THE EFFECT OF PERCEPTUAL SENSITIVITY ON FACE RECOGNITION ABILITIES IN INDIVIDUALS WITH AUTISM: AN EYE TRACKING STUDY

by

Catherine A. Best

B.A., Dickinson College, 2001

M. S., University of Pittsburgh, 2004

Submitted to the Graduate Faculty of

Arts and Sciences in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2010

UNIVERSITY OF PITTSBURGH

ARTS AND SCIENCES

This dissertation was presented

by

Catherine A. Best

It was defended on

July 22, 2010

and approved by

Jana M. Iverson, PhD, University of Pittsburgh

Carl N. Johnson, PhD, University of Pittsburgh

Diane L. Williams, PhD, Duquesne University

Dissertation Advisor: Mark S. Strauss, PhD, University of Pittsburgh

THE EFFECT OF PERCEPTUAL SENSITIVITY ON FACE RECOGNITION ABILITIES IN INDIVIDUALS WITH AUTISM: AN EYE TRACKING STUDY

Catherine A. Best, Ph.D.

University of Pittsburgh, 2010

Research demonstrates that individuals with autism process facial information in a different manner than typically developing individuals. Several accounts of the face recognition deficit in individuals with autism have been posited with possible underlying mechanisms as the source of the deficit in face recognition skills. The current study proposed a new account that individuals with autism are less sensitive at perceiving configural manipulations between faces than typically developing individuals leading to their difficulty recognizing faces. A change detection task was used to measure perceptual sensitivity to varying levels of configural manipulations involving the eye and mouth regions. Participants with and without autism, matched on chronological age, verbal IQ, performance IQ, full scale IQ, visual acuity, and gender, studied upright and inverted faces in a delayed same/different face recognition test. An eye tracker recorded eye gaze throughout the experiment. Results revealed a significant group difference with respect to detection accuracy. The control group was more accurate at detecting subtle changes between upright faces than the autism group, particularly with manipulations to the spatial relation of eyes. Furthermore, an analysis of detection accuracy within groups revealed that a greater proportion of participants in the control group were better at detecting differences at subtler levels of spatial manipulations. Eye tracking results revealed a significant group difference in number of fixations to relevant vs. irrelevant areas of interest; however, both groups utilized eye information more than mouth information to detect changes in both upright and inverted faces.

TABLE OF CONTENTS

Furthermore, there was some indication that eye gaze differed within groups, with a small proportion of individuals in both the autism and control groups demonstrating a bias to look more toward the mouth than eyes. Results are discussed with respect to featural vs. configural processing in autism and the use of eye vs. mouth information in face processing strategies by individuals with autism.

LIST OF TABLES

LIST OF FIGURES

PREFACE

Acknowledgments

The successful completion of my PhD would not have been possible without the support of my husband. Thank you for listening to my research ideas amid conversations of our hopes and dreams beyond graduate school and especially for packing my lunch every morning. Thank you to my parents for their unconditional love, support, and guidance throughout my many years of formal education. You instilled in me an eternal gratitude for the ability to share my knowledge with others. Thank you to my grandparents for their endless encouragement and praise. Thank you to my brother and sister for keeping me grounded in reality by knowing who I am and from where I came.

I am very grateful to the members of the Infant and Toddler Development Center. I thank Rachel Chung for her computer programming skills, Eva Dundas for setting up and maintaining the eye tracker, and Stacey Becker for screening and scheduling participants. A special thank you goes to Eva Dundas, Holly Gastgeb, Keiran Rump, Desiree Wilkinson, Sarah Hannigen, Sara Green, Kao Wei Chua, and countless undergraduate volunteers for their help testing participants. Additional gratitude goes to Melanie Nyhof, Lisa Newell, and Geetha Ramani for continuous moral support and laughter. Finally, thank you to my advisor, Mark Strauss, for freely giving of his experience and knowledge through the years. The research opportunities I had with you were ever-engaging and helped shape my future career path.

1.0 INTRODUCTION

1.1 SPECIFIC AIMS

Evidence shows that individuals with autism have difficulty discriminating and recognizing faces. The cause of these difficulties with faces has been predominantly attributed to an inability to process the spatial (i.e., configural) information among facial features. However, additional cognitive mechanisms may account for the difficulty individuals with autism have with face recognition. One hypothesis not readily discussed within current research is that individuals with autism may be able to process spatial information but may not be as perceptually sensitive to subtle facial information as typically developing individuals. Therefore, the purpose of the current project is to study how perceptual sensitivity to the natural and subtle variance of configural information within a face affects the development of recognition abilities in individuals with autism.

The goal of the proposed experiment is to understand the underlying cause of the aberrant development of face recognition abilities in individuals with autism. The major aim of the project is to examine whether the ability to visually perceive subtle differences in facial configurations differs between typically developing individuals and individuals with autism. The significance of the current research is that its findings will help researchers gain a better understanding of what may cause individuals with autism to have difficulties discriminating and remembering faces. Drawing upon research of face recognition in typically developing individuals as well as previous research of face recognition in individuals with autism, the current project explores the perception of subtle configural differences among faces as it relates to face recognition abilities. The current experiment compares face recognition abilities of individuals with autism to those of typically developing individuals to investigate differences and similarities in the level of perceptual sensitivity to subtle configural changes in facial information based on diagnosis. Specifically, the current project addresses what effect the level of perceptual sensitivity to subtle configural facial information has on face recognition abilities in individuals with autism.

1.2 SIGNIFICANCE

Autism, a neurodevelopmental disorder, is receiving much attention in the scientific community and in the media. The most recent reports from the United States Department of Health and Human Services suggest that approximately one of every 110 children develops an autism spectrum disorder (Centers for Disease Control and Prevention, 2009). With the incidence of autism spectrum disorders (ASD) rising world-wide (Chakrabarti & Fombonne, 2005), it is essential for researchers to understand the underlying deficits of those individuals currently affected by this complex developmental disorder. The Diagnostic and Statistical Manual of Mental Disorders, 4th edition text revision, (*DSM-IV-TR*) describes a diagnosis of autism as presenting reciprocal social interaction deficits, communicative impairments, and restricted and repetitive behaviors and interests. Typical onset of autism is prior to 3 years of age; however, symptoms last for life (American Psychiatric Association, 2000).

Although not a diagnostic measure for autism, difficulty discriminating and recognizing faces is one of the more commonly documented deficits in individuals with autism (e.g., Dawson, Webb, & McPartland, 2005; Marcus & Nelson, 2001; Sasson, 2006). Therefore, it has been informative for researchers to study how their performance on face recognition tasks compares to performance of individuals from non-autistic populations. Current research shows that compared to individuals who are typically developing, individuals diagnosed with an autism spectrum disorder do not perform as well on tests of face recognition (for reviews, see Dawson, et al., 2005; Marcus & Nelson, 2001; Sasson, 2006). Individuals with autism, although not completely devoid of all face recognition skills, seem to lack an essential element necessary for developing the typical expertise in face recognition abilities seen in neurotypical adults. Ultimately, the current research will provide necessary insight into the developmental nature of the face recognition deficit in individuals with autism and perhaps help future researchers identify where intervention work is most applicable for improving face recognition with respect to the appropriate kind of intervention.

1.3 BACKGROUND RESEARCH

1.3.1 Face Recognition Abilities in Typically Developing Individuals

The problem with perceiving and recognizing a face lies in the way that faces are similar to one another. All faces have two eyes positioned above one nose with two coupled lips underneath. It is therefore the subtle differences among the homogeneous arrangement of a face that create individuality. The uniqueness of one's face creates a stable identity that is visually perceived by others. Variations in facial information—eye color, chin shape, nose size—combine to create faces that look dissimilar from one another. Yet, the spatial variance among the features of a face is highly constrained by the size, shape, and arrangement of features, as well as by boundary of the three-dimensional canvas upon which components of a face rest. Given the challenges of face recognition, adults have an extraordinary memory for people's faces (e.g., Bahrick, Bahrick, & Wittlinger, 1975). The human ability to discriminate and remember individual faces is a remarkable feat when one considers the number of different identities encountered in a lifetime. In fact, memory for familiar faces transcends transformations from aging, lighting, environmental context, viewpoint, and expression (e.g., F. N. Newell, Chiroro, & Valentine, 1999). Furthermore, throughout the life span, discriminating people by face is necessary to maintain relationships and to communicate effectively with others, skills valuable as early as infancy.

Face perception abilities emerge very early in infancy with a general attraction to faces. Newborn infants prefer to look at faces rather than objects and prefer to look at face-like patterns rather than non face-like patterns (Fantz, 1965; Mondloch, et al., 1999; Morton & Johnson, 1991; Valenza, Simion, Cassia, & Umilta, 1996; Wilcox, 1969). Memory for familiar people is also evident early in life. Even in the first few days of life, an infant will look longer at his or her mother's face when it is paired with a comparable (e.g., similar complexion and hair color) female stranger's face despite contrast sensitivity limitations with vision (Bushnell, Sai, & Mullin, 1989). However, Morton (1993) has suggested that when a newborn is shown only internal features of the face, the infant does not seem to recognize his or her mother's face until at least 90 days after birth. Internal facial features provide detailed information and are more stable than external features (e.g., hair), so it is critical to develop the ability to discriminate faces by internal features alone. Evidence of infants' eye movements suggests that 4-month-old infants are able to perceive the internal facial features as useful for discriminating familiar people from strangers (Mauer, 1985); however, it is not until six or seven months that infants display recognition memories for faces that are robust over time (Fagan, 1973).

The arrangement of internal facial features includes featural and configural information. This distinction between the different kinds of facial information has received a lot of attention because it is difficult to agree on a clear definition of each. Rakover (2002) defines "featural information in reference to isolated facial features in everyday use – hair, brow, eyes, nose, mouth, cheeks, and chin; and configural information in reference to the spatial relations between the features, their interaction, and to various proportions, such as nose length to brow length, or brow area to face area" (2002, pp. 1-2). Mauer and colleagues (2002) have further divided configural facial information into three types. First-order spatial relations refer to the homogeneity of the arrangement of all faces such that there are always two eyes situated above one nose and one mouth for all faces. In other words, first-order relations are those that make a face a unique and meaningful entity. This special arrangement has led Morton and Johnson (1991) to argue that infants' attention to faces at birth is controlled by an operating mechanism, CONSPEC, which constrains innate information about faces such that infants require no previous exposure to be able to pay attention to faces. Morton and Johnson's theory of CONSPEC assumes that this innate mechanism triggers attention to faces (but see also Simion, Cassia, Turati, & Valenza, 2001) ultimately enabling the development of face perception. Once infants know a face from a non-face, they must be able to differentiate individual faces. Using internal facial features to perceive subtle differences among faces requires processing what Mauer and colleagues call second-order relations, which reflect the actual distances perceived among facial features. When researchers discuss configural processing, they typically mean the second-order relations in a face. However, Mauer and colleagues describe a third type of configural processing as holistic or gestalt perception of a face as a whole entity. By consolidating a face as a global whole, featural and configural information becomes unified. Holistic processing is still based on configural processing, but it is at a higher level than first- or second-order processing.

Sensitivity to featural information and the three types of configural information develops beginning with typically developing newborn infants' preference for faces and face-like patterns with first-order relations (Fantz, 1965; Mondloch, et al., 1999; Valenza, et al., 1996; Wilcox, 1969). Processing second-order configural information requires more experience with faces and sensitivity to the variance in spatial information among all faces. Thus, adults generally rely on configural information; whereas, young children rely more heavily on featural information before developing the ability to process configural information. Typically developing children as young as 6 years of age are capable of processing faces holistically (Carey & Diamond, 1994); yet, evidence supports that children younger than 5 years predominantly use featural processing when categorizing faces (Schwarzer, 2002). Therefore, whereas adult-like face processing is present in typically developing children (Pellicano, Rhodes, & Peters, 2006) and infants (Cohen & Cashon, 2001), featural processing seems to dominate face processing strategies early in development (Mondloch, Le Grand, & Maurer, 2002). Furthermore, research with typically developing children suggests that this predominance on featural processing shifts to a reliance on configural information (i.e., second-order spatial information) in later childhood at around 10 years of age (Carey & Diamond, 1977; Diamond & Carey, 1977). Still, this shift may not be caused by a stronger sensitivity to holistic processing but rather due to general improvements in perception and memory for faces (Mondloch, Maurer, & Ahola, 2006; Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007). The discussion of whether individuals with autism develop sensitivity to featural and configural information following a similar developmental trajectory as typically developing individuals remains at the forefront of the autism face recognition research.

It is plausible that individuals with autism are not as perceptually sensitive to aspects of facial information that assist encoding and storing of faces in memory as are typically developing individuals. Facial information that helps one to distinguish among various identities can enhance the efficiency of recognition memory. For instance, the degree to which a face appears to be distinctive-looking will help the encoding and later identification of that unique individual. Valentine's (1991) theory of a multi-dimensional framework for systematically encoding and storing mental representations of faces (i.e., a "face space") can explain a well known effect of facial memory, which finds that distinctive faces are remembered by adults better than typical or less distinctive faces (Bartlett, Hurry, & Thorley, 1984; Chiroro & Valentine, 1995; Light, Kayra-stuart, & Hollander, 1979; Shepherd, Gibling, & Ellis, 1991; Valentine, 1991; Valentine & Bruce, 1986a, 1986b; Valentine & Endo, 1992). Typical faces that have average values on facial dimensions are stored closest to the center of the face space. In contrast, faces with less typical, or distinctive, facial values are stored along the outer edges of the face space. Since facial features, and therefore faces, are assumed to be normally distributed, there should be a dense cluster of typical faces at the center of the face space; whereas, distinctive faces should be stored in more sparsely populated regions of the face space, along the perimeter (See Figure 1). With less similarity and density among the distinctive exemplars and more similarity and density among the typical exemplars, retrieval is easier and faster for distinctive faces.

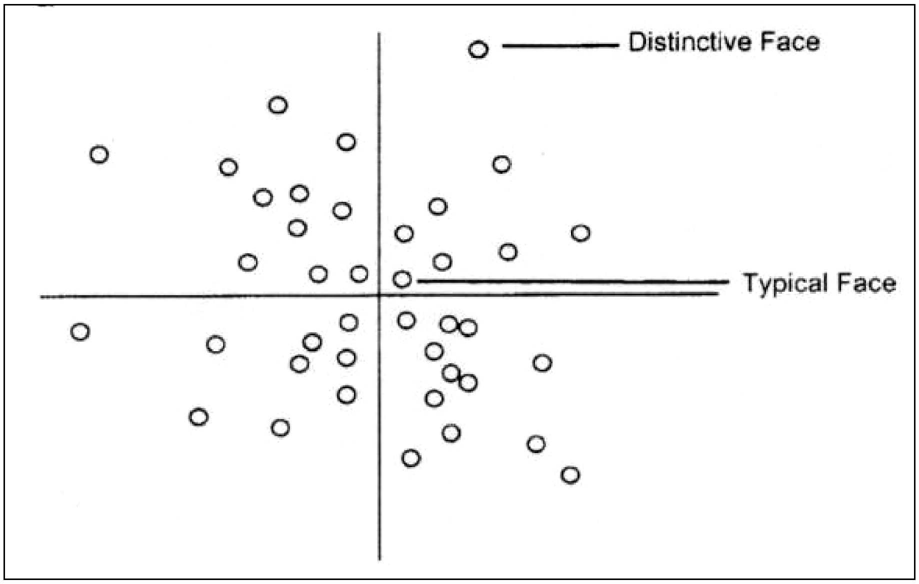

Figure 1. Multidimensional face space (adapted from de Haan, Humphreys, & Johnson, 2002).

