson & Otteson, 1980).

Gaze is instrumental in interactions but shifting gaze in group settings is largely understudied in the literature. Misinterpreting or not noticing shifting gaze can result in missed opportunities for shared social information. Humans will look where others are looking which aids in following a conversation between multiple people and in gathering information that the speaker is trying to convey (Driver IV et al., 1999). Although gaze is usually considered to be a prosocial action, it may also be interpreted negatively. Threatening or competitive gaze, for instance (Jellison & Ickes, 1974), is negatively interpreted, and results in autonomic arousal for most people and avoidance of gaze for the particularly anxious.

Once eye contact is properly noticed and interpreted, additional social processes begin. Making eye contact allows for faster access to stored, categorical social information, such as gender and race (Macrae & Bodenhausen, 2000). Macrae et al. (2002) assessed the interaction of gaze and access to categorical social information. They found that participants were significantly faster at categorizing targets in photographs as male or female when the targets were looking straight ahead with open eyes, similar to "direct gaze." Furthermore, Macrae et al. used similar images flashed briefly before stereotypically male or female words and showed that these words were sorted significantly faster when the flashed target was looking straight ahead. Proper detection of direct gaze can provide one with more social information with which to enter a social interaction.

Accessing stored knowledge has obvious advantages but the ability to respond to another in real time, such as reading another's emotional state, is also necessary for successful socializing. Shorter times to access this information can ease an interaction, as past interactions or social information will inform a current interaction, highlighting the importance of efficient gaze detection. Obviously, in the automatic processes of gaze detection, there are a number of social skills, physiological abilities, and cognitive processes at play. To facilitate these nonverbal behaviors, gaze must first be noticed – which is why the stare-in-the-crowd effect is particularly important. The goal of this study was to develop a model that describes the stare-in-the-crowd effect more fully to better understand the critical beginnings of social interactions.

1.1.3 Gaze for Emotion Identification

In addition to the social information provided by gaze, gaze detection also enables rapid identification of emotions displayed by others. Viewing the eye region results in significantly better identification of basic emotions (such as anger and happiness) than viewing the mouth region. Direct gaze also results in quicker identification of basic emotions. For non-basic emotions (such as "flirtatious" or "thoughtful"), displaying the eye region or whole face results in the same accuracy of emotion identification (Baron-Cohen, Wheelwright, & Jolliffe, 1997). Moreover, for non-basic emotions, gaze direction also does not significantly impact the speed of identification (Adams & Kleck, 2003).

One possible explanation for these findings is encompassed in how humans display emotion. To modulate social responses, humans exert cognitive control over the lower half of their faces. For instance, a social thinker may be cognizant that facially showing frustration may not be appropriate in a particular work setting. Thus, even if they are feeling frustrated, they will consciously display a more appropriate emotion in the lower half of their face. They cannot, however, exert the same control over their eyes. Frustration, therefore, would still be detectable through the eye region. Not only would the emotion in the eyes provide information to the observer, but so would the mismatch between emotions detected through the eyes and the lower half of the face. Part of why looking at the eyes of another is so informative is that the eyes transmit information about emotions that cannot be controlled (E. D. Ross, Shayya, Champlain, Monnot, & Prodan, 2013; R. G. Ross, Harris, Olincy, & Radant, 2000). Thus, the eyes provide an unfiltered emotional response. More basic emotions, such as anger or happiness, may be easier to read from just the eyes. Non-basic emotions may require more intentional demonstrations and thus direct gaze (or reading emotions from the eyes only) simply does not provide enough information.

1.2 Current State of the Field

1.2.1 Eye Tracking

Eye tracking has been the main tool used to study the stare-in-the-crowd effect. Without invasive procedures or lengthy setup times, eye tracking allows for this phenomenon to be studied simply by capturing how viewers take in visual stimuli. Hundreds of variables are collected, including interest area dwell time (how much time a viewer spends looking in a pre-determined area across a trial), time to first fixation (how long it takes a viewer to first stop on a feature of the image), and fixation duration (how long the eye stops on a feature). The outcomes from the eye tracker reflect a viewer's experience of that visual stimulus. For instance, fixating on a particular area of an image conveys emotional saliency on the part of the viewer (Mogg, Philippot, & Bradley, 2004). The time humans spend looking at objects indicates how informative that visual stimulus is (Loftus & Mackworth, 1978; Mackworth & Morandi, 1967). Thus, by presenting an image or video and calculating where, when, and for how long fixations occur, researchers can draw conclusions about what aspects of an image are providing the viewer with the most information. The number of times a subject returns to an area (i.e., the number of saccades into a region) as well as how much time is spent looking there (i.e. the fixation duration) is generally interpreted as an area that a subject finds interesting, surprising, or informative.

For the purpose of studying complex social situations, social scenes can be presented and the most salient parts of a scene can be identified based on eye tracking outcomes (e.g., Klin, Jones, Schultz, Volkmar, & Cohen, 2002). This allows one to ask questions about how humans derive social information, and to examine comparisons between groups with different types of psychopathology. Because eye movement research is not reliant on self-report, there is a high potential for its use in research with populations unable to engage verbally, such as infants or those diagnosed with severe psychopathology, communication disorder, or autism spectrum disorders. Farroni and colleagues (2002) demonstrated with an eye tracking paradigm that infants show a preference for their mother's face over a stranger's within weeks of birth. For studying reactions to quickly presented stimuli, eye tracking captures immediate gaze responses as the social information process begins.

1.2.2 Stimulus Design

Despite all of the functions gaze detection fills and the relative ease of eye tracking paradigms to test them, the study of the stare-in-the-crowd effect has been relatively limited. To study this phenomenon, the stimuli to be used must be mindfully designed. Many studies of gaze detection use sketches on eyes (von Grunau & Anston, 1995) or images of eyes only (without the rest of the face) (Senju, Kikuchi, Hasegawa, Tojo, & Osanai, 2008). These studies are useful in isolating reactions to eye movements but have less utility in understanding the stare-in-the-crowd effect. Other studies, using video or photographs, more closely approximate "real life" settings; however, when gaze shifts, the orientation of a target's head and neck also shifts (Bockler, Timmermans, Sebanz, Vogeley, & Schilbach, 2014b; Klin et al., 2002), thus providing more clues to the viewer about gaze other than just the eyes. Multi-sitter images in which eye movements are the only change between images should be used to begin to explore the stare-in-the-crowd effect in more depth, specifically in relation to situations such as "getting caught staring" or "catching another staring."

1.3 Pilot

To improve upon the current methodology, we developed a new paradigm to capture the stare-in-the-crowd effect. In this paradigm, we utilized images with groups of people (Figure 1) and two new dynamic social gaze conditions (getting caught staring and catching another staring). The stimuli were created for the purpose of the pilot study and the paradigm was tested in a pilot study of typically developing adults. To create the stimuli, and after informed consent to use their likenesses was obtained, we took photographs of groups of adults. With head and body oriented in the same way, two photographs were taken; one with all eyes directed at the camera (at the viewer) and one with all eyes directed elsewhere (Figure 2). Adobe Photoshop was then used to create two sets of stimuli; for the first, the photograph in which all eyes are directed elsewhere was utilized. For the second, one set of eyes was edited by overlaying the other half of the photograph pair so that a single pair of target eyes was directed at the viewer and all others were averted.

Figure 1. An example of the visual stimuli developed for this study. In each image, either one stimulus face is self-directed or none are self-directed, i.e. averted.

These stimuli differ from other research endeavors in three primary ways. First, each image uses a group of sitters, thus mimicking gaze detection amongst multiple faces. Second, the heads and necks of the targets never shift, only their eyes. Third, the use of trigger boundaries (once the viewer's eyes cross this boundary, a new image is displayed) allows for shifting images from averted gaze to self-directed gaze, ideally recreating the experiences of "getting caught staring" (in which a face initially displaying averted gaze shifts to "look" at the viewer once the viewer fixates on that face) or "catching another staring" (in which a target face shifts from viewer-directed gaze to averted gaze once the viewer fixates on their face) (Figure 2). To our knowledge, there are few studies looking at these common experiences and none that incorporate stimuli which "react" to the behavior of the viewer.

Figure 2. The left face illustrates “mutual” gaze. The right face illustrates “averted” gaze. The ovals are boundaries used to trigger a change in the gaze and for analytic purposes.

In the pilot study of 35 typically-developing adults, self-directed gaze resulted in longer looking times (longer dwell times as well as more fixations). Second fixation duration was significantly higher in conditions in which there was shifting gaze (e.g. the initial glance had triggered a new image) except if the stable gaze was direct, in which case self-directed gaze resulted in longer second fixation durations, even in comparison to shifting images. These stimuli successfully demonstrated the stare-in-the-crowd effect. Additionally, by using shifting images, the experiences of “getting caught staring” and “catching another staring” were recreated to allow for further development of a social perceptual model.

Two significant correlations with the behavioral measures were found in the pilot study, and one trend-level association was observed. The Expressive subscale of the Social Responsiveness Scale (SRS) was positively correlated with pupil size (r = .53, $p<.05$). In addition, analysis of the Liebowitz Social Anxiety Scale, on which participants rate a list of situations based on both their fear of this situation and their avoidance of this situation, demonstrated that fear of “Looking at people you don’t know very well in the eyes” was negatively correlated with fixation count at the trend level (r = -.45, p = .05). Avoidance of looking at people in the eyes was also significantly negatively correlated with fixation count (r = -.49, p < .05). Given that participants without any psychopathology were specifically recruited, the limited range of these measures likely limited other significant correlations. Despite this restriction in the range of impairment in this typically-developing sample, the presence of significant findings related to social behavior was the impetus for the current proposal – to study the stare-in-the-crowd effect in a clinical population.

1.4 Current Study

Given the success of experimentally simulating the stare-in-the-crowd effect and building on the foundation developed in the course of the pilot study, this study examined two domains thought to be pertinent in understanding the stare-in-the-crowd effect: psychopathology and autonomic arousal.

1.4.1 Psychopathology

For the purposes of this study, characteristics relating to autism (including theory of mind and social responsiveness) and social anxiety traits were examined. Given the social impairments relating to each, it is not surprising that autism and social anxiety are two diagnoses that have been previously studied using eye tracking. Although ASD and TD individuals comprised most of the group comparisons in this study, traits of social anxiety were factored into the dimensional analysis of gaze detection and arousal and thus these traits are discussed here as well.

1.4.2 Autism Spectrum Disorder

Pelphrey and colleagues' (2002) widely-recognized study focused on visual scanning of faces in adults with autism spectrum disorder (ASD). They found that typically-developing (TD) individuals scan faces with primary focus on the “T-zone” (includes the eyes and the mouth) when presented with a face whereas the adults with ASD spent less time looking at the eyes and less time looking in this T-zone. Because this region conveys emotions, intentionality and social referencing, all of these data are then missed by individuals with ASD. Not surprisingly, more complex social perceptual abilities appear to be different in individuals with ASD as well. Children with autism were less able to recognize repeated facial stimuli when compared to matched controls, even though their ability to recognize inanimate, non-social objects may have been superior to controls (Trepagnier, Sebrechts, & Peterson, 2002). Von Hofsten, Uhlig, Adell, and Kochukhova (2009) found that children with ASD were able to follow the movements of a rolling ball with the same smooth pursuit as typical controls but that they were significantly less likely to visually anticipate shifts in speakers during a conversation. There is something unique about the social aspect of faces that is less readable for individuals with ASD. In general, individuals with autism make less eye contact than their typically-developing counterparts (Werner, Dawson, Osterling, & Dinno, 2000) and struggle to follow gaze in a multiple-participant interaction (Dawson et al., 2004). Even eye contact after a strong emotionally-valenced social interaction, such as tickling, results in less eye contact from children with ASD than typically developing children or children with intellectual impairments (Mundy, Sigman, Ungerer, & Sherman, 1986). These deficits suggest that the stare-in-the-crowd effect in particular would be less strong in individuals with social responsiveness impairments.