The development of the face space has been investigated with studies demonstrating the distinctiveness effect in typically developing children. Johnston and Ellis (1995) found that by 9 years of age children, like adults, remember distinctive faces better than typical faces. In addition, McKone and Boyer (2006) found that 4-year-old children were sensitive to facial distinctiveness in a perceptual forced choice task where children were asked to pick the unusual or weird looking face. They found a positive correlation between the 4-year-olds' rate of choosing the more distinctive face and the adults' rate of choosing the more distinctive face suggesting that children are developing an adult-style sensitivity to facial distinctiveness. There is also research that shows that typically developing 3- and 4-year-old children (Best, Strauss, Newell, Gastgeb, & Costello, 2004) and infants (Best, 2004; Best & Strauss, 2007; Humphreys, 2003) find distinctive faces easier to remember then typical faces, provided that faces are very distinctive. In contrast, evidence suggests that children and adults with autism do not capitalize on facial distinctiveness to aid memory, at least not during serial face recognition tasks (Best, Newell, Strauss, & Minshew, in prep; Newell, Best, Gastgeb, Rump, & Strauss, in press). Although these data may provide preliminary evidence for the lack of a face space in individuals with autism, the published research focusing on individuals with autism has suggested some other possible reasons for the difficulties with face recognition.

1.3.2 Face Recognition in Individuals with Autism

Most of the empirical research within the autism face recognition literature merely document whether or not there is a face recognition deficit; only a few studies have further investigated *why* this deficit may exist. The current discussions of underlying mechanisms for a face recognition deficit remain somewhat limited. The most widely accepted explanation for the face recognition deficit in individuals with autism discussed by the current autism face recognition literature is *impaired face processing abilities*. It is plausible that individuals with autism do not develop face processing strategies such as configural processing. It has been suggested that individuals with autism rely heavily on features for face processing and are poor at using configural information (for review, see Dawson, et al., 2005). The most convincing evidence of impaired configural processing comes from the results of studies testing recognition memory with inverted faces. Inverting a face is thought to disrupt the processing of second-order configural information because spatial relations are less familiar in an inverted face. There is a robust effect, known as the face inversion effect, in which recognition of inverted faces becomes more difficult than upright faces for typically developing individuals (Valentine, 1988; Yin, 1969). Langdell (1978) first discovered that the facial recognition abilities of individuals with autism were less affected when viewing inverted faces than were the recognition abilities of typically developing children. He argued that children with autism were able to recognize inverted faces because they were focusing more on facial features (i.e. non-spatial information that is not readily disrupted by inversion) rather than processing faces in a configural manner. The idea that individuals with autism have limited ability for processing configural facial information is currently the prevalent explanation for the face recognition deficits associated with autism as evidenced by research on memory for inverted faces (Boucher & Lewis, 1992; Boucher, Lewis, & Collis, 1998; Davies, Bishop, Manstead, & Tantam, 1994; de Gelder, Vroomen, & Van der Heide, 1991; Hobson, Ouston, & Lee, 1988; Klin, et al., 1999; Tantam, Monaghan, Nicholson, & Stirling, 1989).

In addition to results from face inversion experiments, researchers have found further instances of differences in processing configural information by individuals with autism. For instance, a study by Deruelle et al. (2004) showed that children with ASD recognized facial identity using different information than typically developing children. In a match-to-target task, children were tested with faces presented with low or high spatial frequency. Faces shown at a low spatial frequency level lack the sharpness needed to perceive facial features thus requiring global processing to accurately recognize identity. In contrast, finer details of faces are available at a high spatial frequency and identity can be recognized through local processing of features. Results indicated that on average typically developing children matched identity better with low spatial frequency information (i.e., configural), whereas the ASD group matched identity better with high spatial frequency information (i.e., featural). The authors interpreted this difference as evidence that the children with ASD were processing facial features locally to recognize identities with high spatial frequency information. In contrast, control groups recognized facial identity through global processing since only configural information was presented in the low spatial frequency faces. Thus, enhanced performance with inverted faces and high spatial frequency information in faces both assume that individuals with autism have impaired configural processing compared to typically developing individuals, which may explain deficits in face recognition abilities in individuals with autism.

Further evidence of impaired face processing comes from research that suggests individuals with autism have limitations in holistic processing. When faces are perceived holistically, they are seen “as a single entity, the whole face.” Furthermore, “the whole face is more accessible in memory than its parts” (Rakover & Cahlon, 2001, p. 86). Although inverting faces disrupts configural information in faces, it also disrupts holistic processing. Carey and Diamond (1994) have demonstrated that holistic processing is disrupted when typically developing children are tested with inverted faces.

Two studies have investigated holistic face processing abilities in individuals with autism. Joseph and Tanaka (2003) used a task that compared memory for whole faces to memory for isolated facial features. Typically developing individuals have better memory with whole faces than parts of faces because of being able to use holistic processing to identify a target face (Donnelly & Davidoff, 1999). By switching one facial feature (e.g., eyes, mouth, or nose) across identities in faces, Joseph and Tanaka (2003) were able to decipher whether children with autism recognized faces with a holistic- versus part-based strategy. They found that children with autism were not completely impaired in holistic face recognition processes, but they did rely more heavily on part-based encoding to remember identities compared to control children. The children with autism encoded some faces holistically, but only when recognition was dependent on the mouth region of the face. Lopez and colleagues (Lopez, Donnelly, Hadwin, & Leekam, 2004) used a similar task that compared memory for whole faces versus isolated facial features. They found that high-functioning adolescents with autism were able to use holistic information, but only when cued to do so in a delayed match-to-target task where the target and distracter face were identical except for one feature. A cue was given prior to the target with a hint about which feature had been changed such as, “look at the mouth”; however, when no cues were given, the adolescents with autism performed significantly worse than control participants on the trials with whole faces, indicating that without assistance, they did not readily use holistic processing for face recognition.

Additional evidence for deficits in processing of faces holistically comes from significant differences in reaction time between typically developing individuals and individuals with autism. Reports of slower processing suggest that individuals with ASD may use different strategies than control children. If individuals with autism tended to use a more part-based rather than holistic-based strategy, then comparing faces feature by feature would require more processing time. Serra et al. (2003) measured reaction time on a delayed match-to-target task and found that children with Pervasive Developmental Disorder Not Otherwise Specified (PDDNOS) were significantly slower to respond whether the target face was present or not present than control children despite performing with similar accuracy scores when the target face was present. The authors speculated that because there was very little difference in accuracy, the children with PDDNOS did not differ from controls in terms of encoding the target face prior to the delay. Instead, they concluded that slower reaction times were indicative of a more attention-demanding processing strategy of comparing features in a piecemeal approach rather than seeing the faces as a whole. Adults with autism also have shown impaired holistic processing as evidenced by significantly slower reaction times for face gender and identity discrimination tasks (Behrmann, et al., 2006).

Although the difference between typically developing individuals and individuals with autism in the ability to process configural and holistic information in faces is notable, it remains unclear whether a deficit in higher-order face processing is the primary or only cause for the difficulties individuals with autism have with faces. One problem with the existing literature is that most studies infer a lack of configural processing from the finding that individuals with autism do not show as strong of an inversion effect as control participants. Yet, as Lahaie and colleagues (Lahaie, et al., 2006) have recently commented, the results of inversion studies may be inconclusive. They argue that individuals with ASD may be capable of processing configural information but may have a bias in favor of processing featural information. Mottron and colleagues (Mottron, Dawson, Soulieres, Hubert, & Burack, 2006) propose an enhanced perceptual functioning model in which individuals with autism have little or no conflict between featural and configural information. They suggest that “the default setting of autistic perception is more locally oriented than that of non-autistics” and therefore “autistics are not obliged to use a global strategy when a global approach to the task is detrimental to performance” (Mottron, et al., 2006, p. 4). In addition, research has shown that children with autism do not have difficulty with configural processing during the Thatcher Illusion (Rouse, Donnelly, Hadwin, & Brown, 2004) in which internal features of a face (e.g., eyes or mouth) are inverted and pasted into an upright face or features are pasted right-side-up into an inverted face. Typically developing individuals notice the bizarre appearance of inverted features when a whole face is upright, but not when a face is inverted (Thompson, 1980). Rouse et al. (2004) found the same results in children with autism suggesting that they are not impaired in processing second-order configural information.

1.3.3 Visual Scanning Patterns of Faces

Research with both adults (Luria & Strauss, 1978; Pelphrey, et al., 2002) and infants (Gallay, Baudouin, Durand, Lemoine, & Lecuyer, 2006; Hunnius & Geuze, 2004) indicate that typically developing individuals have relatively stable eye movement patterns when viewing faces. It may be that these stable patterns of eye movement help in abstracting subtle spatial information from faces. If the distance between eyes is always calculated with a left to right movement for a particular person, then these scan patterns would be disrupted in an inverted face thus making measurement of spatial components of the face difficult.

If individuals with autism are not developing consistent scanning or tracking patterns when viewing faces, they may not become as efficient in measuring spatial distances and therefore would not have much disruption with inverted faces. Indeed, Pelphrey and colleagues (2002) have shown that the scan paths of individuals with an autism spectrum disorder (ASD) while viewing upright faces are neither systematic nor strategic. This evidence of irregular face scanning suggests that individuals with ASD may have different processing strategies than typically developing individuals. If the manner of encoding faces differs in individuals with ASD, perhaps aberrant visual scanning patterns may help explain the deficits in face recognition abilities. Alternatively, individuals with autism may not be able to integrate multiple dimensions while scanning a face. There is a natural hierarchy of importance within facial information (e.g., eyes are more prominent features than ears). Saliency of features influences face recognition because more salient features will be quickly scanned and efficiently processed compared to less salient features. Individuals with autism may only pay attention to a subset of the dimensions that make up a face.

Eyes are extremely salient features and have received much attention by autism researchers because individuals with autism do not readily make eye contact during social interactions (American Psychiatric Association, 2000). Three explanations are proposed in the existing literature for why individuals with autism have difficulty processing eye information, resulting in perhaps an increased reliance on mouths during face processing. First, researchers suggest that eye avoidance by individuals with autism is due to an overarousal from the heightened emotional information conveyed by eyes. The intensity of eyes may be disconcerting or threatening to individuals with autism, and Dalton et al. (2005) found amygdala activation was positively associated with eye fixations for individuals with autism. Second, researchers suggest that greater attention to mouths helps individuals with autism obtain verbal information. Thus, they become accustomed to looking at mouths rather than eyes (e.g., Klin, Jones, Schultz, Volkmar, & Cohen, 2002). Joseph and Tanaka (2003) proposed that language impairments associated with autism may "foster an early and enduring tendency to attend to mouths in an effort to disambiguate speech sounds via lip reading, especially when other communicative cues from the eyes are inaccessible" (p. 538). Finally, researchers suggest that individuals with autism simply cannot process information from eyes well, and therefore learn to compensate by relying on mouth information instead (e.g., Joseph & Tanaka, 2003). Individuals with autism may be less adept at processing the subtle information present in eyes and therefore may not find information in eye regions particularly useful for face recognition. For typically developing individuals, information about emotional intensity can be abstracted from eyes; yet, research on amygdala activation to fearful expressions suggests that individuals with autism do not process the significance of emotional intensities like typically developing individuals do (Ashwin, Baron-Cohen, Wheelwright, O'Riordan, & Bullmore, 2007; Howard, et al., 2000). Processing subtle facial information is necessary to succeed at face recognition, and it requires some expertise to be able to abstract subtle information from eyes in particular. Individuals with autism may not find eyes particularly informative for face recognition if they are not sensitive to subtle variations. Perhaps individuals with autism spend less time looking at eye regions not because they are fearful or have difficulty with language, but because they cannot process the subtlety in eyes.

Research indicates that there are *differences in scanning or tracking patterns* between typically developing individuals and individuals with autism. Several face processing deficits related to the perception of faces have been reliably identified in individuals with autism including abnormal eye gaze (Spezio, Adolphs, Hurley, & Piven, 2007; Trepagnier, Sebrechts, & Peterson, 2002) and irregular visual scanning of faces (Pelphrey, et al., 2002). Impairments in these perceptual skills suggest that individuals with autism process faces in a different manner than typically developing individuals. For instance, whereas typically developing infants on average attend with most interest to the upper half of faces—especially to the eyes (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Janik, Wellens, Goldberg, & Dell'Osso, 1978; Leo, 2006), individuals with ASD, on average, direct their gaze to mouths or non-features in the lower half of faces (Klin, et al., 2002; Langdell, 1978). Furthermore, Pelphrey et al. (2002) found that visual scanning paths differed for faces displaying emotions in that participants with autism spent less time looking at core facial features (e.g., eye, mouth, nose) compared to control participants.

Consequently, individuals with autism may not have deficits in processing configural or holistic information, but rather deficits in processing configural information when it is subtle. Difficulty processing subtle differences in second-order relations may underlie the face recognition deficit such that individuals with autism are able to process configural information but are unable to process the *subtlety* of spatial variability among faces or the fine level of facial information that helps to differentiate very similar identities. If individuals with autism are not able to perceive highly subtle differences in facial information, perhaps discriminating very similar faces becomes difficult unless the differences are more obvious perceptually. If evidence shows that individuals with autism have difficulty scanning and processing facial information, what could be underlying these cognitive difficulties? Could these information processing deficits be related to a lack of perceptual sensitivity? If individuals with autism are not able to perceive fine levels of detail within a face that make it possible to discriminate similar identities, then gaze patterns as well as information processing skills should reflect this problem. One way to test the possibility of a lack of perceptual sensitivity of subtle facial information is with a paradigm known as change detection.

1.3.4 Processing Subtle Facial Information in Typically Developing Individuals

The majority of research on processing subtlety in faces utilizes a face change detection paradigm where participants respond as to whether a change has occurred between two face images. Researchers can manipulate how obvious or subtle the changes are to stimuli in order to identify threshold levels across individuals or between groups.

Since all faces share the same general configuration (i.e., first-order relations), distinguishing different individuals requires processing facial variations that are more subtle (i.e., second-order relations). These subtle differences that make faces unique may only be micro-spatial and require a high level of processing to abstract the qualitative differences among faces. Change detection studies generally discuss detection ability by the smallest change participants can detect in terms of visual angles. By calculating the visual angle of an object at the retina, researchers can quantify perception. For example, individuals with 20/20 vision can normally perceive the difference between a cycle of sinusoidal gratings (i.e., a black to a white line) when one cycle subtends a visual angle of approximately 0.017° or 1.02 minutes.[1] In terms of face perception, Brooks & Kemp (2007) found that typically developing adults could reliably detect nose displacements as small as 7.3 minutes, changes to eye separation as small as 7.2 minutes, and mouth displacements as small as 5.6 minutes. In a recognition memory task by Haig (1984), typically developing adults on average discriminated original from modified faces by perceiving changes in second-order relations by as little as 1.2 minutes for upward displaced mouths and on average, detected the displacement of eyes as small as 2.5 minutes when separation was widened and 1.7 minutes when separation was narrowed. Furthermore, sensitivity to subtle differences in facial information is not limited to adults. Mondloch and colleagues (2002) found that typically developing 6-, 8-, and 10-year-old children showed age-related improvements when tested in a same/different perceptual judgment task involving faces where eye and mouth placement was changed by as little as 3.5 minutes; however, all groups of children were less sensitive to the configural changes compared to a group of adults tested in the same task.

Also related to this issue of subtlety is significant concern of prior studies in the cognitive development literature that researchers have not controlled for the degree of distinctiveness of the featural versus configural changes in stimuli. Featural changes are often perceptually more obvious (e.g., eye color changes) than configural changes (e.g. smaller eye separation). Therefore the lack of configural processing seen in individuals with autism may not be due to a difference in the types of information they process, but rather due to a limited ability to process

[1] One degree equals 60 minutes.

very subtle information on a fine level that is not perceptually obvious. Research indicates that when typically developing children are shown faces where featural and configural information has been matched for the degree of distinctiveness, even children as young as 7 years of age are able to process both featural and configural information to correctly identify previously learned faces (Glichrist & Mckone, 2003). Perhaps with development and increased experience with faces, typically developing individuals improve discrimination abilities of fine level differences for featural and configural information, but individuals with autism do not. Current research investigating the ability to process subtle facial information in individuals with autism is limited.

1.3.5 Processing Subtle Facial Information in Individuals with Autism

Although processing subtle facial information has not been readily researched in individuals with autism, there is some limited evidence to suggest that they have difficulty. For instance, Rump, Giovannelli, Minshew, and Strauss (2009) tested individuals with autism on their emotion recognition abilities. By varying the subtlety of the facial expression of four emotions (i.e., happy, sad, angry, and afraid), they found that the 5- to 7-year-old children with autism were especially poor at identifying emotion from the more subtle facial expressions compared to typically developing 5- to 7-year-old children. Similarly, older children and adults with autism never reached the expert performance level of age- and IQ-matched control adults on emotion recognition of subtle expressions of four basic emotions (i.e., angry, afraid, surprise, and disgust). Similar results were also found in adults with autism for categorizing and discriminating subtle expressions (Humphreys, Minshew, Leonard, & Behrmann, 2007).

To date, only three studies have employed a change detection paradigm testing individuals with ASD. First, Rutherford, Clements, and Sekuler (2007) digitally manipulated eye and mouth placement within one male face and one female face to created 10 new faces. The amount of change within faces ranged from 8.4 to 33.4 minute increments (i.e., 2 to 10 pixels). Participants were familiarized with all 10 faces prior to an "odd one out" task where three faces were presented and only one face was different. Participants searched for the different face (i.e., "the odd one out") in trials with upright faces and trials with inverted faces. Results indicated that adults with ASD were less accurate than control adults at discriminating the modified faces from the unmodified faces, and this difference was more pronounced in the trials where eye placement was changed than in the trials where mouth placement was changed. For faces with the greatest eye displacement of 33.4 minutes, results across all trials (inverted and upright combined) indicated that the adults with ASD were 58% accurate as a group compared to the adult controls who were 78% accurate as a group. In contrast, group performance was similar on all trials with the greatest displacement of the mouths at 20.9 minutes (i.e., ASD = 71%, control = 77%).

Although Rutherford, et al. (2007) tested sensitivity to eye and mouth displacement, their sample of individuals with ASD was not well matched to their control sample. Rutherford and colleagues matched groups only on chronological age and Performance IQ scores. Still, they did find that control adults were quite adept at perceiving subtle differences in facial information, which supports previous change detection research with typically developing adults. Moreover, Rutherford, et al. (2007) found that adults with ASD were not as perceptually sensitive to subtle changes in facial information as control adults; however, they did not test participants' memory for faces.

Faja, Aylward, Bernier, and Dawson (2008) tested recognition memory for faces. They first trained five individuals with autism to attend to faces on a computer. The rule-based training included eight sessions over the course of three weeks in which participants were instructed to "attend to the entire face, because information about the distances between features could be helpful in remembering faces." After training, participants' sensitivity to second-order relations was tested using a match-to-target paradigm. In this task, faces were digitally manipulated by moving eyes up, down, in or apart by 6 or 12 pixels and moving mouths up or down by 6 or 12 pixels. Target and test faces were presented sequentially with a 1 second delay in between. Participants responded yes or no for whether the two faces matched. They found that participants detected the 12 pixel changes better than the 6 pixels changes, and that the trained group performed better than a group of five individuals with autism who did not participant in the training sessions.

Faja, et al. (2008) did not have a typically developing control group, but did test recognition memory. In a recognition memory test, participants must compare a test face to a stored representation of a previously learned face. For instance, in a delayed same/different task, such as Faja, et al. (2008) conducted, participants judge whether two faces are same or different by comparing a stored representation of the first face to a current image of a second face. This type of paradigm employs a more stringent test of face recognition compared to matching a test face to a target face in which two faces can be simultaneously compared online.

Finally, Riby, Doherty-Sneddon, and Bruce (2009) tested children and adolescents with autism by varying eye and mouth placement. Eyes were widened or narrowed by 9 pixels, and mouths were lowered or raised by 6 pixels. They did not varying levels of manipulations like Rutherford, et al. or Faja, et al. In addition, half of the trials manipulated configural information, and half manipulated featural information (i.e., replacing one eye or mouth for another). Also tested were three control groups: one matched with the autism group by verbal mental age, one matched by nonverbal mental age, and one matched by chronological age. All participants were presented with 32 same/different trials (i.e., 16 same and 16 different). Of the 16 different trials, half of the trials measured configural changes and half measured featural changes. Results showed that all participants performed reliably above chance for the 8 trials with featural changes. However, the autism group performed at chance for 8 trials with configural changes; whereas, all three matched control groups performed reliably above chance for the 8 trials with configural changes.

Evidence from Riby, et al. (2009) confirms findings the previous studies of change detection by reliably demonstrating that individuals with autism are less adept at perceiving configural changes within faces, but the sample was not able to perceive any configural changes reliably above chance which contrasts with findings from Rutherford, et al. (2007) and Faja, et al. (2008). Though Riby, et al.'s experiment was not as systematic as Rutherford, et al. (2007) or Faja, et al. (2008), they found the difference between autism and control groups for children and adolescents.

1.3.6 Current Predictions

The current study specifically investigated recognition memory for faces by measuring group differences between typically developing individuals and individuals with autism as well as measuring individual differences within each group. The current study systematically examined whether face recognition deficits in individuals with autism overlap with the ability to perceive subtle changes in configural information in faces. Like previous research using change detection paradigms, eyes and mouths will be displaced at varying levels of subtlety. However, the current study is the first attempt to test individuals with autism in a change detection task measuring face recognition while measuring eye movements. No face change detection study has ever concurrently measured eye movements while participants made perceptual judgments about whether they detect subtle configural changes in faces. By measuring eye movements, it may become clearer as to where attention is focused within a face when detecting subtle configural changes. The current study tested memory for upright and inverted faces using a delayed same/different paradigm where participants are presented with two faces sequentially with a delay in between presentations.

The current project proposes that the deficit in face recognition abilities in individuals with autism is related to a lower level of perceptual sensitivity to subtle configural information within faces. In order to measure any similarities and differences in perceptual sensitivity between typically developing individuals and individuals with autism, both behavioral response and eye gaze data were collected. Accuracy dependent measures (i.e., response accuracy and response latency) were recorded to assess the following two predictions:

(1) If greater accuracy is an index of efficient processing, then it is expected that individuals with autism will demonstrate less accuracy than typically developing individuals overall and by level of change.

(2) If shorter response latency is an index of efficient processing, then it is expected that individuals with autism will demonstrate greater response latencies than typically developing individuals overall and by level of change.

In addition to accuracy measures, two eye gaze dependent measures, proportion of fixations to pre-defined areas of interest (AOIs) and latency of first looks to AOIs were recorded to assess the following two predictions:

(3) If greater numbers of fixations are an index of active and attentive processing, then it is expected that individuals with autism will demonstrate fewer fixations than typically developing individuals.

(4) If a shorter latency of first looks to critical AOIs is an index of efficient processing, then it is expected that individuals with autism will demonstrate longer latencies to first looks at AOIs than typically developing individuals.

2.0 METHOD

Participants were tested in a behavioral task while their eye movements were tracked. Participants completed two same/different recognition tasks using a change detection paradigm where subtle configural changes were made to the faces. The first task was a delayed same/different task testing memory with upright faces, and the second task was a delayed same/different task testing memory with inverted faces. For both tasks, participants needed to detect subtle configural changes to faces in order to accurately judge whether two faces were an exact match or slightly different. It was expected that overall, typically developing individuals would be better at detecting subtle configural manipulations than individuals with autism.

2.1 PARTICIPANTS

A total of 103 participants ranging in age from 14 to 45 years were recruited and tested. After excluding a total of 42 participants because of imprecise/incomplete data (N = 29), poor visual acuity (N = 10), program error (N = 2), and existing eye conditions (N = 1), there was a final matched sample of 56 individuals with 24 individuals in the autism group and 32 individuals in the control group. (*N.B.* Five eligible participants were excluded for matching purposes.) The control group was matched to the autism group (same mean with equal variances) on chronological age, Verbal IQ (VIQ), Performance IQ (PIQ), and Full Scale IQ (FSIQ) scores, as well as gender and visual acuity, as shown in Table 1.

	Autism Group (N=24)		*Control Group (N=32)*	
	M (SD)	*Range*	*M (SD)*	*Range*
Chronological Age	21 (6)	14 - 37	23 (6)	15 - 45
Verbal IQ	108 (13)	83 - 127	111 (9)	94 - 127
Performance IQ	110 (12)	83 - 127	113 (9)	93 - 128
Full Scale IQ	110 (11)	88 - 131	114 (9)	97 - 128
Visual Acuity	20/20	20/10 - 20/30	20/20	20/15 - 20/30
Gender	22 men / 2 women		30 men / 2 women	

Table 1. Demographic characteristics used to match groups

Participants with autism were administered a diagnostic evaluation consisting of the Autism Diagnostic Observation Schedule-General, ADOS-G (Lord, Rutter, DiLavore, & Risi, 2003) and the Autism Diagnostic Interview-Revised, ADI-R (Rutter, LeCouteur, & Lord, 2003) with confirmation of autism diagnoses by the expert clinical opinion of Dr. Diane Williams. Both instruments were scored using the DSM-IV (American Psychiatric Association, 2000) algorithm for autism. Individuals with Asperger's Disorder or PDD-NOS were excluded. All individuals with autism had combined total ADOS scores of 10 or greater. See Table 2 for ADOS scores. Participants with autism were required to be in good physical health, free of seizures, and have a negative history of traumatic brain injury. Participants' IQs were assessed using the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999). Participants with VIQ, PIQ, and FSIQ scores below 80 were excluded. Participant recruitment was handled by experienced staff at the Center of Excellence for Autism Research (CEFAR) supervised by Dr. Nancy Minshew. CEFAR used various recruitment strategies such as posters, flyers, and newspaper as well as radio and television advertisements.

	Autism Group (N=24)	
	M (SD)	*Range*
ADOS Communication	5 (2)	3 - 8
ADOS Social Interaction	9 (2)	6 - 14
ADOS Combined Total	14 (3)	10 - 22

Table 2. ADOS scores for autism group.

Control participants were typically developing individuals with a negative family history of ASD or Pervasive Developmental Disorders (PDD) in first and second degree relatives and a negative family history of affective and anxiety disorder or other major psychiatric disorder in first degree relatives as assessed with a family history screen (Weissman, et al., 2000). Control participants were in good physical health, free of past or current neurological or psychiatric disorders. Participants were excluded if they have a history of poor school attendance or evidence of a learning disability as assessed by the Wide Range Achievement Test-IV, WRAT4 (Wilkinson & Robertson, 2006).

2.2 STIMULI

Stimuli included full-frontal color images of Caucasian adults selected from facial images collected under the FERET program, sponsored by the Department of Defense Counterdrug Technology Development Program Office and from the Productive Aging Laboratory Face Database (Minear & Park, 2004). Faces were digitally modified using Adobe Photoshop CS3 Extended software version 10.0.1 that allowed for seamless movement of facial features such that the configural information could be carefully manipulated and precisely measured. All configural modifications were measured in visual angles for consistency across faces by using a scale of 1 pixel = 1.2 minutes. Configural modifications included lateral changes to the placement of eyes and vertical changes to the placement of mouths. Eight base faces, four male and four female, were normed by adjusting interpupillary distance for all faces to approximately 2.3° apart and adjusting mouth position approximately 0.7° below the base of the nose. Then, for each base face, 4 new versions with widened eye separation and 4 new versions with narrowed eye separation were created (8 base faces X 8 modifications = 64 new faces), and 4 new versions with raised mouth placement and 4 new versions with lowered mouth placement were created (8 base faces X 8 modifications = 64 new faces). Therefore, a total of 128 stimuli were created by digitally displacing eyes and mouths within the eight base faces.

To create a range of subtlety, configural modifications to the placement of eyes and mouths varied along four levels such that configural changes at Level 1 was more subtle than configural changes at Level 4. For eye separation, interpupillary distance was widened or narrowed by increments of 4.8 minutes (i.e., 2.4 minutes per eye), resulting in eye displacements of 4.8 minutes at Level 1 (i.e., 2 pixels), 9.6 minutes at Level 2 (i.e., 4 pixels), 14.4 minutes at Level 3 (i.e., 6 pixels), and 19.2 minutes at Level 4 (i.e., 8 pixels). For mouth height, the mouth region was moved as a unit up or down in relation to the base of the nose by increments of 2.4 minutes, resulting in mouth displacements of 2.4 minutes at Level 1 (i.e., 2 pixels), 4.8 minutes at Level 2 (i.e., 4 pixels), 7.2 minutes at Level 3 (i.e., 6 pixels), and 9.6 minutes at Level 4 (i.e., 8 pixels). Figure 2 and Figure 3 illustrate levels of eye and mouth displacements. Incremental changes of 2.4 pixels per eye and mouth were patterned after Rutherford et al. (2007) and Barton, Keenan, & Bass (2001) who made similar incremental changes to faces using a scale of 1 pixel = 2.1 minutes.

(a)

(b)

Level 1	Level 2	Level 3	Level 4
			
Widened by 4.8 minutes (2 pixels)	Widened by 9.6 minutes (4 pixels)	Widened by 14.4 minutes (6 pixels)	Widened by 19.2 minutes (8 pixels)

Figure 2. Eye displacement. Shown are (a) base face and (b) four levels of subtlety for the configural change of eyes where eye separation is laterally widened by increments of 4.8 minutes.