These differences in gaze behavior are indicative of neural activation differences relative to ASD status on gaze detection paradigms as well. Visual change detection in adults with ASD is known to be atypical relative to typically-developing controls. There is abnormal activation in the anterior cingulate cortex when presented with a changing visual stimulus in individuals with ASD that is not observed in TD adults (Clery et al., 2013). Different neurological responses relative to diagnostic status are also observed in response to social material, indicating again that there is something unique about social stimuli for individuals with ASD. Adults with ASD do not exhibit differences in reflexive gaze following but there are different neural mechanisms underlying the process (Greene et al., 2011). During a gaze detection paradigm, increased negativity, when it is observed, is lateralized to the right hemisphere in typically-developing children but this lateralization was not observed in children with ASD (Senju, Tojo, Yaguchi, & Hasegawa, 2005). Thus, the neurological activity occurring during social perceptual tasks differs relative to ASD status. Although neural activation was not studied in this current project, it is important to be aware of these activation differences to possibly explain some of the gaze behavior differences we predicted.

1.4.3 Theory of Mind

One's level of theory of mind has been shown to be associated with gaze detection ability. Theory of mind describes one's ability to attribute mental states to oneself and others and has been identified in both humans and chimpanzees (Baron-Cohen, Leslie, & Frith, 1985; Premack & Woodruff, 1978). Theory of mind is related to gaze behavior: eye contact is the main source of information about the mental states and intentions of others (Phillips, Baron-Cohen, & Rutter, 1992). In fact, the theory of mind neural network (which activates when engaged in tasks determining mental states of others) significantly overlaps with the networks activated by direct gaze. Much of the work on theory of mind has been conducted with individuals with ASD as limited theory of mind is one of the challenges of autism. Children with and without mental handicaps (and without ASD) can infer mental states based on eye gaze whereas children with ASD cannot (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995). Since a less developed theory of mind is present in individuals with ASD, it is hypothesized that these eye gaze deficits are related to theory of mind abilities.

The detection and conveying of emotions requires not only emotional knowledge but theory of mind as well. Looking at self-directed gaze indicates interest in that gaze. Von dem Hagen et al. (2013) hypothesized that TD individuals (assumed to have developed theory of mind) recognize the agency of someone looking at them. Based on this knowledge, they may initiate a conversation or respond to this gaze in some way. Imaging studies have shown that, in these situations, individuals with ASD display less activation in areas associated with theory of mind than TD individuals (von dem Hagen, Stoyanova, Rowe, Baron-Cohen, & Calder, 2013). Since theory of mind is generally impaired in individuals with ASD, this suggests that the ability to attribute thoughts or feelings to others also impacts how individuals detect and react to self-directed gaze. This study examines the relation between theory of mind and the stare-in the-crowd effect more closely.

A better understanding of theory of mind and gaze detection would be beneficial for two reasons. The first is that gaze detection develops very early on, before theory of mind can be assessed, and a well-vetted gaze detection task could serve as an early screener for theory of mind deficits. The second is that, by understanding how they are related, interventions that target either gaze behavior or theory of mind concepts can be developed to improve functioning in this area. But before either of these goals can be achieved, the relation between theory of mind and gaze behavior must be more clearly defined.

1.4.4 Social Responsiveness

Social responsiveness, another domain traditionally impaired in individuals with ASD, has also been explored in gaze research. Specific correlates of gaze detection and traits related to autism vary by study. Many studies rely solely on categorical diagnostic status (Nakano et al., 2010; Neumann, Spezio, Piven, & Adolphs, 2006; Phillips et al., 1992). However, given the variability possible within an ASD diagnosis, there is more to learn about specific behavioral correlates of gaze detection. In this proposal, social responsiveness will be assessed dimensionally to further characterize the relation between ASD and gaze detection.

Social responsiveness encompasses the ability to be aware of, to interpret, and to respond to the social behaviors of others in an appropriate way (Constantino et al., 2003). Picking out and reacting to gaze necessarily hinges on the knowledge that another person is using gaze to communicate. Thus, as with theory of mind, one's social responsiveness is likely related to the ability to detect self-directed gaze. Disorders in which social ability is impaired, such as ASD, Turner syndrome, or Williams syndrome, have repeatedly been shown to be associated with deficits in perception of eye movements of others (Elgar, Campbell, & Skuse, 2002; Mobbs et al., 2004; Phillips et al., 1992). Specific domains of social responsiveness have yet to be fully explored in the literature. Social responsiveness is known to be impaired in ASD (Schreibman, 1988) and thus was included in the dimensional analyses here.

1.4.5 Social Anxiety

Although not specific to ASD, social anxiety has been shown to influence gaze behavior [for a brief review, see Schulze, Renneberg, & Lobmaier, 2013]. Individuals with social anxiety tend to be overly watchful for self-directed gaze (Gamer, Hecht, Seipp, & Hiller, 2011). Once noticed, however, the avoidance of eye contact in social anxiety has been well-documented and may be a maintaining factor of the disorder (Baker & Edelmann, 2002). Individuals with social anxiety disorder have been shown to make less eye contact during social conversations and to make less gaze fixations on eyes during eye tracking studies. Given the amount of social information conveyed via eye contact, it is likely that this missed information may only be supporting maladaptive thinking patterns commonly observed in individuals with social anxiety. Using a behavioral questionnaire about eye contact, self-reported eye contact was found to be significantly negatively correlated with social anxiety (Daly, 1978). Social anxiety traits were, therefore, measured as part of this study to begin to understand how these may affect gaze detection, both on their own and in the context of theory of mind and social responsiveness.

1.4.6 Autonomic Arousal

Identification of neurological correlates of these social and non-social processes would provide additional insight into the effects of ASD on social perception and gaze. In a study by Loth, Carolos, Gomez, and Happe (2008) comparing detection of scene-unrelated objects, scene-related objects, or object substitutions, TD adults could identify differences in images depending on the condition. However, for the adults with ASD, there was no effect of condition on ability to detect change and, in comparison to the TD group, these individuals were significantly less successful at identifying scene-unrelated objects. This suggests that adults with ASD develop less schematic expectations. For the current study, we expected that this may translate into differences between adults with ASD and TD adults in their reactions to shifting gaze in an image. We expected that the TD adults would experience autonomic arousal whereas the adults with ASD would look at changes in the images in the same manner but respond differently, as they would not interpret this shift as anything beyond a stimulus change.

The autonomic nervous system (ANS) refers to the “fight or flight” and “rest and relax” systems that are unconsciously activated in new situations. The ANS has two components: the sympathetic and parasympathetic systems. Because these mechanisms are activated automatically rather than intentionally, they make for strong markers of internal activity. In this proposal, pupil dilation and heart rate were measured, since both are under sympathetic and parasympathetic control and provide a convenient window into the ANS.

Previous research has suggested that pupil dilation indicates surprise or an increase in cognitive effort (Preuschoff, Hart, & Einhauser, 2011). This increase, however, was less apparent in unmedicated depressed adults in comparison to healthy controls, indicating that psychopathology moderates the relation between cognitive effort and pupil dilation (Siegle, Steinhauer, & Thase, 2004).

In addition to measuring pupil dilation to capture autonomic reactions to visual stimuli, heart rate variability was measured as a complementary measure of ANS function. The study of gaze and heart rate has been a particular focus in infant research. Sroufe and Waters (1977) studied gaze aversion and autonomic arousal in infants and found that gaze aversion followed heart rate acceleration followed by a return to base levels. Generally, unmet gaze was not related to autonomic arousal (i.e. avoidance of gaze appears to be an effective avoidance strategy to circumvent increased heart rate) but the feeling of increased heart rate often resulted in gaze aversion. Sroufe and Waters suggest that gaze aversion appeared to be a coping mechanism in the infant population.

Studies of heart rate variability in stressful situations have shown increased heart rate, with girls and young people showing significantly more increase than boys and elderly adults, respectively (Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004). In a study of rhesus macaques, heart rate during social interactions was measured (Aureli, Preston, & de Waal, 1999). In the more stressful situations, such as approach by a dominant group member, heart rate increased. Conversely, grooming behaviors by group members caused significantly more decrease in heart rate in comparison to a control time; thus, the interpretation of a social situation can be informed by using heart rate variability. The study of real-world social situations, however, demands adaptive social functioning. In disorders such as ASD, this may not be a given, and calls for an alternative experimental approach.

Broadly, children with ASD have been observed to have faster heart rates than typically developing children (Bal et al., 2010). There is overlap between symptoms of autism and dysfunction of the ANS (Ming, Julu, Brimacombe, Connor, & Daniels, 2005) and the continued study of ANS functioning in specific social situations is important to develop a model of autonomic arousal and social processing in ASD. Generally speaking, cardiovascular changes are not observed in response to sensory intake in children with ASD (Kootz & Cohen, 1981). The effect of social perception on heart rate is also a topic of interest relative to social anxiety. The perception of direct gaze is related to increased heart rate in highly socially anxious adults, with a significantly greater increase than those without social anxiety (Wieser, Pauli, Alpers, & Muhlberger, 2009). In the study of shifting gaze, as studied here, comprehensive measures of psychopathology phenotypes and heart rate were examined to allow for maximal modeling of how social perceptual systems function (or are impaired) in clinical populations.

1.5 Specific Aims

Given what knowledge we have already acquired and the pursuit of more careful characterization of the stare-in-the-crowed phenomenon, this proposal incorporated eye tracking and autonomic arousal while taking into account social responsiveness, theory of mind, and social anxiety. A group of adults with ASD were recruited, as social responsiveness and theory of mind are lower in this population. Additionally, pupil diameter and heart rate data were collected during the presentation of the stimuli. For these analyses, the term arousal is used to refer to IA pupil size and RMSSD. This study had three specific aims and related hypotheses:

Specific Aim 1: To determine how stimulus condition affects eye tracking and arousal outcomes.

Hypothesis 1a: Interest area dwell time and interest area fixation count will be greater in conditions with more direct gaze (mutual and getting caught staring) than less direct gaze (averted and catching another staring).

Hypothesis 1b: Second fixation duration will be greater for dynamic conditions (getting caught staring and catching another staring) than stable conditions (mutual and averted).

Hypothesis 1c: Arousal will be greater in dynamic conditions (getting caught staring and catching another staring) than stable conditions (mutual and averted).

Specific Aim 2: To determine the relation of diagnosis and diagnosis by condition with tracking and arousal outcomes.

Hypothesis 2a: Across conditions, eye tracking measures and arousal will be greater in the TD group than in the ASD group.

Hypothesis 2b: For two of the eye tracking measures (IA dwell time, IA fixation count), there will be an interaction between diagnosis and condition, with the eye tracking measures being greater in the TD group than in the ASD group in the more direct gaze conditions (mutual and getting caught staring).

Hypothesis 2c: For second fixation duration and arousal, there will be an interaction between diagnosis and condition, with second fixation duration and arousal being greater in the TD group than in the ASD group in the dynamic conditions (getting caught staring and catching another staring).

Specific Aim 3: To establish how specific dimensionally-measured traits relate to eye tracking and arousal outcomes, regardless of diagnosis.

Hypothesis 3a: Higher scores on the Social Responsiveness Scale (indicating more problems with social responsiveness) will be negatively associated with eye tracking measures and arousal.

Hypothesis 3b: Higher scores on the Theory of Mind Inventory (indicating greater theory of mind) will be positively associated with eye tracking measures and arousal.

Hypothesis 3c: Higher scores on Liebowitz Social Anxiety Scale (indicating more social anxiety) will be negatively associated with eye tracking measures but positively associated with arousal.