(a) 

(b)

Level 1	Level 2	Level 3	Level 4
			
Lowered by 2.4 minutes (2 pixels)	Lowered by 4.8 minutes (4 pixels)	Lowered by 7.2 minutes (6 pixels)	Lowered by 9.6 minutes (8 pixels)

Figure 3. Mouth displacement. Shown are (a) base face and (b) four levels of subtlety for the configural change of mouth where mouth placement is vertically lowered by increments of 2.4 minutes.

2.3 APPARATUS

Eye movement data were recorded using a noninvasive Tobii X120 Eye Tracker that records the accuracy of eye movements to 0.5° of visual angle. The eye tracker measures visual scanning by computing the pupil-corneal reflection at a sampling rate of 60 Hz (i.e. 60 gaze data points are collected per second for each eye). Stimuli were displayed on a large screen using rear projection with an Epson Powerlite 54c Projector at a viewing distance of 152.4 cm from the seated participant. The eye tracker was placed between the presentation screen and the seated participant and was positioned approximately 86.0 cm high and below the presented stimuli. The eye tracker was aimed upward to capture looking behavior without blocking participants' range of vision as illustrated in Figure 4. An additional camera was located beside the eye tracker to display a live feed view of the participant that the experimenter could monitor during testing. Finally, a two-button Ergodex DX1 Input System Wired keypad was used to record participants' same/different responses.

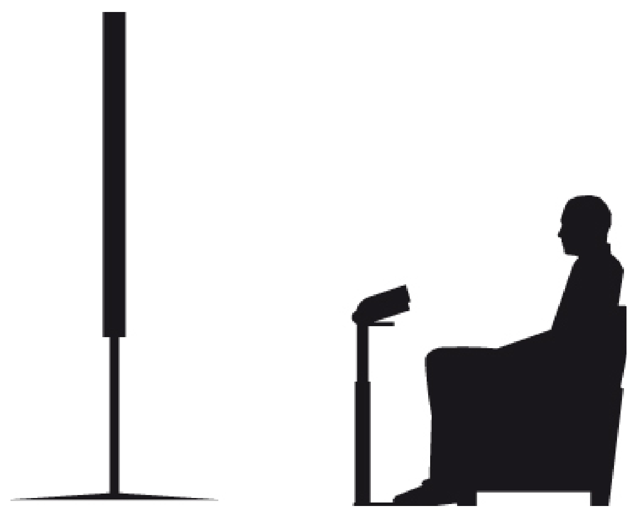

Figure 4. Experimental set-up. (adapted from www.tobii.com).

2.4 PROCEDURE

Before testing, written informed consent was obtained using procedures approved by the University of Pittsburgh Medical Center Institutional Review Board. All participants received monetary compensation for participating in the current experiment in part with a larger set of studies completed during a two-hour laboratory visit.

It was necessary for all participants to have normal or corrected-to-normal vision. Therefore, prior to the experimental procedure, visual acuity for combined eye sight was measured using a Snellen eye chart. Any participants unable to accurately read the line of letters for 20/30 visual acuity was tested and compensated, but excluded from the analyses. In addition, when available, past vision information was also obtained from medical reports on file with the CEFAR staff to exclude participants with existing eye conditions that might affect acuity.

During the experimental procedure, participants were tested individually, in a quiet darkened testing booth optimal for eye tracking while the experimenters remained outside the testing booth. Participants were carefully positioned by the experimenter to be centered in front of a screen at a distance of 68.6 cm inches from the eye tracker. Prior to the start of both tasks, each participant completed a simple five- to nine-point calibration by fixating on a moving dot shown on the screen. Once calibration was complete, the experimenter read the instructions to the participant and testing began. See Appendix for detailed instructions.

The presentation order of the upright vs. inverted trials was counterbalanced across participants. In addition, the face identities were randomly selected across the two tasks so that each orientation tested four discrete identities out of the total eight base faces. There were 40 same/different test trials where participants' memory for upright faces was tested and 40 same/different test trials where participants' memory for inverted faces was tested. Test trials were randomly presented with 80% of the trials as different trials (i.e. 2 features X 4 levels of change X 4 faces = 32 different trials) and 20% of the trials as same trials (i.e., 2 features X 4 faces = 8 same trials). To minimize the number of possible manipulations presented in each task, the direction of change for each base face (i.e., eyes widened or narrowed, mouths raised or lowered) was modified in one direction per feature per face per task. Thus, for each stimulus, participants were tested at each level of change once with eye displacements and once with mouth displacements per task.

2.4.1 Practice Trials

Two non-face examples were given while instructions were read aloud to participants. These examples served as practice trials to help participants conceptually understand the task and also allow them to practice using the keypad. The non-face stimuli consisted of color photographs of wall clocks. One example was given to demonstrate how two clocks could be the "same" (See Figure 5), and a second example was given to demonstrate how two clocks could be "different" (See Figure 6). It was particularly important that participants understood that in the example where the clocks were different that even though it was a picture of the very same clock, the reason the two clocks were in fact "different" was that something had changed between the two pictures (i.e., the hands of the clock changed). Therefore, corrective feedback was provided for both practice trials to ensure comprehension of the task.

Figure 5. Clocks presented in "same" practice trial

Figure 6. Clocks presented in "different" practice trial

2.4.2 Test Trials

For each trial, a target face was displayed in the middle of the screen for 3 seconds. Following an interstimulus interval of 1 second, a test face appeared. During the 1-second interstimulus interval, participants simply saw a centered white square the same size as the faces which prevented any residual afterimages of the target face. Each face was projected subtending a horizontal visual angle of 7.6° and a vertical visual angle of 10.0°. Participants made same/different decisions by pressing one of two buttons on a keypad to indicate their response upon viewing the test face. Test faces remained on the screen until participants made a decision. Between trials, participants saw a plain white screen, which indicated the anticipation of a new target face. All behavioral data were recorded on a computer using Tobii Studio gaze analysis software.

2.4.3 Benton Facial Recognition Test

In addition to the eye tracking experiment, all participants completed the Benton Facial Recognition Test (Benton, Sivan, Hamsher, Varney, & Spreen, 1994). The long form consists of

54 trials. For each trial, participants must match one of six test faces to a target face based on facial identity. The test is divided into three sections. In the first section the match and target faces are identical. In the second section, the match and target faces are presented in different poses. In the third section, the match and target faces are presented with different lighting cues. Scores ≥ 41 are considered within the normal range.

3.0 RESULTS

3.1 BENTON FACIAL RECOGNITON TEST

Mean scores from the Benton Facial Recognition Test were compared using an independent *t*-test. The control group (M = 0.45, SD = 0.04) did not differ from the autism group (M = 0.43, SD = 0.04) on accuracy. The Benton Facial Recognition Test is standardized, with scores ≥ 41 considered to be within the normal range. The majority of participants from both groups scored within normal range; however, 14 participants, (i.e., seven participants per group) scored below 41, which is indicative of impairment.

3.2 BETWEEN GROUP ANALYSES

Participants completed same/different judgments for 40 upright faces and 40 inverted faces. Within each task, 32 face pairs were different and 8 face pairs were the same. Within the 32 different face pairs, there were 8 trials per 4 levels. Results focused on participants' performance during the different face pairs because the goal of the task was to detect changes between faces at varying levels of manipulation. Data were analyzed separately for upright and inverted faces. The primary analyses included measures of response accuracy and eye gaze.

Results for these two measures are presented first at the group level to examine performance between groups and then at the level of the individual to examine performance within groups.

3.2.1 Accuracy Results between Groups

Accuracy was measured using three dependent variables: 1) proportion of correct responses (i.e., % correct), 2) discriminability (i.e., d prime), and 3) response latency (i.e., reaction time). Mean scores for each dependent variable were calculated by feature (eye vs. mouth manipulations) and by level of change (2, 4, 6, or 8 pixels).

3.2.1.1 Proportion of Correct Responses

Participants' same/different judgments were summed by the number of correct trials to calculate the mean proportion of correct responses, with lower proportions reflecting poorer thresholds of detecting differences between faces. A summary of the group means is presented in Table 4.

Autism Group (N = 24)				
Proportion of Correct Responses	**2 pixels**	**4 pixels**	**6 pixels**	**8 pixels**
Upright Eyes	0.41 (0.28)	0.39 (0.23)	0.59 (0.29)	0.61 (0.35)
Upright Mouths	0.35 (0.28)	0.36 (0.29)	0.41 (0.28)	0.53 (0.25)
Inverted Eyes	0.39 (0.30)	0.42 (0.28)	0.54 (0.29)	0.67 (0.26)
Inverted Mouths	0.38 (0.28)	0.24 (0.19)	0.34 (0.27)	0.28 (0.21)
Control Group (N = 32)				
Proportion of Correct Responses	**2 pixels**	**4 pixels**	**6 pixels**	**8 pixels**
Upright Eyes	0.32 (0.26)	0.48 (0.31)	0.64 (0.28)	0.73 (0.28)
Upright Mouths	0.20 (0.24)	0.39 (0.29)	0.41 (0.32)	0.60 (0.32)
Inverted Eyes	0.39 (0.26)	0.48 (0.22)	0.56 (0.30)	0.57 (0.29)
Inverted Mouths	0.38 (0.25)	0.34 (0.24)	0.34 (0.24)	0.34 (0.26)

Table 3. Group means (standard deviations) for proportion of correct responses by orientation, feature, and level

Hypothesis 1 stated that individuals with autism will demonstrate less accuracy than typically developing individuals overall and by level of change. To address this prediction, two separate repeated measures ANOVAs (analyses of variance), one for upright trials and one for inverted trials, were conducted on mean proportion of correct responses with group (control vs. autism) as the between-subjects factor and feature (eye vs. mouth manipulations) and level (2 vs. 4 vs. 6 vs. 8 pixel manipulations) as the within-subjects factors.

(a) Upright Faces

The ANOVA for upright trials revealed a main effect of feature, $F(1, 54) = 12.63$, $p < .01$, with greater accuracy for upright trials with eye manipulations ($M = 0.52$, $SE = 0.03$) than mouth manipulations ($M = 0.40$, $SE = 0.03$). There was also a main effect of level, $F(4, 216) = 32.69$, $p < .001$. As seen in Figure 7, a trend analysis of the within-subjects effect of level revealed a significant linear component, $F(1, 54) = 64.41$, $p < .001$, indicating that accuracy increased as the level of manipulation increased. There was no main effect of group.

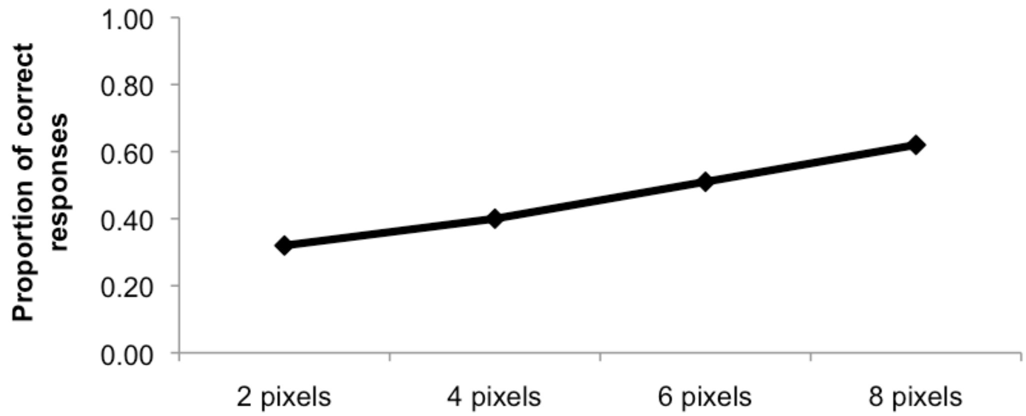

Figure 7. Marginal means for main effect of level from proportion correct ANOVA conducted on upright trials.

Finally, there was a significant Level X Group interaction, $F(4, 51) = 4.23$, $p < .01$. Paired samples *t*-tests revealed that the control group significantly detected differences with increasing accuracy across all levels [2 vs. 4 pixels, $t(31) = 4.43$, $p < .001$; 4 vs. 6 pixels, $t(31) = 2.66$, $p < .05$; 6 vs. 8 pixels, $t(31) = 3.88$, $p < .01$]; whereas, the autism group detected differences with increasing accuracy only from changes of 4 vs. 6 pixels, $t\ (23) = 2.48$, $p < .05$ (see Figure 8).

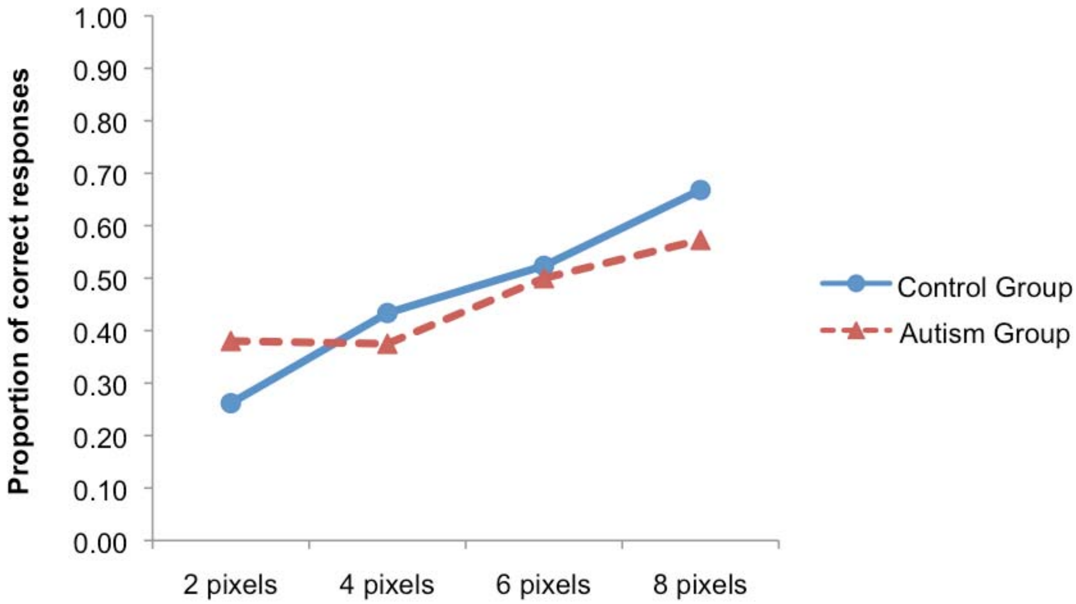

Figure 8. Marginal means for Level X Group interaction from proportion correct ANOVA conducted on upright trials.

(b) Inverted Faces

The ANOVA for inverted trials revealed a main effect of feature, $F(1, 54) = 33.02$, $p < .001$, with greater accuracy for inverted trials with eye manipulations ($M = 0.50$, $SE = 0.02$) than mouth manipulations ($M = 0.33$, $SE = 0.02$). There was also a main effect of level, $F(4, 216) = 4.75$, $p < .01$. As seen in Figure 9, a trend analysis of the within-subjects effect of level revealed a significant linear component, $F(1, 54) = 9.57$, $p < .01$, indicating that accuracy increased as the level of manipulation increased.