CHAPTER 2: METHODS

2.1 Subjects

Two main groups were recruited: a group with ASD and a TD group. For the group with ASD, individuals were required to have a diagnosis of ASD or Pervasive Developmental Disorder (PDD) that was documented by a medical professional. For the TD group, inclusion criteria also included no known diagnosis of ASD or PDD and no current psychotropic medications. Subjects were recruited through four primary channels: (1) undergraduate students enrolled in an introductory psychology courses; (2) individuals with ASD recruited through a supportive living environment at UVM; (3) individuals with ASD recruited through child psychiatry at UVM; and (4) community means, including flyers and newspaper advertisements. A total of 36 participants ages 18-35 were recruited.

2.2 Study Visit

Eligible participants were consented and the setup for the eye tracking and VU-AMS system (for heart rate monitoring) was explained as they were connected to these systems. Study staff first attached the VU-AMS electrodes to the participant. The participant was then seated in front of the eye tracker and the adjustable head rest was set up. The visual stimuli were presented on a screen 18 inches from the participant and they were instructed to look at the images. At the end of the stimuli presentation, the VU-AMS electrodes were removed. The cognitive assessment was then administered, followed by completion of the behavioral measures and a demographics form, which included questions about current medications, any vision troubles, and documentation of their current psychology course if they were seeking course credit.

2.3 Visual Stimuli

To assess the stare-in-the-crowd effect, a previously validated visual stimuli set was presented. These stimuli fall into four conditions; mutual gaze, averted gaze, getting caught staring, and catching another staring. These conditions are described below and illustrated in Figure 3. For the purposes of clarity, the term "sitter" will be used to describe the people in these photos and the term "target" will be used to describe the sitter who is of interest in that particular image.

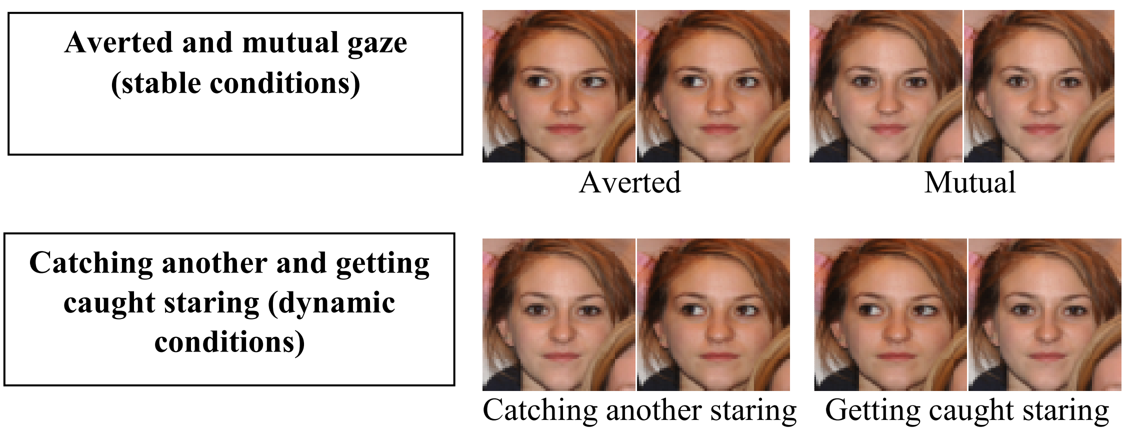

Figure 3. Example of gaze condition comparisons. For the "dynamic" conditions, fixation on the eyes of the first picture triggers the change in gaze of the second image. In the "stable" conditions, fixation on the face does not result in shifting gaze.

Each condition is simulated using two images. A trigger boundary is drawn around the face of one of the sitters. Once the participant's gaze crosses this boundary, the second image is cued up. If the first and second image were the same, this is considered a "stable" condition (i.e., no change in gaze). If the first and second image were different such that the gaze of the target shifted in some way, this is considered a "dynamic" condition. For instance, if the participant looks in the trigger boundary area of a target with averted gaze, this will cue up a new image in which the eyes of the target are now participant- ("self-") directed. Each condition is described below (also see Figure 3).

1) For the averted gaze condition, all sitters will display averted gaze in both identical images.

2) For the mutual gaze condition, two identical images with one target directing gaze at the participant and all other sitters looking away.

3) In the catching another staring condition, the first image will have one participant-directed target and 'eye contact' with this individual will cue up a photo with all averted gaze sitters.

4) In the getting caught staring condition, the initial image will consist of all averted gaze sitters and 'eye contact' with one sitter will cue up the second image with one participant-directed target.

To facilitate detection of changes in physiological responses to the conditions, participants viewed five blocks of images, one for each condition and one that was a combination of the two dynamic conditions. Each block consisted of 20 visual stimuli. The order of the images were counter-balanced across blocks and subjects, although the first and third block only included the mutual or averted gaze experiences to serve as a baseline.

2.4 Behavioral Measures

The Social Responsiveness Scale- Adult Self-Report (SRS) (Constantino & Gruber, 2005) is a 65-item measure of the frequency of social response. The SRS has a

Cronbach's alpha of .71 in typically developing populations (Bolte, 2012). Respondents rate each item on a 1 (Not True) to 4 (Almost Always True) scale. A total and five subscale (Receptive, Social, Expressive Language, Cognitive, Preoccupations) scores are calculated. The presence of ASD is suggested by a high total score on this measure. Although the SRS-A is not a diagnostic tool, it has utility in identifying adults with profiles similar to those who have ASD. Only the total score was used in the current project.

The Theory of Mind Inventory (ToMI) (Hutchins, Prelock, & Bonazinga, 2012) is a 48-item inventory that measures the ability to take another's perspective. Use of this measure allowed for parsing out theory of mind effects over and above social responsiveness across the TD and ASD adults. The parent-report ToMI has a Cronbach's alpha of .98. Typically completed by parents, the ToMI was rephrased into "I" statements for participants to complete about themselves. A total score was calculated, as well as subscales measuring early, basic, and advanced level of theory of mind.

The Liebowitz Social Anxiety Scale (LSAS) (Heimberg et al., 1999) is a highly reliable ($\alpha = .96$) 24-item measure of social anxiety. The respondent rates each item on a scale from 0-3 for fear or Anxiety and from 0-3 for Avoidance. Item #19 ("Looking at people you don't know very well in the eyes") was isolated for use in analyses described below due to its relevance to the paradigm.

2.5 Cognitive Assessment

The Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) was used to obtain an estimate of the cognitive ability of each participant. The WASI was designed as a brief cognitive screener for individuals ages 6-89. Summary IQ scores have a mean of 100 and a standard deviation of 15. For this study, two subscales were administered (Vocabulary and Matrix Reasoning) and combined for the estimated Full Scale IQ- Two Subtest. This overall score was used in subsequent analyses.

2.6 Psychophysiological Measures

2.6.1 Eye Tracking

The EyeLink1000 collects over 100 measures of gaze behavior, the term used here to refer to eye movements such as fixation location, fixation duration, saccades, blinks, etc. The sensitivity of the camera allows for detection of eye movements as small as 0.5 degrees of visual angle. Sitting 18 inches from a computer monitor, this translates into 0.2 inches on the monitor. Given the images used here, this allows for differentiation between a glance at the left versus right eye. Preset areas of interest allow for comparisons of time spent looking at different regions of an image, for instance the eyes vs. non-eye facial regions. The quantitative monitoring of these fixation locations, fixation durations, and looking patterns conveys inner processes of the viewer.

2.6.2 VU-AMS

The VU-AMS measures heart rate variability (HRV) and respiratory rate. This small box is worn on the belt and there is a 6-electrode system that records ECG and thoracic activity. The skin is cleaned with alcohol and then the ECG disposable electrodes are attached to the chest. Participants are asked to sit still, to decrease the effects of movement on HRV. Physiological outcomes were calculated by comparing each participant’s baseline rate to relevant points during the stimuli presentation.

2.7 Preparation of Variables

2.7.1 Eye Tracking Variables

Four main outcome variables were used for analysis, based on the results of the pilot study: Interest Area Dwell Time, Interest Area Fixation Count, Second Fixation Duration, and Interest Area Pupil Size. Averages were calculated and analysis of variance (ANOVA) procedures were used to test for significant differences by diagnosis and condition. Moving forward, "interest area" will be denoted by the abbreviation "IA."

2.7.2 VU-AMS

Although multiple measures of heart rate variability (HRV) can be calculated from the VU-AMS data, we operationalized HRV using the root mean square of successive differences (RMSSD) for each of the conditions for participants. ANOVA procedures were used to determine if RMSSD was significantly different by diagnosis and condition.

2.8 Data Analyses

Aims and hypotheses are restated below, followed by the data analytic approach for each to promote clarity. Additionally, the hypothesized findings are presented in the Appendix.

2.8.1 Specific Aim 1 and Hypotheses

Specific Aim 1: To determine how stimulus condition affects eye tracking and arousal outcomes.

Hypothesis 1a: IA dwell time and IA fixation count will be greater in conditions with more self-directed gaze (mutual and getting caught staring) than less (averted and catching another staring).

Hypothesis 1b: IA second fixation duration will be greater for dynamic conditions (catching another staring and getting caught staring) than stable conditions (averted and mutual).

Hypothesis 1c: Arousal will be greater in dynamic conditions (catching another staring and getting caught staring) than stable conditions (averted and mutual).

2.8.2 Specific Aim 2 and Hypotheses

Specific Aim 2: To determine the relation of diagnosis and diagnosis by condition with tracking and arousal outcomes.

Hypothesis 2a: Across conditions, eye tracking measures and arousal will be greater in the TD group than in the ASD group.

Hypothesis 2b: For two of the eye tracking measures (IA dwell time, IA fixation count), there will be an interaction between diagnosis and condition, with the eye tracking measures being greater in the TD group than in the ASD group in the self-directed conditions (mutual and getting caught staring).

Hypothesis 2c: For second fixation duration and arousal, there will be an interaction between diagnosis and condition, with second fixation duration and arousal being greater in the TD group than in the ASD group in the dynamic conditions (getting caught staring and catching another staring).

For specific aims 1 and 2, repeated measure ANOVAs (with condition as the repeated measure and diagnosis as the independent variable) were conducted with the following measures as dependent variables: IA dwell time, IA fixation count, IA second fixation duration, IA pupil size, and RMSSD. Main effects of diagnosis and condition were considered for Hypotheses 1a-c and 2a and the interaction term was considered for Hypothesis 2b and c.

2.8.3 Specific Aim 3 and Hypotheses

Specific Aim 3: To establish how specific dimensionally-measured traits relate to eye tracking and arousal outcomes, regardless of diagnosis.

Hypothesis 3a: Higher scores on the Social Responsiveness Scale (indicating more problems with social responsiveness) will be negatively associated with eye tracking measures and arousal.

Hypothesis 3b: Higher scores on the Theory of Mind Inventory (indicating greater theory of mind) will be positively associated with eye tracking measures and arousal.

Hypothesis 3c: Higher scores on Liebowitz Social Anxiety Scale (indicating more social anxiety) will be negatively associated with eye tracking measures but positively associated with arousal.

For specific aim 3, hierarchical regressions were conducted with the Social Responsiveness Scale (total score), Theory of Mind Inventory (total score and subscales), and Liebowitz Social Anxiety Scale (Item #19) as independent variables, eye tracking measures and arousal as dependent variables, and age, sex, and IQ as fixed effects. To capture the variation in response to the different conditions, difference scores were calculated. Difference scores for IA dwell time, IA fixation count, IA s0econd fixation duration, IA pupil size, and RMSSD were calculated relative to stable and dynamic conditions (e.g. How many more IA fixations did a person make in the catching another staring and getting caught staring conditions versus the averted and mutual conditions?) and relative to amount of self-directed gaze conditions (e.g. What was the difference in RMSSD between the averted and catching another staring conditions versus mutual and getting caught staring conditions?). Pearson correlations between the behavioral questionnaire scales and the eye tracking and arousal difference scores were calculated (Table 2) and significant correlations were then modeled.