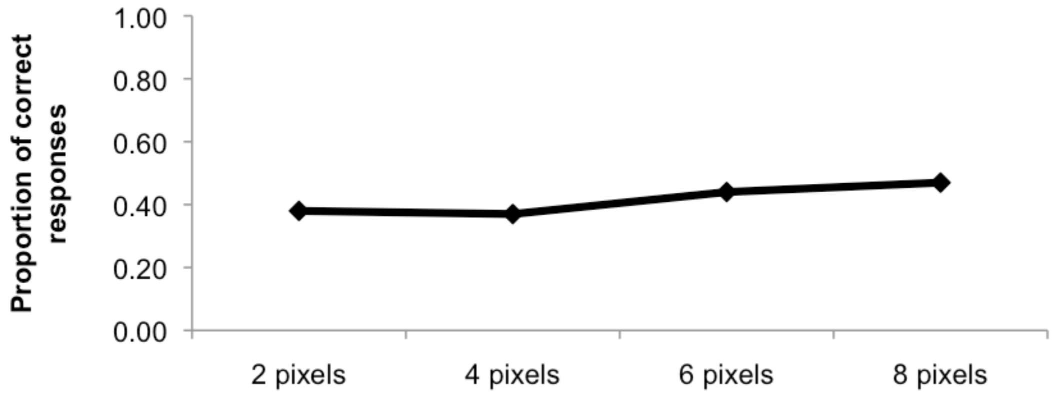

Figure 9. Marginal means for main effect of level from proportion correct ANOVA conducted on inverted trials.

Finally, there was a significant Feature X Level interaction, $F(4, 51) = 7.41$, $p < .001$. Results indicated that participants detected differences between faces with eye manipulations better than faces with mouth manipulations at certain levels of change (see Figure 10). Specifically, paired samples *t*-tests revealed that accuracy for trials with eye manipulations was significantly greater than accuracy for trials with mouth manipulations at 6 and 8 pixels of change, $t(55) = 4.16$, $p < .001$, and $t(55) = 2.32$, $p < .05$, respectively. There was no main effect or interaction of group.

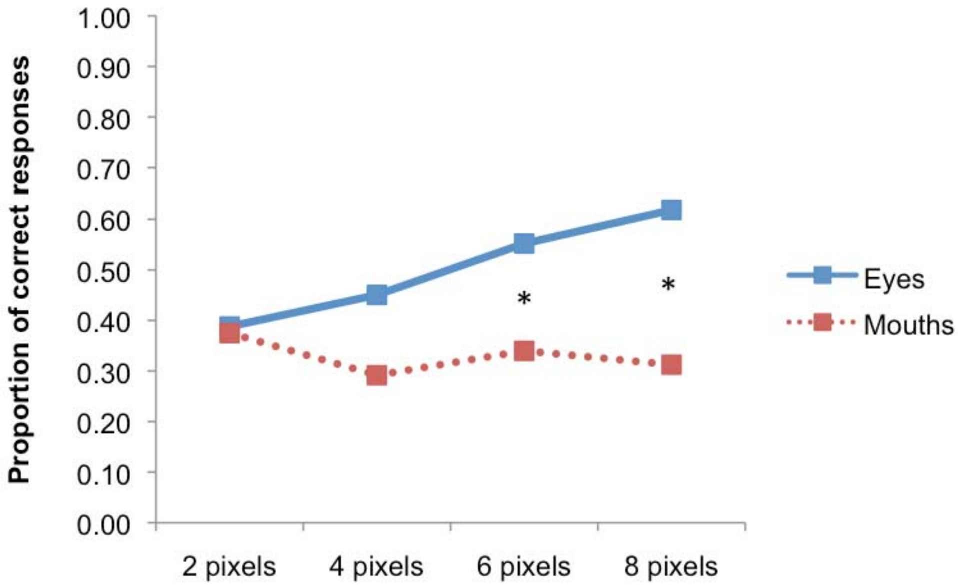

Figure 10. Marginal means for Feature X Level interaction from proportion correct ANOVA conducted on inverted trials.

3.2.1.2 Discriminability

Although, proportion correct provides a measure of accuracy, d-prime is an appropriate measure for dealing with participants who may demonstrate a response bias (e.g., especially participants biased to respond "same" on all trials). Therefore, d-prime scores were calculated for each participant using the proportion of hits (i.e., responding "different" to a different pair) and the proportion of false alarms (i.e., responding "same" to a different pair). Mean d-prime scores of 0 reflected no discriminability (e.g., responding "same" on every trial); whereas, scores of 6.18 reflected perfect discriminabilty (e.g., responding "same" on all same trials and "different" on all different trials). Any participant with no hits (i.e., responding "same" to every different pair) in addition to false alarm responses (i.e., responding "different" to same pairs) generated a negative d-prime score. A summary of the group means is presented in Table 5.

Autism Group (N = 24)				
d-prime Scores	**2 pixels**	**4 pixels**	**6 pixels**	**8 pixels**
Upright Eyes	-1.73 (3.12)	2.59 (0.97)	1.59 (3.55)	3.58 (1.96)
Upright Mouths	-1.86 (2.72)	-0.84 (3.57)	1.85 (2.52)	3.28 (1.21)
Inverted Eyes	0.68 (4.32)	1.82 (2.66)	0.96 (3.55)	3.83 (1.50)
Inverted Mouths	-0.92 (3.22)	0.16 (2.53)	1.87 (1.99)	2.05 (1.30)
Control Group (N = 32)				
d-prime Scores	**2 pixels**	**4 pixels**	**6 pixels**	**8 pixels**
Upright Eyes	-1.47 (3.23)	3.02 (1.80)	2.22 (3.11)	4.62 (1.49)
Upright Mouths	-1.57 (2.69)	0.96 (2.56)	2.39 (2.16)	3.57 (1.73)
Inverted Eyes	0.72 (4.20)	2.13 (2.47)	2.33 (2.87)	3.91 (1.29)
Inverted Mouths	-1.61 (2.79)	-0.30 (3.07)	1.17 (2.59)	2.06 (1.65)

Table 4. Group means (standard deviations) for d-prime by orientation, feature, and level

Two separate repeated measures ANOVAs, one for upright trials and one for inverted trials, were conducted on mean d-prime scores with group (control vs. autism) as the between-subjects factor and feature (eye vs. mouth manipulations) and level (2 vs. 4 vs. 6 vs. 8 pixel manipulations) as the within-subjects factors.

(a) Upright Faces

Corroborating the accuracy results with proportion of correct responses, the d-prime ANOVA for upright trials revealed a main effect of feature, $F(1, 54) = 8.36$, $p < .01$, with greater accuracy for upright trials with eye manipulations (M = 1.80, SE = 0.22) than mouth manipulations (M = 0.97, SE = 0.21). There was also a main effect of level, $F(3, 162) = 105.27$, $p < .001$. As seen in Figure 11, a trend analysis of the within-subjects effect of level revealed a significant linear component, $F(1, 54) = 185.27$, $p < .001$, indicating that accuracy increased as the level of manipulation increased.

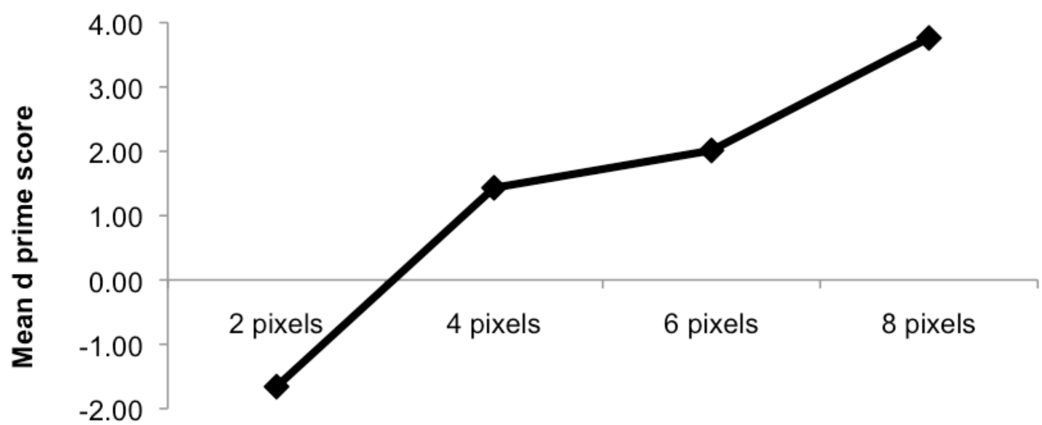

Figure 11. Marginal means for main effect of level from d-prime ANOVA conducted on upright trials.

In contrast to accuracy results with proportion of correct responses, the d-prime results revealed a main effect of group, $F(1, 54) = 4.27$, $p < .05$, with greater discriminability by the control group (M = 1.72, SE = 0.20) than by the autism group (M = 1.06, SE = 0.24). The significant difference between groups suggests that some participants demonstrated a response bias, and therefore, d-prime is a more appropriate measure of this dataset than proportion of correct responses.

Finally, there was a significant Feature X Level interaction, $F(3, 162) = 9.73$, $p < .001$. Results indicated that participants detected differences between upright faces with eye manipulations better than faces with mouth manipulations at certain levels of change (see Figure 12). Specifically, paired samples *t*-tests revealed that accuracy for trials with eye manipulations was significantly greater than accuracy for trials with mouth manipulations at change of 4 and 8 pixels, $t(55) = 5.73$, $p < .001$ and $t(55) = 2.52$, $p < .05$, respectively. There were no interactions of group.

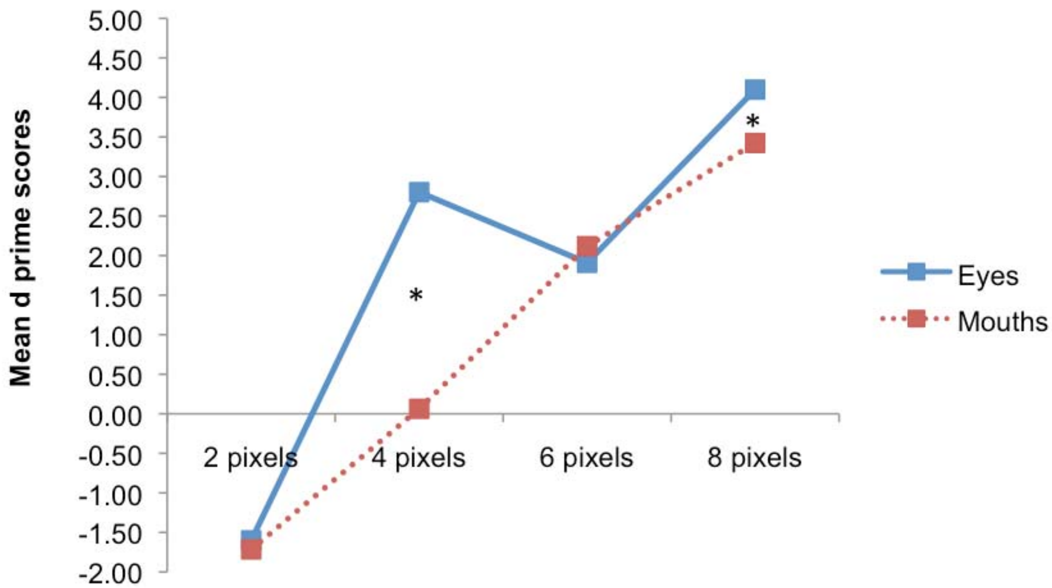

Figure 12. Marginal means for Feature X Level interaction from d-prime ANOVA conducted on upright trials.

(b) Inverted Faces

The ANOVA for inverted trials revealed a main effect of feature, $F(1, 54) = 18.25$, $p < .001$, with greater accuracy for inverted trials with eye manipulations ($M = 2.05$, SE = 0.29) than mouth manipulations (M = 0.56, SE = 0.23). There was also a main effect of level, $F(3, 162) = 32.82$, $p < .001$. As seen in Figure 13, a trend analysis of the within-subjects effect of level revealed a significant linear component, $F(1, 54) = 61.88$, $p < .001$, indicating that accuracy increased as the level of manipulation increased.

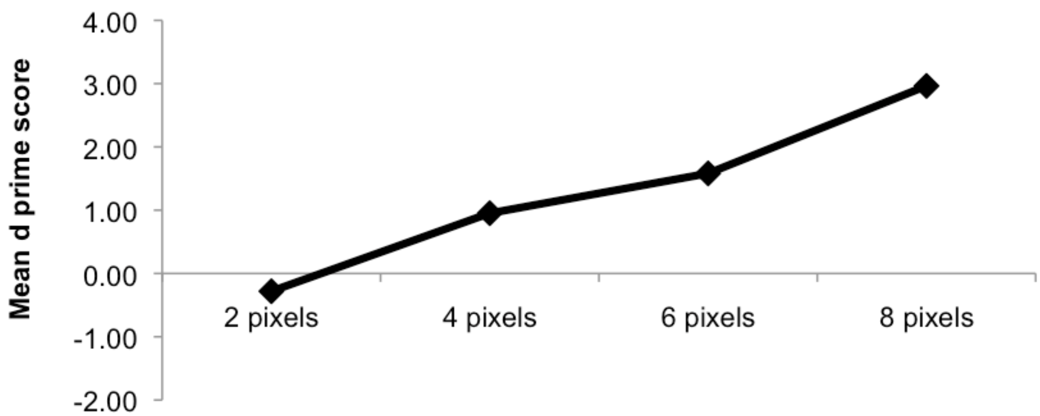

Figure 13. Marginal means for main effect of level from d-prime ANOVA conducted on inverted trials.

Finally, there was a significant Feature X Level interaction, $F(1, 162) = 4.57$, $p < .01$. Results indicated that participants detected differences between faces with eye manipulations better than faces with mouth manipulations at certain levels of change (see Figure 14). Specifically, paired samples *t*-tests revealed that accuracy for inverted trials with eye manipulations was significantly greater than accuracy for inverted trials with mouth manipulations at changes of 2, 4, and 8 pixels, $t(55) = 3.32$, $p < .01$, $t(55) = 4.49$, $p < .001$, and $t(55) = 6.83$, $p < .001$, respectively. There was no main effect or interaction of group.