2.9 Power

Using G-Power, we calculated that with a sample of 36, we would have the power to detect an effect size of .19, using alpha = 0.05 and 1-beta = 0.8 for the ANOVA. For the regression analyses, we calculated that we will have the power to detect an effect size of .29, using alpha = 0.05 and 1-beta = 0.8.

CHAPTER 3: RESULTS

3.1 Preliminary Analyses

3.1.1 Demographics

The overall sample included 36 adults (M_{Age} = 20.53 years, SD = 2.22; 41.7% female). Of these, 15 were diagnosed with ASD or PDD and 21 were not. There were no significant differences between the two groups by age, sex, or IQ. Complete data were available for the Social Responsiveness Scale (α = .92), Theory of Mind Inventory (α = .92), and Liebowitz Social Anxiety Scale (α = .94). Total scores on each of these measures differed significantly by group membership (Table 1). Correlations between behavioral measures and difference scores are listed in Table 2.

Initially, participants were matched between the ASD and TD groups. Exploratory comparisons were made to determine if including data from all available TD individuals significantly changed the outcome of the analyses; it did not. Thus, these additional TD individuals were included in the analyses to provide additional power.

Table 1. *Descriptives*

	Typically-developing		ASD	
	M	SD	M	SD
Age	20.05	1.16	21.20	3.10
Sex	48% female		33% female	
IQ	109.71	14.05	117.00	11.73
Theory of Mind Inventory-Total*	19.09	,76	17.63	2.07
ToMI Early	18.15	1.50	16.74	2.80
ToMI Basic	19.22	.78	18.57	2.41
ToMI Advanced****	19.353	.69	16.89	2.36
Social Responsiveness Scale total****	35.90	12.24	78.13	35.57
SRS Awareness*	6.67	1.39	8.67	3.31
SRS Cognition****	4.76	2.53	12.07	7.19
SRS Communication****	11.29	5.44	25.73	12.76
SRS Motivation****	8.62	4.34	16.13	6.88
SRS Autistic Mannerisms****	4.57	2.77	15.53	8.45
LSAS Total*	36.05	15.29	53.20	26.01
LSAS Fear/Anxiety*	18.48	6.88	27.80	12.68
LSAS Avoidance	17.57	9.19	25.40	15.39
LSAS #19 Fear*	1.33	.48	1.87	.92
LSAS #19 Avoidance*	1.14	.36	1.93	1.28

*Indicates significant difference between diagnostic groups at $p < .05$ level, ** $p < .01$, *** $p < .005$, and **** $p < .001$

Table 2. *Correlations between behavioral measures and difference scores.*

		Theory of Mind Inventory				SRS	LSAS#19	
		Early	Basic	Advanced	Total	Total	Fear/Anx	Avoid
IA Dwell Time	*Stable vs. Dynamic*	-.04	.03	.28	.14	-.06	.06	-.22
	More EC vs. Less	.37*	.25	.65**	.51**	-.46**	-.24	-.25
IA Fixation Count	*Stable vs. Dynamic*	-.13	.06	.17	.08	.16	.17	-.16
	More EC vs. Less	.36*	.30	.62**	.52**	-.33*	-.31	-.23
IA Second Fixation Duration	*Stable vs. Dynamic*	.06	.03	.14	.09	-.04	.13	.13
	More EC vs. Less	.25	.01	.38*	.24	-.48**	-.23	-.30
IA Pupil Size	*Stable vs. Dynamic*	-.19	-.14	-.08	-.15	.17	.07	.13
	More EC vs. Less	-.14	-.17	-.34*	-.27	.06	.14	.12
RMSSD	*Stable vs. Dynamic*	-.20	.01	-.15	-.12	.22	.09	.04
	More EC vs. Less	-.15	-.13	-.30	-.24	.06	.15	.07

*indicates $p < .05$, ** $p < .01$

3.1.2 Missing Data

For the eye tracking variables, cognitive assessment, and behavioral questionnaires, there were no missing data. Heart rate data were missing for eight participants, six in the control group (28%) and two in the ASD group (13%). Missing data occurred as a result of system error with the VU-AMS for seven of the participants; one participant from the ASD group could not tolerate the electrodes and thus no heart rate data was collected during their study visit. Comparisons were made between the groups with and without missing heart rate data and there were no significant differences of diagnosis, age, sex, IQ, SRS total score, ToMI total score, or LSAS item #19 score.

3.1.3 Addressing Normality Violations

Prior to conducting the ANOVAs, variables of interest were examined for possible assumption violation. Positive skewness was a significant concern for two of the variables of interest, IA second fixation duration and IA pupil size. A logarithmic transformation was applied and this brought these variables within acceptable normality limits. For pairwise comparisons, Bonferroni corrections were used to adjust for multiple comparisons.

Assumptions of hierarchical multiple regression were tested prior to analysis. For the dependent variables, transformations described in the analyses above were again applied to IA second fixation duration and IA pupil size, thus correcting for normality. The Durbin-Watson statistic fell within the acceptable range for each model, indicating no issues with auto collinearity. All dependent variables were free of extreme outliers and inspection of scatter plots indicated the assumption of homoscedasticity was met. Many of the independent variables were not normally distributed; negative skew was significant for most of the behavior questionnaires. Attempts to transform these variables (using reciprocal, square root, and logarithmic transformations) did not significantly improve the normality. Thus, the un-transformed behavioral questionnaire scores (independent variables) were used in analyses and thus results should be interpreted with this in mind.

3.2 Analyses

Specific Aims 1 & 2: To determine how stimulus condition affects eye tracking and arousal outcomes and to determine the relation of diagnosis and diagnosis by condition with tracking and arousal outcomes.

3.2.1 IA Dwell Time

Due to violation of sphericity, a Greenhouse-Geisser correction was used for IA dwell time analyses. There was a significant main effect of diagnosis, $F(1, 34) = 17.00$, $p < .001$, with TD individuals exhibiting significantly more IA dwell time ($M = 778.78$, $SD = 307.35$) than the individuals with ASD ($M = 399.12$, $SD = 213.69$), as hypothesized. There was also a significant main effect of condition, $F(1.85, 62.89) = 44.38$, $p < .001$, with the getting caught staring condition eliciting the longest dwell time ($M = 991.78$, $SD = 621.54$), followed by the mutual condition ($M = 791.69$, $SD = 506.04$), the catching another staring condition ($M = 416.07$, $SD = 229.86$), and then the averted condition ($M = 282.82$, $SD = 139.59$). Simple main effects were conducted to compare the four conditions. As hypothesized, the mutual and getting caught staring conditions were associated with longer IA dwell time than the averted and catching another staring conditions ($p < .005$ for each comparison).

These main effects were qualified, however, by a diagnosis by condition interaction; IA dwell time differed significantly by diagnosis and condition, $F(1.85, 62.89) = 11.24$, $p < .001$ (Figure 4), confirming part of Hypothesis 2b. Pairwise comparisons revealed that there was no significant difference on IA dwell time by diagnosis in the averted condition, $t(34) = 1.31$, $p = .20$. Thus, when limited social information was presented in the stimuli (i.e. no direct gaze and no shifting gaze), the dwell time did not differ between diagnostic groups. The diagnostic groups did differ significantly on the amount of IA dwell time for each of the other conditions ($p < .05$ for all cases), with the TD group having more dwell time than the group with ASD.

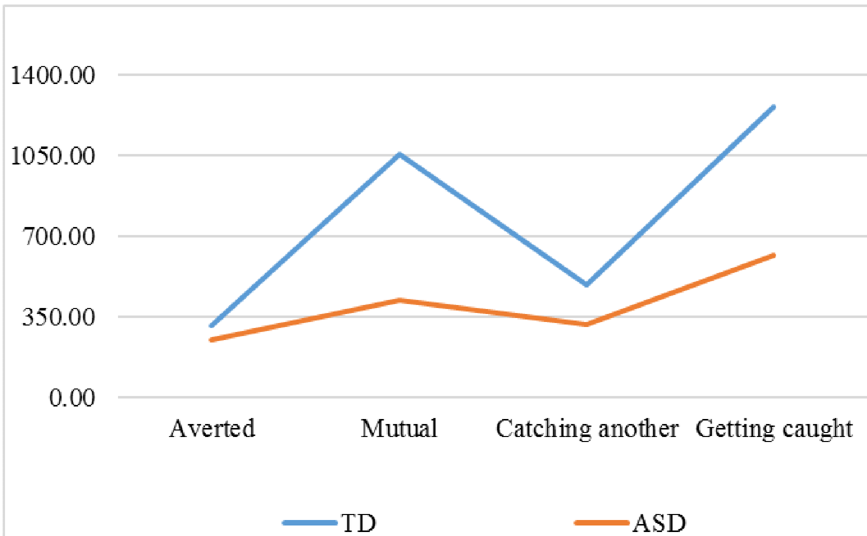

Figure 4. IA dwell time by diagnosis and condition.

3.2.2 IA Fixation Count

A repeated measures ANOVA revealed a significant main effect of diagnosis, $F(1, 34) = 9.149$, $p = .005$, with TD individuals making significantly more IA fixations ($M = 1.97$, $SD = .78$) than individuals with ASD ($M = 1.24$, $SD = .62$),as hypothesized. There was also a significant main effect of condition, $F(3, 102) = 44.10$, $p < .001$, with the getting caught staring condition eliciting the most fixations ($M =2.29$, $SD = .19$), followed by the mutual condition ($M = 1.90$, $SD = .17$), the catching another staring ($M = 1.22$, $SD = .10$), and the averted condition ($M = 1.02$, $SD = .08$). As hypothesized, the mutual and getting caught staring conditions were associated with more IA fixations than the averted and catching another staring conditions ($p < .001$ for each comparison).

These main effects were qualified by a significant interaction; IA fixation count differed significantly by diagnosis and condition, $F(3, 102) = 6.180$, $p = .001$ (Figure 5) , confirming part of Hypothesis 2b. The same pattern of differences occurred as with IA dwell time. In the averted condition, the IA fixation count was not significantly different between the two diagnostic groups, $t(34) = 1.75$, $p = .09$. As with IA dwell time, this indicates that simply being presented with a visual stimulus that lacks self-directed gaze attracts the same number of IA fixations regardless of diagnosis. The diagnostic groups did differ significantly on the amount of IA fixation count for each of the other conditions ($p < .05$ for all cases), with the TD group having more fixations than the group with ASD.

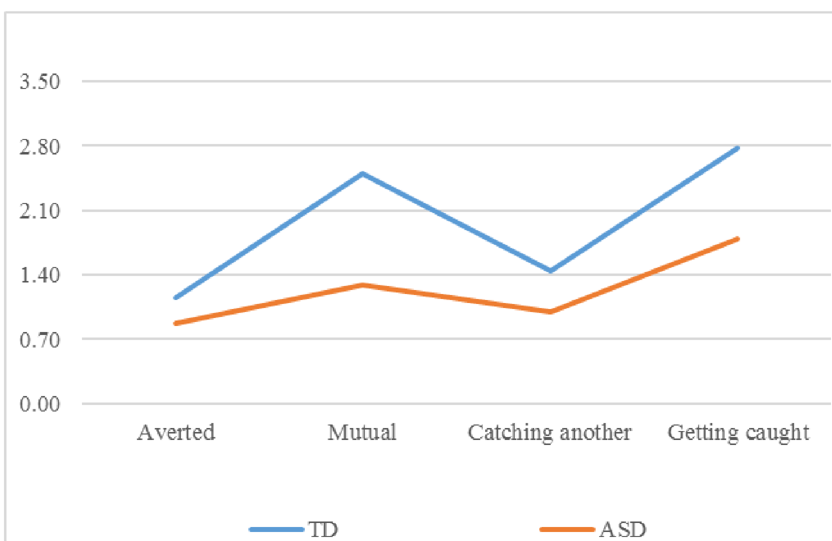

Figure 5. IA fixation count by diagnosis and condition.