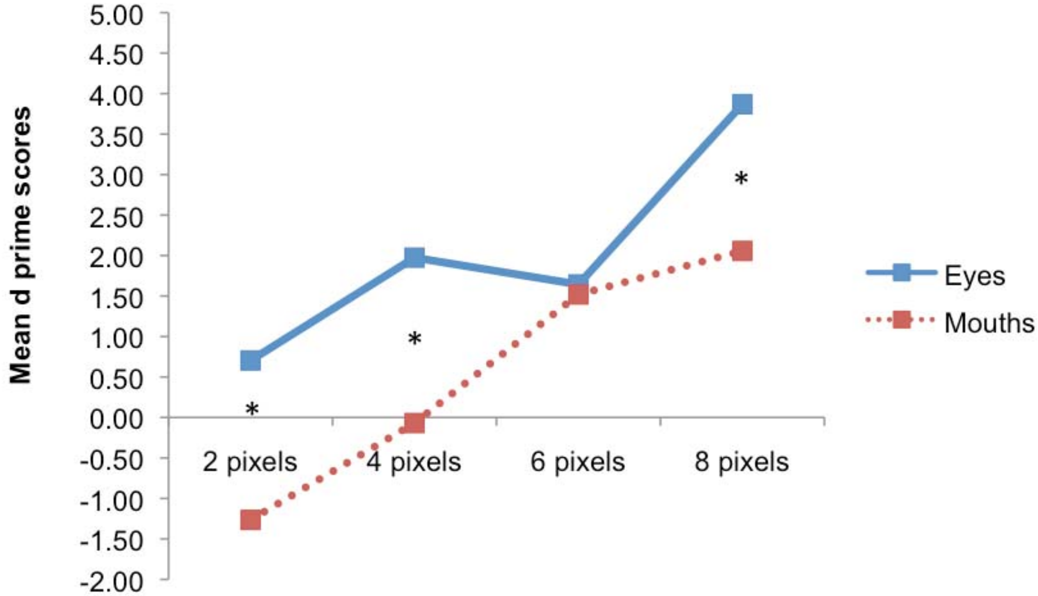

Figure 14. Marginal means for Feature X Level interaction from d-prime ANOVA conducted on inverted trials.

3.2.1.3 Response Latency

Participants' response latencies were averaged across the number of trials with correct responses, yielding reaction time means for correct upright trials and reaction time means for correct inverted trials. A summary of the group means is presented in Table 6.

Autism Group (N = 24)				
Response Latency for Correct Trials	**2 pixels**	**4 pixels**	**6 pixels**	**8 pixels**
Upright Eyes	1848ms (851ms)	1914ms (806ms)	1708ms (919ms)	1832ms (1251ms)
Upright Mouths	2866ms (3671ms)	1991ms (1139ms)	1632ms (867ms)	1850ms (943ms)
Inverted Eyes	1886ms (792ms)	1820ms (913ms)	1707ms (902ms)	1896 (1225ms)
Inverted Mouths	1796ms (882ms)	1929 (1131ms)	1577ms (1003ms)	1692ms (918ms)

Control Group (N = 32)				
Response Latency for Correct Trials	**2 pixels**	**4 pixels**	**6 pixels**	**8 pixels**
Upright Eyes	1512ms (470ms)	1577ms (687ms)	1496ms (977ms)	1668ms (958ms)
Upright Mouths	1583ms (573ms)	1708ms (683ms)	1805ms (953ms)	1531ms (507ms)
Inverted Eyes	1611ms (551ms)	1725ms (666ms)	1605ms (626ms)	1580ms (666ms)
Inverted Mouths	1547ms (587ms)	1673ms (646ms)	1800ms (649ms)	1611ms (608ms)

Table 5. Group means (standard deviations) for response latency by orientation, feature, and level

Hypothesis 2 stated that individuals with autism will demonstrate greater response latencies than typically developing individuals overall and by level of change. After removing one outlier (i.e., a participant with mean reaction times > 4 SD from mean), this prediction was tested with two separate repeated measures ANOVAs, one for upright trials and one for inverted trials, were conducted on reaction time means with group (control vs. autism) as the between-subjects factor and feature (eye vs. mouth manipulations) and level (2 vs. 4 vs. 6 vs. 8 pixel manipulations) as the within-subjects factors.

(a) Upright Faces

The ANOVA for upright trials revealed a marginally significant main effect of group, $F(1,22) = 4.05$, $p = .057$, with shorter response latencies from the control group ($M = 1556$, SE = 207) compared to the autism group ($M = 2202$, $SE = 245$). An independent *t*-test revealed that the mean response latency for correct responses was significantly greater in the autism group ($M = 1929$ms, $SD = 881$) than in the control group ($M = 1625$ms, $SD = 436$), $t(53) = 1.69$, $p < .05$. There were no main effects or interactions of feature or level.

(b) Inverted Faces

The ANOVA for inverted trials revealed a significant main effect of level, $F(1,78) = 4.89$, $p < .01$. As seen in Figure 15, a trend analysis of the within-subjects effect of level revealed a significant linear component, $F(1, 26) = 5.08$, $p < .05$, and a significant cubic component, $F(1, 26) = 7.70$, $p < .05$. The combined trend indicated that response latency means increased from 2 pixels to 4 pixels then decreased again from 4 to 6 pixels and leveled off from 6 to 8 pixels. There were no main effects or interactions of feature or group.

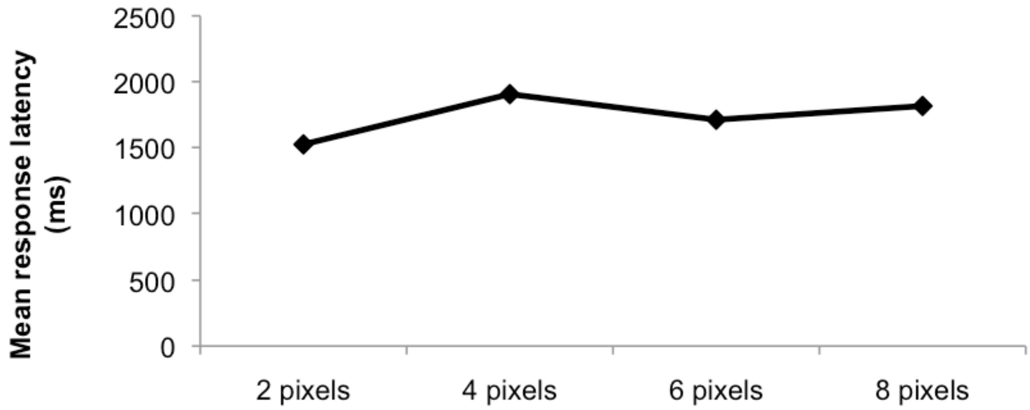

Figure 15. Marginal means for main effect of level from response latency ANOVA conducted on inverted trials.

3.2.2 Eye Gaze Results between Groups

Approximately one-third of the sample (i.e., 21 participants) were disqualified from eye tracking analyses due to missing data (i.e., lost track of eyes during task; could not calibrate eyes at start of task), reducing the total sample from 56 to 35, with 16 participants in the autism group and 19 participants in the control group.

Eye gaze data were calculated according to areas of interest (AOI) for upright and inverted trials. The two critical AOIs were the mouth and eye regions, as these were the locations of the configural manipulations. See Figure 16 for illustration of pre-defined AOIs.

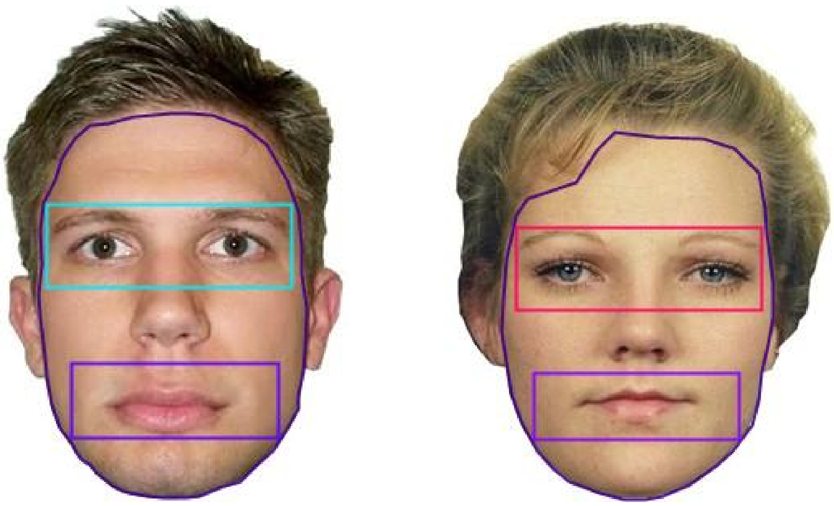

Figure 16. Pre-defined areas of interest for eye, mouth, and whole face

Of primary interest was how participants allocated attention during the change detection task. Therefore, the proportion of looking to AOIs as well as the latency of the first looks to eye and mouth AOIs provided two measures of attentional strategies. A summary of the group means is presented in Table 7.

	Autism Group (N = 16)	*Control Group (N = 19)*
Proportion of Fixations to Upright Eye AOIs	0.35 (0.23)	0.54 (0.21)
Proportion of Fixations to Upright Mouth AOIs	0.21 (0.20)	0.18 (0.12)
Proportion of Fixations to Inverted Eye AOIs	0.42 (0.24)	0.52 (0.18)
Proportion of Fixations to Inverted Mouth AOIs	0.06 (0.07)	0.12 (0.12)

Table 6. Group means (standard deviations) for proportion of fixations by orientation and AOI

3.2.2.1 Proportion of Fixations to AOIs

To determine if groups differed in overall number of fixations to the face as a whole, an independent *t*-test was conducted on the mean number of fixations to the whole face in trials that required a same/different judgment. Results revealed that the groups did not differ significantly in total number of fixations to the entire face (autism group *M* = 180, *SE* = 72 and control group *M* = 235, *SE* = 105, $t(33) = 1.79$ $p > .05$). Therefore, the number of fixations to eye and mouth regions was divided by the total number of fixations to the AOI of the whole face, yielding a proportion of looking to eyes and a proportion of looking to mouths. Mean proportion of fixations for each dependent variable were calculated by level of change (2, 4, 6, or 8 pixels).

Hypothesis 3 stated that individuals with autism will demonstrate fewer fixations than typically developing individuals. To address this prediction, two separate ANOVAs, one for upright trials and one for inverted trials, were conducted on mean proportion of looking with group (control vs. autism) as the between-subjects factor and AOI (eye vs. mouth regions) and level (2 vs. 4 vs. 6 vs. 8 pixel manipulations) as the within-subjects factors.

(a) Upright Faces

The ANOVA for upright trials revealed a main effect of AOI, $F(1, 31) = 33.34$, $p < .001$, with greater proportion of looking to eye regions (*M* = 0.44, *SE* = 0.04) than to mouth regions (*M* = 0.14, *SE* = 0.02). In addition, there was a main effect of level, $F(3,93) = 2.79$, $p < .05$. As seen in Figure 17, a trend analysis of the within-subjects effect of level revealed a significant linear component, $F(1, 31) = 6.73$, $p < .05$, indicating that proportion of fixations to AOIs increased as the level of manipulation increased.

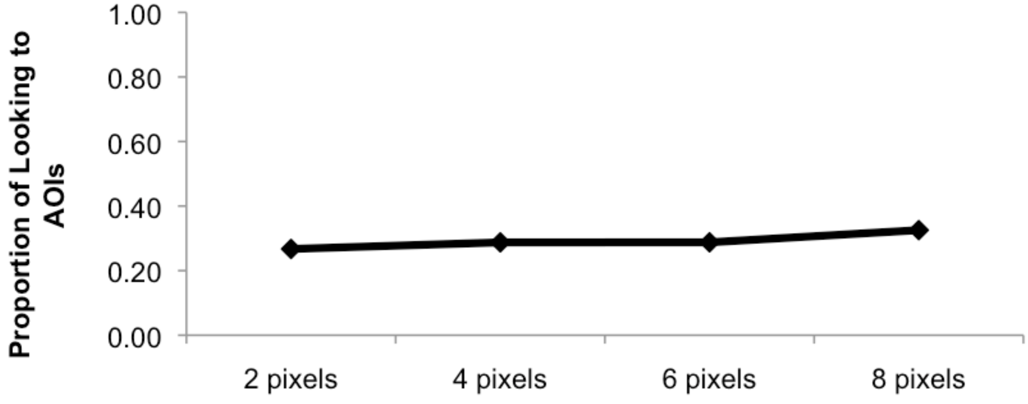

Figure 17. Marginal means for main effect of level from ANOVA conducted on upright trials.

There was also a main effect of group, $F(1,31) = 13.18$, $p < .01$, with an overall greater proportion of looking to eye and mouth AOIs combined by the control group ($M = 0.34$, $SE = 0.02$) than by the autism group ($M = 0.24$, $SE = 0.02$). Finally, there was a significant AOI X Level interaction, $F(3, 93) = 3.59$, $p < .05$. Results indicated that participants looked to eye regions more than to mouth regions at certain levels of change (see Figure 18). Specifically, independent *t*-tests revealed that the proportion of looking to eye AOIs was significantly greater than the proportion of looking to mouth AOIs at all manipulations, t's(32) > 4.05, p's < .001.

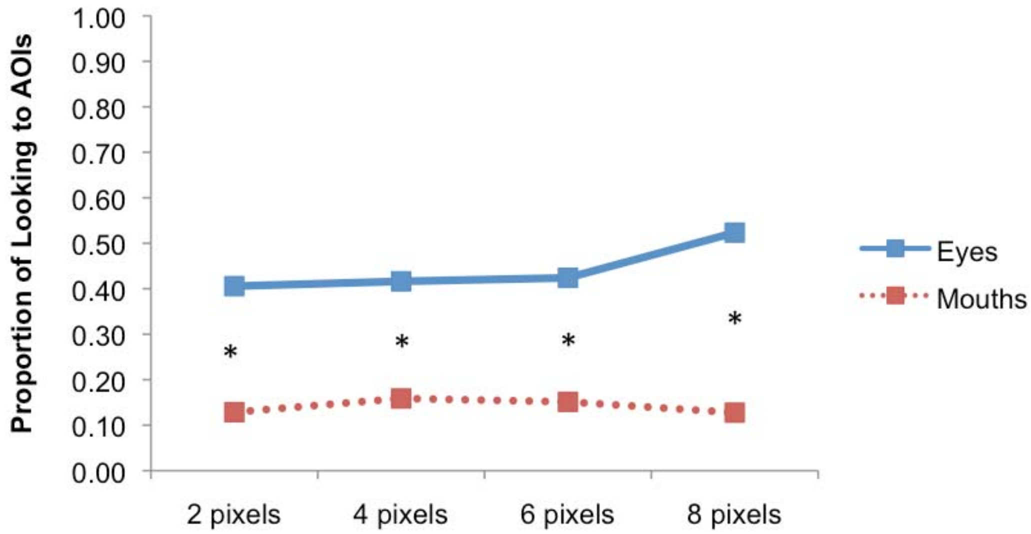

Figure 18. Marginal means for AOI X Level interaction from proportion of fixations ANOVA conducted on upright trials.

(b) Inverted Faces

The ANOVA for inverted trials revealed a main effect of AOI, $F(1, 31) = 81.48$, $p < .001$, with greater proportion of looking to eye regions ($M = 0.48$, $SE = 0.04$) than to mouth regions ($M = 0.08$, $SE = 0.02$). There were no main effects or interactions of level or group.

3.2.2.2 Latency of First Looks to Eye and Mouth AOIs

The mean latency of participants' first looks to eye and mouth AOIs was analyzed for every same/different judgment trial. A summary of the group means is presented in Table 8.