3.2.3 IA Second Fixation Duration

A repeated measures ANOVA revealed a significant main effect of diagnosis, $F(1, 32) = 6.30$, $p = .02$, with TD individuals displaying significantly longer IA second fixation duration ($M = 421.70$ ms, $SD = 101.55$) than individuals with ASD ($M = 338.78$ ms, $SD = 70.68$), as hypothesized. There was also a significant main effect of condition, $F(3, 96) = 12.41$, $p < .001$, with the mutual condition resulting in the longest IA second fixation duration ($M = 486.33$ ms, $SD = 237.42$), followed by the getting caught staring condition ($M = 443.99$ ms, $SD = 207.15$), the catching another staring condition ($M = 335.83$ ms, $SD = 116.11$), and then the averted condition ($M = 274.35$ ms, $SD = 110.68$). This is not consistent with the hypothesis that the dynamic conditions (getting caught staring and catching another staring) would result in longer IA second fixation durations.

These main effects were qualified by a significant interaction of diagnosis and condition, $F(3, 96) = 5.13$, $p = .002$ (Figure 6). The differences resulting in this significant interaction were not in the pattern hypothesized, however. One of the dynamic conditions (catching another staring) was not significantly different between the two diagnostic groups. Thus, in contrast to what was hypothesized, IA second fixation duration did not differ significantly between groups based on whether or not a condition was dynamic. It is important to note that for the group with ASD, there were no significant differences between the IA second fixation durations across the mutual, catching another staring, or getting caught staring conditions.

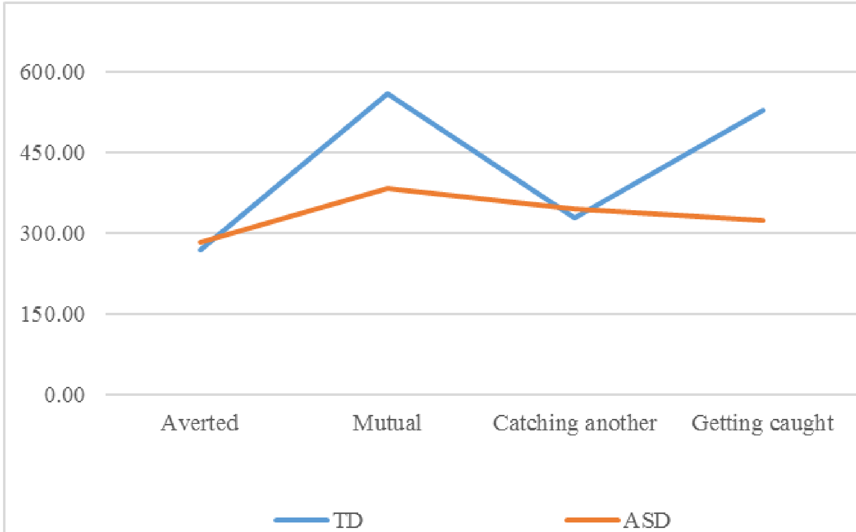

Figure 6. IA second fixation duration by diagnosis and condition.

3.2.4 IA Pupil Size

A repeated measures ANOVA revealed no significant interaction of condition and diagnosis on pupil size, $F(3, 99) = 2.53$, $p = .06$, nor any significant main effects of condition, $F(3, 99) = .64$, $p = .59$ or diagnosis, $F(1, 33) = .75$, $p = .39$ (Figure 7). Thus, arousal measured by pupil size was not affected by condition, diagnosis, or an interaction of the two, failing to support my hypothesis.

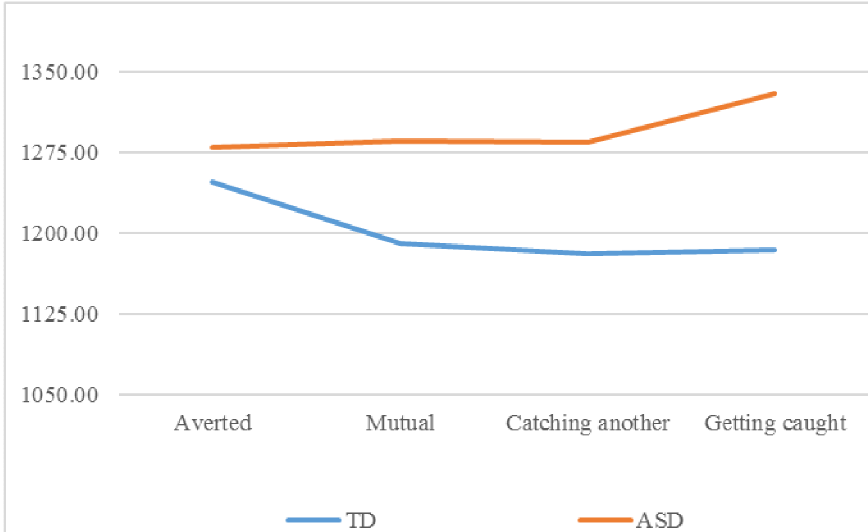

Figure 7. IA pupil size by diagnosis and condition.

3.2.5 RMSSD

A repeated measures ANOVA of RMSSD by condition and diagnosis was non-significant, $F(3, 75) = 1.027$, $p = .385$. Main effects of condition, $F(3,75) = 1.775$, $p = .159$, and diagnosis, $F(1,25) = .318$, $p = .578$, were also non-significant (Figure 8). As above, this demonstrates that arousal did not vary relative to diagnosis, condition, or the interaction of the two. My hypothesis was not supported.

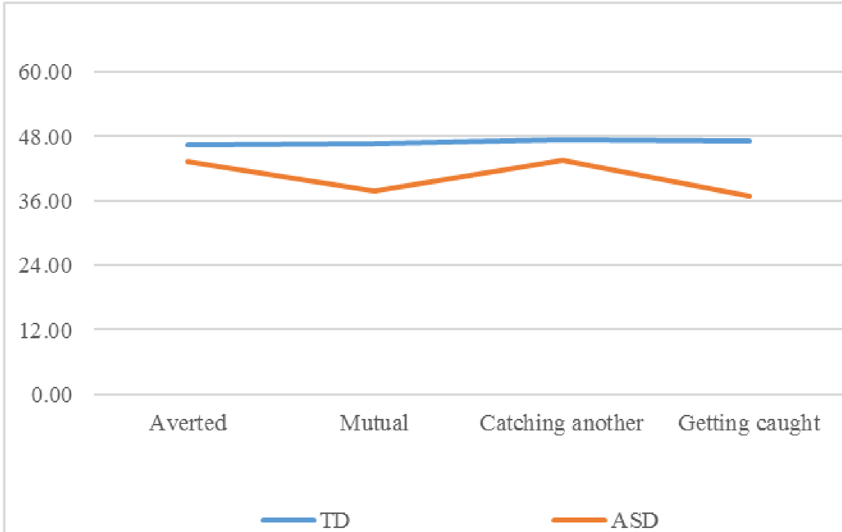

Figure 8. RMSSD by diagnosis and condition.

Specific Aim 3: To establish how specific dimensionally-measured traits relate to eye tracking and arousal outcomes, regardless of diagnosis.

3.2.6 Social Responsiveness Scale

Significant correlations emerged between the SRS Total Score and IA dwell time more vs. less gaze difference score, IA fixation count more vs. less gaze difference score, and IA second fixation duration more vs. less gaze difference score. Subsequently, a regression analysis was conducted where age, sex, and IQ were entered at step one and SRS Total Score was entered at step two. No significant models emerged (Table 3).

Table 3. *SRS Total Score Regression Results*

	b	***SE***	β	***t***	***p***	ΔR^2
DV: IA dwell time, Difference Score Between More and Less Eye Contact (*N* = 36)						
$F = 1.89$; $p = .14$; $df = 4$; $R^2 = .20$						
Age	-11.44	36.36	-.06	-.32	*ns*	
Sex	-3.32	141.83	.00	-.02	*ns*	
IQ	-.12	5.40	.00	-.02	*ns*	
SRS Total Score	-5.50	2.57	-.41	-2.14	.04	.12
DV: IA fixation count, Difference Score Between More and Less Eye Contact (*N* = 36)						
$F = 1.61$; $p = .12$; $df = 4$; $R^2 = .17$						
Age	-.02	.07	-.06	-.29	*ns*	
Sex	-.27	.27	-.17	-1.03	*ns*	
IQ	.00	.01	.00	-.03	*ns*	
SRS Total Score	-.01	.01	-.35	-1.81	*ns*	.09

(*Table 3 continued*)

DV: IA second fixation duration, Difference Score Between More and Less Eye Contact [a] (N = 34)						
F = 2.44; p = .07; df = 4; R^2 = .25						
Age	.00	.07	.00	-.02	*ns*	
Sex	.08	.28	.05	.29	*ns*	
IQ	-.01	.01	-.16	-.95	*ns*	
SRS Total Score	-.01	.01	-.45	2.38	.02	.15

[a] The scale has undergone a logarithmic transformation for these analyses

3.2.7 Theory of Mind Inventory

Significant correlations emerged between the ToMI-Total Score and IA dwell time more vs. less gaze difference score and IA fixation count more vs. less gaze difference score. Subsequently, a regression analysis was conducted where age, sex, and IQ were entered at step one and ToMI-Total Score was entered at step two. No significant models emerged (Table 4).

Table 4. *Theory of Mind Inventory- Total Score Regression Results*

	b	***SE***	β	***t***	***p***	ΔR^2
DV: IA dwell time, Difference Score Between More and Less Eye Contact (*N* = 36) $F = 1.53$; $p = .22$; $df = 4$; $R^2 = .17$						
Age	-13.81	37.99	-.07	-.36	*ns*	
Sex	21.10	114.12	.02	.15	*ns*	
IQ	-3.79	5.39	-.12	-.70	*ns*	
ToMI- Total	95.18	52.74	.35	1.81	*ns*	.09
DV: IA fixation count, Difference Score Between More and Less Eye Contact (*N* = 36) $F = 1.90$; $p = .14$; $df = 4$; $R^2 = .20$						
Age	-.01	.07	-.01	-.07	*ns*	
Sex	-.23	.26	-.15	-.90	*ns*	
IQ	-.01	.01	-.11	-.68	*ns*	
ToMI- Total	.20	.10	.40	2.09	.05	.11

Significant correlations emerged between the ToMI-Early Score and IA dwell time more vs. less gaze difference score and IA fixation count more vs. less gaze difference score. Subsequently, a regression analysis was conducted where age, sex, and

IQ were entered at step one and ToMI-Early Score was entered at step two. No significant models emerged (Table 5).

Table 5. *Theory of Mind Inventory- Early Scale Regression Results*

	b	***SE***	β	***t***	***p***	**ΔR^2**
DV: IA dwell time, Difference Score Between More and Less Eye Contact (N = 36)						
F = .72; p = .59; df = 4; R^2 = .09						
Age	-37.27	42.51	-.19	-.88	*ns*	
Sex	10.65	152.12	.01	.07	*ns*	
IQ	-2.44	5.63	-.08	-.43	*ns*	
ToMI- Early Scale	22.28	43.05	.11	.52	*ns*	.01
DV: IA fixation count, Difference Score Between More and Less Eye Contact (N = 36)						
F = 1.08; p = .38; df = 4; R^2 = .12						
Age	-.03	.08	-.08	-.35	*ns*	
Sex	-.28	.28	-.17	-1.00	*ns*	
IQ	.00	.01	-.05	-.32	*ns*	
ToMI- Early Scale	.09	.08	.25	1.16	*ns*	.04

Significant correlations emerged between the ToMI-Advanced Score and IA dwell time more vs. less gaze difference score, IA fixation count more vs. less gaze difference score, IA second fixation duration more vs. less gaze difference score, and IA pupil size more vs. less gaze difference score. Subsequently, a regression analysis was conducted where age, sex, and IQ were entered at step one and ToMI-Advanced Score was entered at step two. Two significant models emerged; one with IA dwell time, difference score more vs less eye contact as the dependent variable and the other with IA fixation count, difference score more vs less eye contact as the dependent variable (Table 6). These results indicated that more developed advanced theory of mind is associated with greater differences in dwell time between conditions with more and less eye contact. In conditions with more salient social information, such as those with more direct eye contact, individuals with more advanced theory of mind are able to modulate their looking response, such that they are looking more (longer dwell times, more fixations) when there is more self-directed gaze.

Table 6. *Theory of Mind Inventory-Advanced Scale Regression Results*

	b	***SE***	β	***t***	***p***	ΔR^2
DV: IA dwell time, Difference Score Between More and Less Eye Contact (*N* = 36)						
F = 3.24; *p* = .03; *df* = 4; R^2 = .30						
Age	6.87	34.80	.04	.20	*ns*	
Sex	48.21	132.71	.06	.36	*ns*	
IQ	-4.57	4.96	-.14	-.92	*ns*	
ToMI- Advanced Scale	119.93	38.75	.56	3.10	.004	.22
DV: IA fixation count, Difference Score Between More and Less Eye Contact (*N* = 36)						
F = 2.94; *p*= .04; *df* = 4; R^2 = .28						
Age	.02	.07	.05	.27	*ns*	
Sex	-.19	.25	-.12	-.75	*ns*	
IQ	-.01	.01	-.13	-.82	*ns*	
ToMI- Advanced Scale	.21	.07	.52	2.86	.007	.19

(*Table 6 continued*)

DV: IA second fixation duration, Difference Score Between More and Less Eye Contact [a] (*N* = 34)						
$F = 1.74$; $p = .17$; $df = 4$; $R^2 = .19$						
Age	.00	.08	-.01	-.03	*ns*	
Sex	.11	.29	.06	.38	*ns*	
IQ	-.01	.01	-.22	-1.28	*ns*	
ToMI- Advanced Scale	.16	.09	.37	1.78	*ns*	.09
DV: IA pupil size, Difference Score Between More and Less Eye Contact [a] (*N* = 35)						
$F = 1.60$; $p = 2.00$; $df = 4$; $R^2 = .18$						
Age	.01	.01	.19	.98	*ns*	
Sex	.05	.05	.19	1.15	*ns*	
IQ	.00	.00	-.01	-.07	*ns*	
ToMI- Advanced Scale	-.02	.01	-.22	-1.12	*ns*	.04

[a] The scale has undergone a logarithmic transformation for these analyses

3.2.8 Liebowitz Social Anxiety Scale

No significant correlations emerged between the fear/anxiety and avoidance ratings for Item #19 ("Looking at people you don't know very well in the eyes") on the LSAS and any of the eye tracking or arousal difference scores. Thus, no models were run.

CHAPTER 4: DISCUSSION

The prevalence of autism spectrum disorders appears to continue to increase (Baron-Cohen et al., 2009; Kim et al., 2011; Nygren et al., 2012). With social deficits causing significant impairment across work, home life, and peer groups, a more comprehensive understanding of these deficits is required for accurate screening and effective intervention. With differences in facial scanning and other gaze behavior relative to diagnostic status being well-established, the goal of this study was to isolate one particular component of social perception and to quantify how this component presents in individuals with and without ASD. The stare-in-the-crowd effect plays an important role in social interactions. Noticing and reacting to gaze is necessary to start these interactions, to modulate their continuation, and to cue the ending. The findings from this study allow us to better understand how the stare-in-the-crowd effect is affected by ASD.

Two analytic approaches were used to examine the data: categorical and dimensional. The categorical analyses revealed that the interaction of diagnosis and condition significantly affected gaze behavior. The overall trend was that gaze behavior was greatest for conditions with more self-directed gaze, such as the mutual and getting caught staring conditions, with individuals with ASD looking less than TD individuals. For the conditions with less self-directed gaze, such as the averted and catching another staring condition, the differences between the two diagnostic groups were either non-existent or much less pronounced than in the conditions with more self-directed gaze. Dimensional analyses illustrated that some traits related to ASD were not as strongly related to gaze behavior and arousal as hypothesized. Only one scale, ToMI-Advanced, was a significant predictor of any gaze behavior or arousal outcomes.

4.1 ANOVA and Eye Tracking

For IA dwell time and IA fixation count, there was a significant effect of both diagnosis and condition on these two outcome measures. The latter significant finding allowed an examination of hypotheses 1a, 1b, and 1c. The amount of self-directed gaze (averted/catching another staring vs. mutual/getting caught staring) was related to less looking in the averted/catching another staring conditions than in the mutual/getting caught staring conditions. This pattern was also observed for the IA second duration fixation, which contradicts hypothesis 1b and part of 2c; significant differences were predicted between the stable and dynamic conditions instead of between conditions with more and less self-directed gaze. It is likely that a combination of factors caused this outcome. The first is that self-directed gaze is more noticeable or "of interest" than shifting gaze. The other is that, since there were not significant differences in the second fixation duration across conditions for individuals with ASD, this eye tracking measure does not reflect social response to visual stimuli for these individuals. This can inform future work, as discussed below.

There was a significant interaction between diagnosis and condition found for IA dwell time, IA fixation count, and IA second fixation duration. Across variables, TD individuals generally responded with more looking behaviors in conditions with more self-directed gaze, followed by conditions with shifting gaze. However, across variables, individuals with ASD did not differ significantly from the TD group in looking behavior in the averted condition. When there is a lack of socially salient information, all individuals viewed the stimuli similarly. This shows that diagnostic differences on other gaze variables are not simply reflecting that individuals with ASD are looking less at the stimuli than the TD individuals; the social saliency of the images draws different looking reactions.

All individuals spent more time looking at self-directed gaze than averted gaze; the pattern of gaze behavior by condition looked similar across diagnostic groups. Overall, the individuals with ASD were responding in what could be described as a "muted" version of the responses of the TD individuals. Closer examination of differences between conditions or types of conditions (e.g. dynamic vs. stable, more vs. less self-directed gaze) uncovers additional details about potential factors driving these differences.

Between the direct gaze conditions, there was increased visual attention in the dynamic condition in the TD group but less of an increase in the group with ASD. This finding is consistent with the literature. Bockler et al (2014a) found a significant difference of the impact of gaze on subsequent looking behaviors between individuals with and without ASD. When visual stimuli provided social cues via eye gaze, such as people looking in a particular direction, TD individuals would notice this and respond appropriately, looking in that direction. Thus, when a picture appeared in that same spot moments later, TD individuals were quickly able to identify that object. When shown the same image with social cues via eye gaze, individuals with ASD did not alter their behavior to react appropriately by following the gaze. As a result, they less quickly identified pictures that appeared where the people in the image had been looking. The conclusion here is that individuals with ASD did not appear to be interpreting the social information from the gaze of the faces and modulating behavior based on this. For the current study, dynamic gaze should elicit different looking patterns, since this shift provides social information. TD individuals would change their behavior accordingly, looking more at dynamic conditions than stable conditions with similar amounts of self-directed gaze. Individuals with ASD exhibited some different looking patterns but the differences were not as dramatic. Thus, the muted gaze behavior response from the ASD group is consistent with an impairment in recognizing the social saliency of gaze, and the appropriate social response (i.e., increased looking). Reacting to differences in the images would elicit some increased looking in certain conditions, as evidenced by these data, but it is the lack of integration of this information into an appropriate response that illustrates some of the social communication deficits observed in ASD.

As mentioned above, across the eye tracking variables, there were not significant differences by diagnosis for the averted condition. When there was minimal socially relevant information, or when no gaze was directed at the viewer, a diagnosis of ASD did not affect how the scene was viewed. This is important because it demonstrates that, at least for individuals with high functioning ASD, straightforward perception of faces is not necessarily impaired. Rather, once there is socially salient information to recognize, interpret, and respond to, group differences by diagnosis begin to emerge.

Another important point of consideration from these analyses is that the IA second fixation duration did not vary significantly across most of the conditions for the individuals with ASD. Although there was a significant difference in IA second fixation duration between the averted and mutual conditions, comparisons demonstrated that the IA second fixation duration was not significantly different for individuals with ASD between the mutual, catching another staring, and getting caught staring conditions. This is not consistent with the significant conditions differences observed for IA dwell time and IA fixation count in the ASD group. Therefore, IA second fixation duration appears not to be a sensitive measure of response to the stare-in-the-crowd effect for individuals with ASD. In combination with the IA dwell time and IA fixation count results, this suggests that the initial reactions (such as the second fixation) to social information are impaired in individuals with ASD. Moving the awareness of social information earlier into the perceptual process may be a key step in implementing interventions to improve perception of and reaction to social information.

The identified differences in gaze behavior confirms that individuals with ASD, at least adults with high-functioning ASD, are susceptible to the stare-in-the-crowd effect. Their pattern of looking in response to self-directed gaze (i.e. looking more often and longer at gaze that is self-directed versus averted) is similar to that of TD individuals but the differences between the conditions were less. Thus, individuals with ASD are indeed noticing and responding to mutual gaze differently than averted gaze. The extent of their reaction or gaze behavior is not reaching some critical threshold, however, and this has a number of implications for intervention possibilities, as outlined below.

4.2 ANOVA and Arousal

Hypotheses about physiological arousal as measured by RMSSD and IA pupil size were not confirmed for any condition groups (Hypothesis 1c, part of 2a, part of 2c). There were no main effects of diagnosis or condition on RMSSD or IA pupil size. The lack of differences in physiological arousal (and lack of difference by condition) can be interpreted in several ways. At first glance, it is possible that these analyses were underpowered due to missing data. Another possibility is that that there truly are not differences in arousal based on stable or dynamic gaze.

The novelty of the dynamic paradigms utilized in this study make direct comparison to other studies in this area difficult, but there are clues from studies using similar diagnostic status (ASD vs. TD) along with mutual vs. averted gaze suggesting that there may not be an effect of an ASD diagnosis on arousal. In a study of 12-19 year olds, Louwerse et al. (2013) used images of neutral faces displaying direct or averted gaze, or closed eyes, and found no difference in heart rate relative to diagnostic status or mutual vs. averted gaze. Similarly, a recent study of toddlers by Nuske and colleagues (2015) found that pupil size did not differ significantly based on ASD status but did differ relative to amount of self-directed gaze.

A second possibility is that differences in physiological arousal do exist yet our method of assessing them was not optimal. Heart rate variability and pupil size have been used previously and successfully to measure response to social scenes (e.g., Martineau et al., 2011 or Sepeta et al., 2012), but so have other measures, such as galvanic skin response, or skin conductance. For instance, in a study of children, skin conductance was found to be a significant indicator of arousal in children with and without ASD (Kylliainen & Hietanen, 2006). Perhaps had we examined skin conductance we may have observed significant differences on arousal measures.