	Autism Group (N = 16)	*Control Group (N = 19)*
Latency of 1st Fixations to Upright Eye AOIs	433ms (402ms)	268ms (243ms)
Latency of 1st Fixations to Upright Mouth AOIs	828ms (568ms)	967ms (750ms)
Latency of 1st Fixations to Inverted Eye AOIs	333ms (349ms)	250ms (191ms)
Latency of 1st Fixations to Inverted Mouth AOIs	973ms (546ms)	908ms (521ms)

Table 7. Group means (standard deviations) for latency of first fixations by orientation and AOI

Hypothesis 4 stated that individuals with autism will demonstrate longer latencies to first looks at AOIs than typically developing individuals. To address this prediction, two separate ANOVAs, one for upright trials and one for inverted trials, were conducted on mean time to first looks to critical AOIs with group (control vs. autism) as the between-subjects factor and AOI (eye vs. mouth regions) as the within-subjects factors.

(a) Upright Faces

The ANOVA for upright trials revealed a main effect of AOI, $F(1, 29) = 12.33$, $p < .01$, with shorter latency of first looks to eye regions (M = 377ms, SE = 61ms) compared to mouth regions (M = 898ms, SE = 124ms). There was no significant group interaction.

(b) Inverted Faces

The ANOVA for inverted trials revealed a main effect of AOI, $F(1, 26) = 29.90$, $p < .001$, with shorter latency of first looks to eye regions (M = 317ms, SE = 53ms) compared to mouth regions (M = 940ms, SE = 104ms). There was no significant group interaction.

3.3 CORRELATIONAL ANALYSES

Correlations were conducted to explore whether any demographic variables, ADOS scores, and/or scores on the Benton Facial Recognition Test were related to experimental performance.

3.3.1 Associations between Accuracy and Participant Characteristics

The relation between change detection performance and participant characteristics was assessed with Pearson's correlations. Two-tailed bivariate correlations were conducted on mean d-prime accuracy scores for upright eyes, upright mouths, inverted eyes, and inverted mouths. Mean d-prime scores for upright eyes were significantly correlated with age, ($r = + 0.33$, $p < .05$), visual acuity, ($r = + 0.28$, $p < .05$), and the Benton Facial Recognition Test, ($r = + 0.38$, $p < .05$). Therefore, participants who were better at detecting difference for upright eye trials were older in age, had better visual acuity, and also scored higher on the Benton Facial Recognition Test.

3.3.2 Associations between Eye Gaze and Participant Characteristics

The relation between eye gaze and participant characteristics was assessed with Pearson's correlations. Two-tailed bivariate correlations were conducted on mean latencies of first looks to upright eye and mouth AOIs and inverted eye and mouth AOIs. Mean latency of first fixations to mouth AOIs for upright faces was significantly correlated with the ADOS social interaction subscale, (r = - 0.62 p < .01), and the ADOS combined total, (r = - 0.50, p <.05). Therefore, participants with shorter latencies of first looks to mouth AOIs for upright faces scored higher on the ADOS.

3.4 WITHIN GROUP ANALYSES

3.4.1 Accuracy Results within Groups

Frequencies of individual mean scores within groups were analyzed by feature (eye vs. mouth manipulations) and by level of change (2, 4, 6, or 8 pixels) for d-prime scores.

3.4.1.1 Discriminability

In the current experiment, participants had to be sensitive to detect the changes between faces. Perceptual sensitivity to the smallest changes made in this task is not unlike a traditional sensitivity threshold to the smallest differences in light or sound that can be physically realized. Therefore, in the current study, the lower an individual's accuracy score, the better his threshold sensitivity to detect configural changes. For that reason, chance performance is not appropriate to discuss in the current data set. Rather, it is more appropriate to think of performance across a sensitivity threshold or continuum. Therefore, data were analyzed at the individual level by identifying those participants within each group who correctly discriminated same/different faces for more than half of the trials (i.e., d-prime score > 3.09) according to feature and level for upright and inverted trials.

(a) Upright Eye Manipulations

Two participants in the control group and zero participants in the autism group demonstrated perfect discrimination for upright eye manipulations across all four levels. Furthermore, as seen in Table 9, the proportion of participants within each group who discriminated same/different faces in more than half of the trials was significantly greater in the control group than in the autism group, specifically for upright eye manipulations of 4 pixels, $\chi^2 = 4.00$, $p < .05$.

	Upright Eyes 2 pixels	*Upright Eyes 4 pixels*	*Upright Eyes 6 pixels*	*Upright Eyes 8 pixels*
Autism Group	0	0.17	0.38	0.50
Control Group	0.09	0.38	0.44	0.72

Table 8. Proportion of participants within groups who discriminated same/different faces greater than 3.09 across different levels of upright trials with eye manipulations

(a) Upright Mouth Manipulations

No participants in either group demonstrated perfect discrimination for upright mouth manipulations across all four levels. However, as seen in Table 10, the proportion of participants within each group who discriminated same/different faces in more than half of the trials was significantly greater in the control group than in the autism group, specifically for upright mouth manipulations of 8 pixels, $\chi^2 = 3.85$, $p < .05$.

	Upright Mouths 2 pixels	*Upright Mouths 4 pixels*	*Upright Mouths 6 pixels*	*Upright Mouths 8 pixels*
Autism Group	0	0.04	0.21	0.33
Control Group	0	0.09	0.19	0.56

Table 9. Proportion of participants within groups who discriminated same/different faces greater than 3.09 across different levels of upright trials with mouth manipulations

(b) Inverted Eye Manipulations

One participant in the control group and 2 participants in the autism group demonstrated perfect discrimination for inverted eye manipulations across all four levels. Furthermore, as seen in Table 11, the proportion of participants within each group who discriminated same/different faces in more than half of the trials was significantly greater in the control group than in the autism group, specifically for eye manipulations of 6 pixels, $\chi^2 = 4.00$, $p < .05$.

	Inverted Eyes 2 pixels	*Inverted Eyes 4 pixels*	*Inverted Eyes 6 pixels*	*Inverted Eyes 8 pixels*
Autism Group	0.33	0.25	0.17	0.58
Control Group	0.34	0.22	0.38	0.63

Table 10. Proportion of participants within groups who discriminated same/different faces greater than 3.09 across different levels of inverted trials with eye manipulations

(a) Inverted Mouth Manipulations

No participants in either group demonstrated perfect discrimination for inverted mouth manipulations across all four levels. Furthermore, as seen in Table 12, the proportion of participants within each group who discriminated same/different faces in more than half of the trials was not significantly different between groups at any level.

	Inverted Mouths 2 pixels	*Inverted Mouths 4 pixels*	*Inverted Mouths 6 pixels*	*Inverted Mouths 8 pixels*
Autism Group	0.13	0	0.04	0.04
Control Group	0.03	0.03	0.06	0.16

Table 11. Proportion of participants within groups who discriminated same/different faces greater than 3.09 across different levels of inverted trials with mouth manipulations

3.4.2 Eye Gaze Results within Groups

3.4.2.1 Proportion of Fixations

Although both groups spent more time looking to eye regions than mouth regions, not all individuals demonstrated a bias to attend to eyes. Table 13 shows the proportion of participant within each group who had greater fixations to mouth AOIs than eye AOIs. Although, the proportion of participants who demonstrated a bias to attend to mouths was not significantly different between groups, there was a trend for more participants in the autism group than in the control group to attend to mouths more than eyes.

	Upright Mouths	*Inverted Mouths*
Autism Group	0.36	0.14
Control Group	0.11	0.11

Table 12. Proportion of participants within groups who had greater mean proportion of fixations to mouths than to eyes

3.4.2.2 Latency of First Looks to Eye and Mouth AOIs

Although both groups demonstrated a shorter latency to look first at eyes than at mouths, not all individuals demonstrated a bias to attend to eyes as first looks. Table 14 shows the proportion of participant within each group who had shorter first look latencies to mouth AOIs than eye AOIs. Although, the proportion of participants who demonstrated a bias to look first to mouths was not significantly different between groups, there was a trend for more participants in the autism group than in the control group to have shorter latencies to look first at mouths more than at eyes.

	Upright Mouths	*Inverted Mouths*
Autism Group	0.13	0.14
Control Group	0.11	0.11

Table 13. Proportion of participants within groups who had shorter mean latencies of first looks to mouths than to eyes

3.4.2.3 Individuals with Biases toward Mouths

An examination of those individuals with autism who showed either greater proportion of fixations to mouths than eyes and/or shorter latencies of first looks to mouths compared to eyes revealed a significant correlation. Mean latencies of first fixations to mouth AOIs for upright faces were significantly correlated with the ADOS social interaction subscale, ($r = -0.86$, $p < .05$). Therefore, participants with biases to fixate on the mouth first for upright faces scored higher on the ADOS.

4.0 DISCUSSION

4.1 SUMMARY OF CURRENT FINDINGS

A few studies have previously examined how well individuals with autism can detect subtle configural changes in facial information (Faja, et al., 2008; Riby, et al., 2009; Rutherford, et al., 2007). However, the current study is the first to have directly tested the ability to detect varying levels of subtle configural changes between faces by using an eye tracker. Directly testing the hypothesis of whether individuals with autism are sensitive to subtle configural changes (i.e., as opposed to inferring it from behavioral responses alone) is crucial for understanding possible perceptual mechanisms underlying the known deficit of face recognition abilities in individuals with autism.

The current study reveals several important findings between groups. First, after accounting for response biases with d-prime, it was found that the control group was able to detect differences better than the autism group for upright faces. Second, both groups were more accurate at detecting differences between faces when eyes were manipulated than when mouths were manipulated. This finding was true whether faces were presented upright or inverted. Third, both group's detection of differences between faces was greatest when manipulations were more obvious (i.e., 8 pixels vs. 2 pixels). Even so, the task was difficult for both groups with mean accuracy only reflecting accurate detection for more than half of the trials at more obvious levels of change. Fourth, participants in the control group were faster to respond correctly than the participants in the autism group, at least for upright faces, indicating that the control group was more efficient with their visual attention when accurately detecting configural changes. Fifth, regardless of diagnosis, both groups looked to the eyes more than to the mouths when making same/different judgments. This finding was true whether the faces were presented upright or inverted. Importantly, however, the control group fixated on eye and mouth AOIs more than the autism group. This difference is reflected in the control group's greater accuracy for upright trials. Sixth, the eye gaze patterns of both groups revealed that attention to eye and mouth regions was greatest when manipulations were more obvious (i.e., 8 pixels vs. 2 pixels), but only for upright trials. Finally, the latency of first looks to eye regions was significantly shorter than the latency to first looks to mouth regions for both groups, indicating that participants generally looked to eyes before mouths. This finding was true whether faces were presented upright or inverted.

The current study also reveals important findings within groups. The proportion of participants who correctly detected changes to the eyes in more than half of the trials was greater in the control group than in the autism group for upright and inverted faces. The same was true for detection of changes to the mouth in upright faces, with a higher proportion of control participants correctly detecting differences in more than half of the trials. In terms of within group performance on eye tracking, there were no significant differences in the proportion of participants within groups who fixated more to mouths than eyes or who had shorter latency of first looks to mouths; however, there was a non-significant trend in the data for a greater proportion of participants with autism than controls to show a bias toward looking to mouths.

Finally, the current study revealed several associations with face recognition performance. First, the scores on the Benton Facial Recognition Test were positively correlated with accuracy for detecting changes to upright eyes. Second, performance on upright eyes was also positively correlated with age and visual acuity. Manipulations to upright eyes appear to be the most sensitive measure for face recognition abilities. Third, scores on the ADOS social interaction subscale were negatively correlated with latency of first fixations to mouth AOIs for upright faces, suggesting that individuals with more symptoms of autism are more likely to look first at mouths than at eyes during face recognition. This negative correlation between performance and the ADOS social interaction subscale was stronger when isolating those participants with autism who demonstrated a bias to look to mouth AOIs over eye AOIs.

Taken together, these findings support the proposed account that individuals with autism are not as perceptually sensitive to configural manipulations within faces as typically developing individuals. This was especially true for recognition of upright faces. Overall, the current findings present evidence that the known face recognition deficit exhibited by individuals with autism may be due in part to poorer perceptual sensitivity and different attentional strategies.

4.2 IMPLICATIONS OF CURRENT FINDINGS

4.2.1 Individuals with Autism's Configural Processing Abilities

The current study raises some interesting questions. First, after taking into account response biases, why were there group differences in response accuracy for upright faces, but not for inverted faces? The expected group difference in accuracy for upright faces within the current study supports numerous evidence from previous research demonstrating a face recognition deficit in individuals with autism. However, both groups performed similarly in terms of accuracy for inverted trials. Given that individuals with autism usually do not demonstrate an inversion effect to which typically developing individuals are more susceptible (i.e., when configural information is most disrupted), there might have been an expectation for the autism group to performed better than the control group on the change detection with inverted faces. However, this is improbable, given that there were no featural changes between faces in the current experiment. Traditionally, the lack of an inversion effect in populations with autism is due to the fact that they can maintain use of featural information (i.e., featural information that is less disrupted than configural information in inverted faces); however, in this task, use of featurual information proved futile to detect changes because there were no featural manipulations. Therefore, the lack of group differences for inverted faces is most likely due to the fact that both groups were susceptible to the inversion effect and had difficulty perceiving configural changes in a less familiar orientation.

Previous research suggests that individuals with autism process faces featurally rather than configurally and have limited ability to process faces configurally (Boucher, et al., 1998; Davies, et al., 1994; de Gelder, et al., 1991; Deruelle, et al., 2004; Hobson, et al., 1988; Joseph & Tanaka, 2003; Klin, et al., 1999; Langdell, 1978). The purpose of the current project was to study how perceptually sensitive individuals with autism are to the natural and subtle variance of configural information within a face with respect to recognition abilities. The current study provides evidence that individuals with autism can process configural information in faces, but not with the same degree of perceptual sensitivity as typically developing individuals. Although individuals with autism may have a bias to process faces featurally (e.g., Lahaie, et al., 2006), the only way to succeed in the current task was to perceive the configural differences between faces. This raises an interesting distinction of whether or not individuals with autism have the ability to process faces configurally versus whether or not they actually engage in configural processing of faces when recognizing faces in the real world. The nature of the current task forced participants with autism to engage in configural processing (i.e., since perception of features alone would not lead to accurate detection of changes between faces) when they otherwise may have used featural processing to recognize faces. Perlman and colleagues (Perlman, Hudac, Pegors, Minshew, & Pelphrey, 2010) made individuals with autism scan a face in the same manner that typically developing individuals would do by having them track a dot moving around the face in a pattern that mimicked typical scanning. In effect, this artificial scanning pattern revealed similar brain activity to what controls produce when scanning a face naturally. If individuals with autism are able to process configural information when necessary, but do not do so spontaneously because it is more difficult, it may be that using featural information is the default method for individuals with autism. Processing faces featurally may be good enough for individuals with autism, but does not allow the development of sufficient expertise with face recognition since spatial information is generally less obvious than featural information and thus useful for finer levels of discrimination among similar faces. It is known that featural information is more obvious than spatial information from the developmental literature in which children are more sensitive to featural changes than configural changes (e.g., Mondloch, Dobson, Parsons, & Maurer, 2004). Infants and children can use both configural and featural information, but are not as efficient with configural information as adults. If individuals with autism are not as sensitive to the configural information as typically developing individuals, then they must rely on other information to recognize faces, thus engaging in atypical face processing strategies compared to control populations. Still, the current study suggests that individuals with autism are not deficient of configural processing altogether and the current data confirm previous evidence suggesting that individuals with autism do not have impaired configural processing, but are less sensitive relative to controls (Joseph & Tanaka, 2003; Lopez, et al., 2004; Rouse, et al., 2004).