4.3 Regression with Behavioral Measures

The regressions yielded fewer significant results than anticipated. There were no significant models of the eye tracking or physiological arousal variables using the Social Responsiveness Scale, which contradicts my hypothesis. There were significant group differences on this measure but analyzing this measure as a continuous variable showed no associations with IA dwell time, IA fixation count, IA second fixation duration, IA pupil size, or RMSSD. These null findings can be interpreted in a few ways. One possible explanation is that the significant group differences are clustered around different means and not continuously distributed. There have been a number of studies on the normal distribution of autistic traits in the population and, more specifically, a normal distribution of social responsiveness as measured by the SRS (Constantino & Todd, 2003). For instance, instead of viewing social awareness (a subscale of the SRS) as a trait that either is present or not, Constantino and Todd demonstrated that such traits exist along a spectrum within the general population. Following this model, one might reasonably suppose that behaviors related to ASD, such as gaze behavior, would also be normally distributed in the population. This has not yet been established. However, the unsuccessful attempt to assess the association between social responsiveness and gaze behavior suggests that the shape of the distribution of each of these in the population is different. This could be a reflection of our recruited participants (see Strengths and

Weaknesses section for further discussion) or could indicate that impairment in gaze behavior are better described categorically.

For the Theory of Mind Inventory, two significant models emerged, with the advanced scale being a significant predictor of IA dwell time and IA fixation count difference scores between conditions with more and less self-directed gaze. Given the high level of functioning in our sample (many of the participants were enrolled in college), it is not surprising that within the Theory of Mind Inventory, the advanced scale is the only factor associated with gaze behavior. This factor of the ToMI taps into understanding sarcasm, white lies, second order of belief (i.e., I recognize that you might have feelings about another person's feelings), and social judgment. Lower scores on this scale would indicate less developed social judgment, a critical component in recognizing and reacting appropriately to gaze (Hutchins, Prelock, & Bouyea, 2014). Larger changes in looking in the interest areas of these visual stimuli (as measured by dwell time or fixation count) between conditions with more and less self-directed gaze indicates the participant is changing their looking reactions appropriately when someone is looking at them versus not. Individuals with more developed advanced theory of mind exhibited bigger differentials between conditions with more mutual gaze compared to conditions with less mutual gaze.

The items relating to looking behavior on the LSAS separately (Item #19 "Looking at people you don't know very well in the eyes") was not significantly associated with any eye tracking or arousal outcomes. The literature examining the stare-in-the-crowd effect and social anxiety appears to be underexplored. This preliminary investigation suggests that this particular item on the LSAS may not capture reactions to self-directed gaze in a simulated setting, or relative to the stare-in-the-crowd effect. In individuals with ASD, about 7% of individuals also meet full DSM-IV criteria for social anxiety (Leyfer et al., 2006). This high rate of comorbidity combined with the knowledge that social anxiety and gaze detection is a rich area of study, surveying for these traits in a study of social perception in ASD is vitally important to understand results in a meaningful way.

One possible explanation for the lack of significant results is that the measures used in this study are not capturing the aspect of ASD that influences gaze behavior and physiological arousal (or at least the self-report versions of these measures). Other examples of self-report measures in studies of ASD are uncommon and either the questionnaire itself or the respondent format may not be a good fit for this population or phenomenon. The behavioral measures chosen were similar to those used in other studies, however, so it is also possible that a dimensional approach to breaking down the stare-in-the-crowd effect is simply not the most informative analytic approach.

4.4 Correlations

Although the regressions did not yield robust significant results, a number of significant correlations emerged. Overall, comparisons of eye tracking measures related to the amount of self-directed gaze in an image were significantly correlated to the ToMI subscales and the SRS and no correlations with LSAS item #19 were observed. Higher scores on the ToMI scales (indicating more developed theory of mind) were associated with more looking, including increased fixations and longer looking durations. Higher scores on the SRS (indicating more impaired social responsiveness) were associated with less looking. These correlations suggest that there is an association between some traits relating to ASD that warrant further exploration with a larger sample size and more normal distributions of responses to these behavioral questionnaires. When including additional variables (age, sex, and IQ), many of the models using significantly correlated behavioral measures were not significant. This indicates that our *a priori* selection of these variables was not well informed.

4.5 Research Applications

The design of this study fits with the National Institutes of Health Research Domain Criteria (RDoC) project. Under the "Systems for Social Processes" heading in the RDoC matrix, this project examined the following constructs: social communication (reception of and production of facial communication) and perception and understanding of others (animacy and action perception), and the following domains: cognitive systems (visual perception) and arousal and regulatory systems (arousal) (*NIMH Research Domain Criteria*, 2011).

Although the recruitment strategy targeted two diagnostic groups, the behavioral measures, eye tracking outcomes, and autonomic arousal data were also analyzed continuously, as has been done previously for other psychopathologies. For instance, individuals with ADHD have demonstrated difficulties in some social responsiveness domains (Reiersen, Constantino, Volk, & Todd, 2007). Although models with the SRS were not significant, correlations between the SRS and the eye tracking measures were significant. Thus, the findings from this study relating to ASD may have utility in understanding social perception deficits in other disorders; if we know individuals with ADHD exhibit limited social responsiveness, this may inform our understanding of how these stare-in-the-crowd results would generalize beyond ASD.

By identifying models of the stare-in-the-crowd effect based on behavioral and autonomic data, this paradigm may be adapted to be clinically useful. Klin's group at the Marcus Autism Center in Georgia is developing an eye contact chart, similar to a height or weight growth chart for children, identifying the trajectories of developing eye contact. Because gaze detection abilities develop so early, gaze detection paradigms provide a unique opportunity for very early screening (Jones & Klin, 2013). When we know more specifically how this stare-in-the-crowd effect relates to theory of mind, social responsiveness, and social anxiety in adults (as proposed here) and in children (a potential next step), we can work backwards to develop screening tools for deficits before they occur. Additionally, given the importance of the stare-in-the-crowd effect, presenting this paradigm pre and post intervention could contribute to developing empirically-based programs.

4.6 Clinical Applications

Hwang and Hughes (2000) reviewed 16 empirical studies and found numerous examples of positive effects of social interventions on eye gaze behavior and joint attention, specifically when interventions employed the "time delay" technique (i.e. waiting continually longer periods of time before prompting individuals to engage in a desired task or behavior, then reinforcing; Neitzel & Wolery, 2009). Imitation of others generally appears to be a strong predictor of changed eye gaze behavior. This modeling could be done in person (Harris, Handleman, & Fong, 1987; Tiegerman & Primavera, 1984) or there is exciting new work being done exploring the potential of modalities such as video modeling on social behavior (Kourassanis, Jones, & Fienup, 2015). Thus, there are empirically-based techniques which have been shown to affect changes in social behavior in ASD. The results of this study demonstrate that there is a base level of appropriately modulated response to mutual and dynamic gaze. Building on these already-present skills using the techniques outlined above will serve individuals with ASD (or social impairments more generally) in detecting and responding to gaze, which has implications for a range of social behaviors. Knowing that individuals with ASD are already reacting to the gaze conditions differently provides a good starting point from which to develop more nuanced skills. As outlined previously, the knowledge that the second fixation duration does not reflect the same modulation in reaction to condition can inform targets for these interventions. Individuals with ASD are demonstrating appropriate increased looking in response to self-directed or shifting gaze, as evidenced by IA dwell time and IA fixation count. However, the increased looking must not happen as quickly as it does for the TD individuals as these same differences are not observed in the IA second fixation duration. Increasing looking (such as IA dwell time and IA fixation count) and moving this increased looking earlier in the perceptual timeline are key important starting points for interventions moving forward.

In sum, the stare-in-the-crowd effect has implications that are dependent on the context of that gaze detection and on the clinical presentation of participating individuals. There are two primary objectives achieved by clarifying how autistic and social anxiety traits, categorical diagnosis, and eye gaze condition are related to gaze behaviors and arousal. First, empirically-informed interventions targeting specific deficits can be developed. Second, our understanding of social impairment in individuals with ASD is clarified in relation to gaze detection, a critical aspect of human social interactions.

4.7 Future Steps

Currently, we are recruiting pre-school and school-aged children with ASD to observe how this effect presents in younger children. This will inform the beginnings of a model of gaze detection development. Moving forward, I would like to incorporate different methods of data collection, including galvanic skin response and fMRI or EEG. There is already a sizable literature measuring and localizing brain activity in response to gaze. Specific facets of gaze behavior, such as joint attention, have already been found to be associated with activation in particular brain regions. For instance, Schilbach et al. (2010) found that the ventral striatum is activated when an individual directs someone else' gaze to an object; findings relating to this specific component of social gaze behavior suggest that the stare-in-the-crowd effect may be driven by a specific region of interest, which could then be compared relative to psychopathological traits. And we would similarly expect that the stare-in-the-crowd effect would elicit neural activity that may vary relative to autistic traits. Further, adding in a question about the participants' reactions to shifting gaze (e.g. "Why do you think the person looked away?") would be interesting in the context of ASD but also related to schizophrenia, depression, or anxiety. Moreover, I would like to incorporate these findings into social interventions.

4.8 Strengths and Weaknesses

As with any study, this one is not without limitations. The reliance on self-report of symptoms, the limited sample size, and functioning level of individuals in the ASD group are all points to consider. The use of self-report for the questionnaires is both a strength and a weakness. This highlighted how individuals view themselves and how these perceptions are associated with eye movements and physiological arousal. Anecdotally, especially in response to some of the social responsiveness and theory of mind questions, there may be a discrepancy between an individual's actual social responsiveness, for instance, and their self-perception of that trait, particularly in the group with ASD. For instance, many individuals with ASD asked for clarification of the phrase "Picking someone up", wondering if that meant physically lifting someone else and not understanding that "picking someone up" was an idiom in a social or romantic context. Once this was clarified, many of these individuals then rated themselves as near perfect on their ability to recognize and understand idioms. Having a parent, close companion, or significant other complete the questionnaires may result in different ratings, that are potentially less positively inflated which may have resulted in different regression findings in particular. However, the perspective of young adults with ASD on their own functioning is an important point to consider and thus, from an inclusion perspective, this type of data collection is an area in need of further exploration and norming. Perhaps collecting and comparing significant other- and self-report data on these measures in the future will be useful in guiding how these results are interpreted.

Due to recruitment challenges, the number of individuals with ASD who were recruited is less than originally proposed. Although significant effects were still identified, it is possible that the lack of more participants in the ASD group left the study underpowered to detect additional effects. For example, on the two measures of arousal (IA pupil size and RMSSD), differences between means existed between diagnostic groups and between conditions but these failed to reach the criterion level of significance. Future studies should either aim to include more participants or to recruit individuals within a wider range of ASD presentations to more fully capture the continuous nature of autistic traits.

Preacher, Rucker, MacCallum, and Nicewander (2005) critiqued the "extreme groups approach" (EGA) used in the first part of this study. Comparing the two diagnostic groups on these variables was important given the current work being done on stare-in-the-crowd effect. Despite its wide reaching implications, this effect is not well studied in the literature and there has not yet been a study establishing how the stare-in-the-crowd effect presents in individuals with ASD. By using this EGA, it is possible that the significant effects found here are overestimates of the actual phenomenon. However, most of the individuals recruited into the ASD group were, in fact, quite high functioning. Thus, our group comparisons are not between two drastic ends of the spectrum. This still may lead to overestimation of effects but the recruitment criteria (IQ and ability to answer questionnaires/sit still during an eye tracking task, tolerate electrodes being stuck to their chest and back) did select out individuals on the more severe end of the autism spectrum.

Preacher et al. offer a number of recommendations if EGA is used that were followed. Specifically, groupings were made prior to data collection or statistical analysis, not afterward. By also testing regression models of these outcomes, I do in fact address one of their concerns about this approach, namely that analyses relying solely on extreme groups may lead to misestimating of effects. Since continuous measurement of traits of interest relative to eye tracking and arousal outcomes are also analyzed here, the potential for misspecification decreases.

The fact that the individuals with ASD recruited for this study were mainly high-functioning is, again, a strength and a weakness. The eye tracking system we used would be feasible in a study of lower functioning individuals but the calibration and validation procedures would be markedly more difficult. By relying on higher functioning individuals, we may not be detecting gaze effects that are related to individuals with lower cognitive and linguistic abilities. However, given that we still observed the stare-in-the-crowd effect in individuals with less impairments, it seems reasonable to expect that these effects would be even further magnified for individuals who have more severe traits of ASD.

4.9 Conclusion

Overall, self-directed gaze elicits more looking from viewers, regardless of whether or not they had ASD or if the images shifted. Establishing a baseline for how symptom presentation affects gaze detection and reactions is important to inform interventions that build upon pre-existing abilities. The lack of significant associations between arousal and stare-in-the-crowd conditions was unexpected. Assessing different measures of physiological arousal in future studies may reveal positive findings that were not accessed by the means used here, or perhaps increased looking with limited arousal is a characteristic of gaze detection. This study describes the stare-in-the-crowd effect by varying conditions that have been largely unexplored in the literature. Especially as social interventions for individuals with ASD (and other types of psychopathology) become more sophisticated, it is my hope that findings such as these can inform tailored interventions that address specific impairments in social perception.

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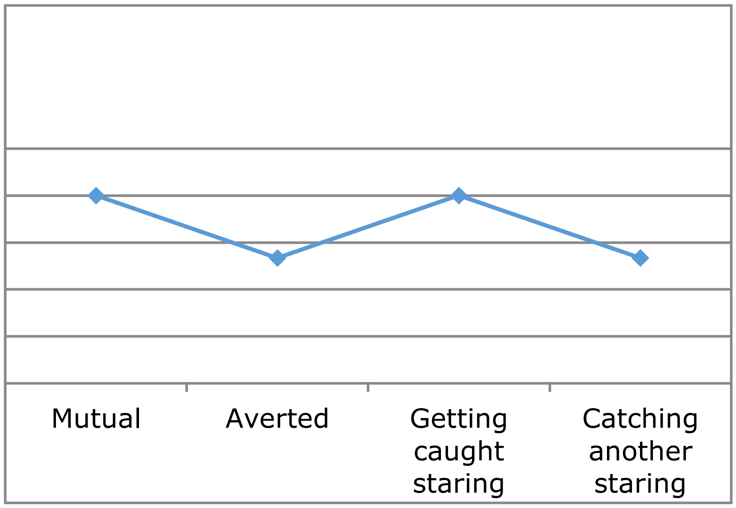
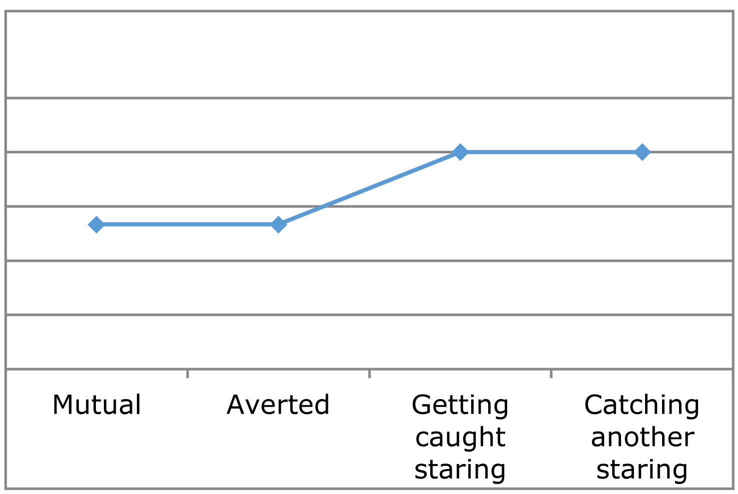
APPENDIX

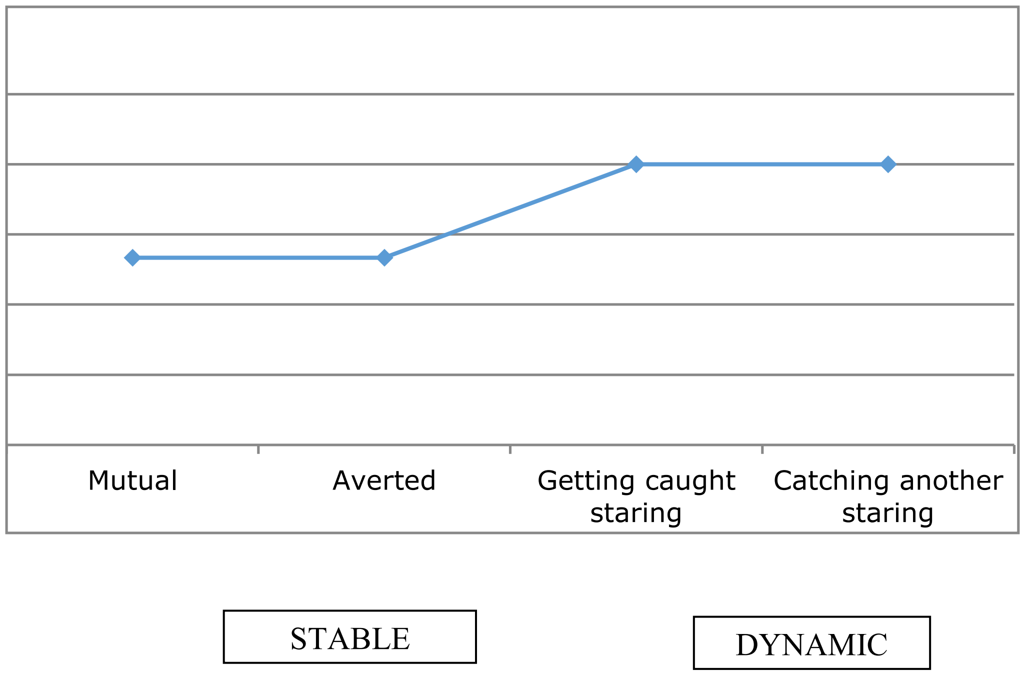
Graphs of hypotheses 1 a-c and 2 b-c



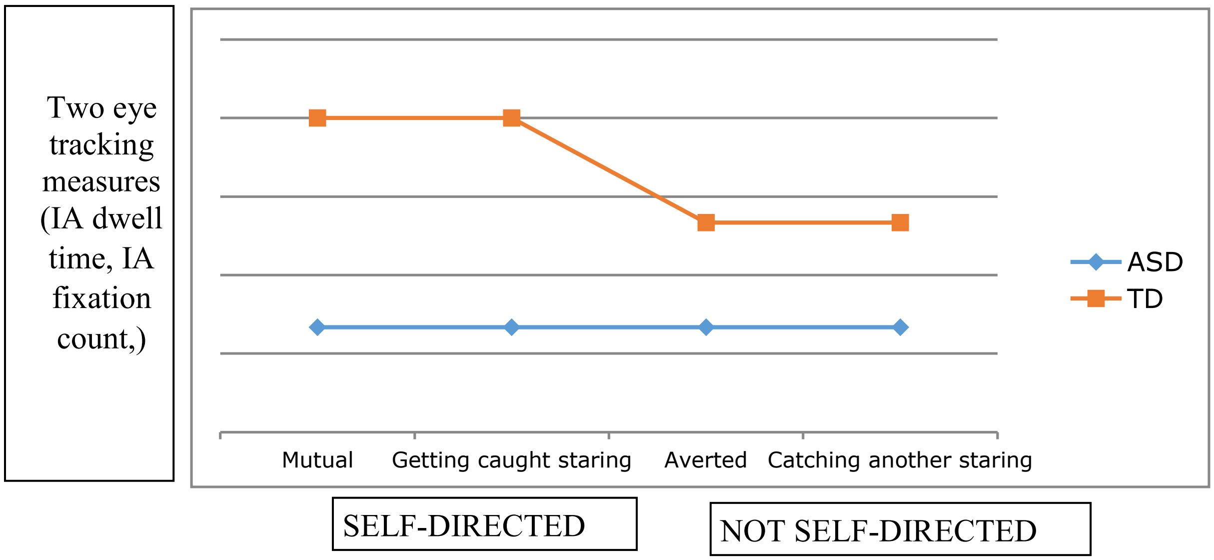
Hypothesis 1a: ***Interest area dwell time and interest area fixation count will be greater in conditions with more self-directed gaze (mutual and getting caught staring) than less (averted and catching another staring)***



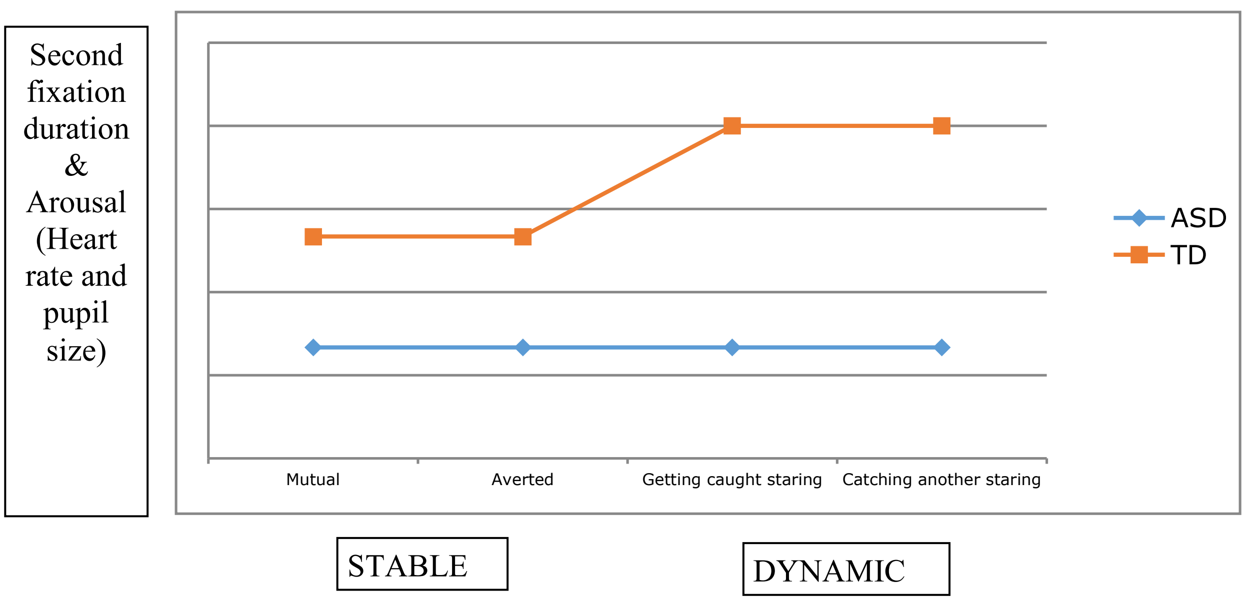
Hypothesis 1b: ***Second fixation duration will be greater for dynamic conditions (getting caught staring and catching another staring) than stable conditions (mutual and averted)***



Hypothesis 1c: ***Arousal (increased HRV and pupil dilation) will be greater in dynamic conditions (getting caught staring and catching another staring) than stable conditions (mutual and averted)***



Hypothesis 2b: ***For two of the eye tracking measures (IA dwell time, IA fixation count), there will be an interaction between diagnosis and relative amount of self-directed gaze (mutual/getting caught staring conditions vs averted/catching another staring conditions), with the eye tracking measures being greater in the TD group than in the ASD group.***



Hypothesis 2c: ***For second fixation duration and arousal (heart rate and pupil size), there will be an interaction between diagnosis and change (mutual/averted conditions vs getting caught staring/catching another staring), with second fixation duration and arousal being greater in the TD group than in the ASD group.***