4.2.2 Individuals with Autism's Use of Eye Information to Recognize Faces

Despite the fact that the control group had a greater proportion of fixations to eye and mouth AOIs combined than the autism group, why did both groups look more to eyes than mouths? Recall that at the group level, the participants with autism and the typically developing participants differed in where their attention was allocated for upright faces, but not for inverted faces. For upright faces, the control group engaged in a greater proportion of fixations to the critical AOIs that were relevant for accurately detecting differences between faces than did the autism group. Because the proportion of looking to the entire face was analogous between groups, participants with and without autism attended to both relevant features (e.g., eyes and mouths) and irrelevant features (e.g., hair, noses, ears) when making same/different judgments; however, the participants in the control group spent more time looking to relevant features of the face than did the participants in the autism group. Still, although it was predicted that the control group would attend to the eyes and mouth more than the autism group, results revealed that within both groups more attention was allocated to eyes than to mouths. This finding is in contrast to previous results that suggest individuals with autism pay less attention to eyes than mouths.

The Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) cites impaired eye to eye gaze as a symptom of autism (American Psychiatric Association, 2000). Empirically, individuals with autism perform worse than typically developing individuals on the "Reading the Mind in the Eyes" Test (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) demonstrating difficulty identifying thoughts and intentions of eyes presented in isolation. Unlike typically developing individuals, individuals with autism process the lower half of faces/mouths better or as well as the upper half of faces/eyes on identity recognition tasks with familiar faces (Langdell, 1978), unfamiliar faces (Riby, et al., 2009), and with isolated facial features (Joseph & Tanaka, 2003). Additionally, previous eye tracking studies reveal that while passively viewing faces, individuals with autism demonstrate greater fixation to mouths compared to individuals without autism during social scenes (Fletcher-Watson, Leekman, Benson, Frank, & Findlay, 2009; Klin, et al., 2002; Norbury, et al., 2009), images of facial emotions (Pelphrey, et al., 2002), and photographs of faces where high-spatial frequency information is removed (i.e., bubble technique, Spezio, et al., 2007). Eye tracking during emotion recognition tasks reveals that individuals with autism fixate on mouths more than individuals without autism (Neumann, Spezio, Piven, & Adolphs, 2006; Pelphrey, et al., 2002; Spezio, et al., 2007). Furthermore, a looking bias to mouths may appear as early as six months of age in infants later diagnosed with autism (Merin, Young, Ozonoff, & Rogers, 2007).

Recall that the existing literature has proposed three explanations for why individuals with autism have difficulty processing eye information, resulting in perhaps an increased reliance on mouths during face processing. First, researchers suggest that eye avoidance by individuals with autism is due to an overarousal from the heightened emotional information conveyed by eyes. Second, researchers suggest that greater attention to mouths helps individuals with autism obtain verbal information. Third, researchers suggest that individuals with autism simply cannot process information from eyes well, and therefore learn to compensate by relying on mouth information instead.

Nevertheless, other empirical evidence, including the current study, demonstrate individuals with autism do attend to and process facial information from eyes better than mouths similar to typically developing individuals. Several eye tracking studies testing individuals with autism also suggest that similar to matched controls, individuals with autism spend significantly more time fixating to the eyes compared to any other feature (Hernandez, et al., 2009) and that initial fixations while passively viewing emotional faces tend to be toward the eyes (van der Geest, Kemner, Verbaten, & van Engeland, 2002). Behavioral evidence also suggests more attention to eyes versus mouths by individuals with autism during emotion recognition (Hobson, et al., 1988). Furthermore, Bar-Haim, Shulman, Lamy, and Reuveni (2006) demonstrated that children with autism did not differ from control children in attention to eyes and mouths during a probe-detection task where participants located a dot that materialized on a face. Rather, children with autism were as fast as children without autism at detecting a dot's onset near the eyes than mouth suggesting attention was oriented toward the eyes in anticipation of the probe for all children. Finally, Best, Minshew, and Strauss (2010) found that with regard to individual differences, most adults with autism used eye information more than mouth information to discriminate facial gender. However a subgroup of adults in the autism group discriminated gender equally well from eyes and mouths.

How do we reconcile these mixed findings? Although eye information is highly salient for typically developing individuals, perhaps eyes are not the default feature used by individuals with autism when processing faces. If subtle information in eyes is less perceptible by individuals with autism, they may use other features to compensate for the lack of expertise with using subtle eye information, but that is not to say that they cannot use eye information at all. The current study indicates that individuals with autism can perceive subtle differences in spatial information in eye regions, but not to the same degree of sensitivity as typically developing individuals. Whereas research focusing on eye and mouth preferences by individuals with autism remains mixed, the current study supports more recent findings that individuals with autism do not avoid eyes and do not have superior mouth processing abilities (e.g., Best, Minshew, & Strauss, 2010; Rutherford, et al., 2007). Like typically developing individuals, individuals with autism in the current study detected subtle changes to the eyes more readily than to the mouth. These findings suggest that at least at the group level individuals with autism attend to eyes more than mouths and are able to perceive subtle differences between faces when eyes have been modified, yet not to the same degree as typically developing individuals. The majority of participants used eye information more than mouth information; however, the current study also revealed that a small sub-set of individuals used mouth information more than eye information for recognizing faces, indicating variability in face processing strategies among individuals. Perhaps the mixed findings for use of eye information in the autism literature stems from heterogeneity in individual symptomology within research samples. The current study found a highly negatively correlation between the ADOS social interaction subscale and a bias to look to mouths, yet the proportion of individuals exhibiting a mouth bias was small. Kirchner, Hatri, Heekeren, and Dziobek (2010) also found that fixations to mouths by individuals with autism during Dziobek's (2008) Multifaceted Empathy Test was a significant predictor of performance on Baron-Cohen's (2001) Reading the Mind in the Eyes Test.

Therefore, use of eye versus mouth information by individuals with autism may vary according to at the very least three elements. First, depending upon the social characteristics of the samples used in previous research, it is probable that findings will vary. Second, depending upon the nature of the face processing task (i.e., emotion vs. identity recognition), result will vary. Finally, results may vary depending upon the amount of competing non-face information (i.e., face vs. face within a social scene).

4.2.3 Justification for Social Intervention Programs

Replicating findings of previous research, the current study demonstrated that individuals with autism have deficits in face recognition relative to typically developing individuals. Faces are incredibly relevant in daily life. With inadequate face recognition skills, social interactions and relationships may suffer. Evidence from the current study suggests that for some individuals, a greater number of social impairments (i.e., as assessed by the ADOS social interaction subscale) was associated with more fixations to mouths. The problem of a face recognition deficit can be very real for individuals with autism. In an online blog, a speech pathologist describes the social consequences of a child with autism who cannot recognize faces:

> One of my students who has a diagnosis of Autism has difficulty recognizing the faces of his peers. When he brought home his class picture, his mom asked him to tell her who the people in the picture were. He told her he didn't know their names. Since it was March and more than half the school year was over, his mom was very surprised that he did not know the names of his classmates… I showed him the class picture and asked him to point to a child that I named who I have seen him play with. He told me that he could not find his friend in the picture because they all look the same to him.

(http://www.autism-community.com/speech-language-pathologist-by-claire/)

Although this case may be more severe than most children with autism, several social skills interventions have focused on improving face recognition skills through computer games and have successfully helped children and adolescents with autism (e.g., Gower, Perez, Adams, & Sheridan, 2010; Hopkins, 2007), suggesting that it is a common problem. However, given the current findings, intervention programs must not focus solely on increasing featural processing strategies with faces, but must incorporate training to improve configural processing with faces. It is therefore essential for researchers to communicate with developers of training programs in order to focus on the underlying mechanisms responsible for the shortcomings. With better understanding of how individuals with autism process (or do not process) faces, we can intervene early to provide structured support for overcoming face recognition deficits and hopefully allowing better social outcomes for individuals with autism. For instance, based on the current findings, a face recognition program could focus on improving configural processing by beginning at a level of discrimination of spatial distances within faces that an individual can detect as different and then working systematically to progress toward detection of smaller spatial differences.

4.3 CURRENT LIMITATIONS

The current study had several limitations. First, the sample size was small and the limited number of children and adolescents did not permit an investigation of developmental differences within and between groups. Given the correlation between accuracy and age for upright eye trials, future research should look at children's versus adults' performance on face recognition change detection tasks. Given that Riby, et al. (2009) found children and adolescents with autism to be less sensitive to configural information, it warrants further investigation. Furthermore, not all participants had useable eye tracking data in the current study, which reduced the sample size further for the eye gaze analyses. Perhaps individuals with difficulty calibrating their eyes or maintaining tracking demonstrated different attentional strategies that could not be recorded. Second, the experiment was designed with few trials per level of change. With only eight iterations per level, detection abilities were not sampled numerous times. Given the length of the two tasks (i.e., approximately 15 minutes), it may have proved useful to have face orientation as a between-subjects measure to reduce the length of the experiment and facilitate an increase in the number of trials per level of change.

4.4 FUTURE DIRECTIONS

The scope of future research on face recognition abilities in individuals with autism needs to focus on three main issues. First, the assumption that individuals with autism cannot use eye information for face processing is not an absolute. Whether or not individuals with autism avoid making eye contact in social interactions, evidence supports that individuals can use eye information to process and recognize faces. Second, the nature of autism spectrum disorders is such that there is incredible variability among individuals with autism. In fact symptomology may be one appropriate predictor of severity of face recognition deficits. Examination of individual differences within individuals with an autism spectrum disorder may provide clarity with future diagnostic sub-divisions, as well as help to personalize training/intervention programs that aid in face recognition skills. Finally, it is crucial for developmental work within the field of autism. Research involving a developing skill like face recognition in a population with a developmental disorder warrants a developmental approach for better understanding of typical and atypical development. It is with these future directions that we can fully understand the underlying cause of the aberrant development of face recognition abilities in individuals with autism and hope to improve the daily lives of all those affected by autism.

APPENDIX

TASK INSTRUCTIONS

Now you are going to do a comparison task. You will compare two pictures and decide whether they are the same or different. You will see one picture at a time. Look at the first picture; then wait for the second picture to appear. Compare the pictures and decide whether anything changed.

If you think the second picture is the same as the first picture and nothing changed, hit the SAME key. If you think the second picture is different from the first picture and something changed, hit the DIFFERENT key.

Let me show you some examples of what I mean:

1) Here is a picture of a clock. *(pause)* And here is a second picture of a clock. Do you think these pictures are the same or different? *(Give corrective feedback.)* Yes, in these two pictures, the clocks are the same, and nothing changed.

2) Here is a picture of a clock. *(pause)* And here is a second picture of a clock. Do you think these pictures are the same or different? *(Give corrective feedback.)* Yes, even though the second clock is the very same as the first clock, something changed. Do you see how the times on the clocks are not the same?

Now I am going to show you pictures of people's faces. Your job is to compare the pictures and decide if they are same or different. Remember to look at the first face; then wait for the second face to appear. If you think nothing changed between the pictures, press the SAME key; but if you think something changed between the pictures, press the DIFFERENT key.

REFERENCES

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders (4th ed.)*. Washington, DC: American Psychiatric Association.

Ashwin, C., Baron-Cohen, S., Wheelwright, S., O'Riordan, M., & Bullmore, E. T. (2007). Differential activation of the amygdala and the `social brain' during fearful face-processing in Asperger Syndrome. *Neuropsychologia, 45*(1), 2-14.

Bahrick, H. P., Bahrick, O. O., & Wittlinger, R. P. (1975). Fifty years of memory for names and faces: A cross-sectional approach. *Journal of Experimental Psychology, 104*, 54-75.

Bar-Haim, Y., Shulman, C., Lamy, D., & Reuveni, A. (2006). Attention to Eyes and Mouth in High-Functioning Children with Autism. *Journal of Autism and Developmental Disorders, 36*(1), 131-137.

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The "Reading the mind in the eyes" Test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry, 42*(2), 241-251.

Bartlett, J. C., Hurry, S., & Thorley, W. (1984). Typicality and familiarity for faces. *Memory and Cognition, 12*, 219-228.

Barton, J. J. S., Keenan, J. P., & Bass, T. (2001). Discrimination of spatial relations and features in faces: Effects of inversion and viewing duration. *British Journal of Psychology, 92*, 527-549.

Batki, A., Baron-Cohen, S., Wheelwright, S., Connellan, J., & Ahluwalia, J. (2000). Is there an innate gaze module? Evidence from human neonates. *Infant Behavior & Development, 23*(2), 223-229.

Behrmann, M., Avidan, G., Leonard, G. L., Kimchi, R., Luna, B., Humphreys, K., et al. (2006). Configural processing in autism and its relationship to face processing. *Neuropsychologia, 44*(1), 110-129.

Benton, A. L., Sivan, A. B., Hamsher, K., Varney, N. R., & Spreen, O. (1994). *Contributions to Neuropsychological Assessment*. New York: Oxford University Press.

Best, C. A. (2004). *Developing a sufficient knowledge base for faces: Implicit recognition memory for distinctive versus typical female faces.* Unpublished master's thesis, University of Pittsburgh, Pittsburgh.

Best, C. A., Minshew, N. J., & Strauss, M. S. (2010). Gender Discrimination of Eyes and Mouths by Individuals with Autism. *Autism Research, 3*(2), 88-93.

Best, C. A., Newell, L. C., Strauss, M. S., & Minshew, N. J. (in prep). The Distinctiveness Effect: Do Individuals with Autism Develop a Face Space?. Unpublished manuscript, University of Pittsburgh.

Best, C. A., & Strauss, M. S. (2007, April). *A face in the crowd: Recognition memory for distinctive faces in infancy.* Paper presented at the biennial meeting of the Society for Research in Child Development, Boston, MA.

Best, C. A., Strauss, M. S., Newell, L. C., Gastgeb, H., & Costello, M. C. (2004, May). *Developing expertise with faces: Preschoolers' implicit recognition memory for distinctive versus typical faces* Paper presented at the Biennial Meeting of International Conference on Infant Studies, Chicago, IL.

Boucher, J., & Lewis, V. (1992). Unfamiliar face recognition in relatively able autistic children. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *33*(5), 843-859.

Boucher, J., Lewis, V., & Collis, G. (1998). Familiar face and voice matching and recognition in children with autism. *Journal of Child Psychology and Psychiatry*, *39*(2), 171-181.

Brooks, K. R., & Kemp, R. I. (2007). Sensitivity to feature displacement in familiar and unfamiliar faces: Beyond the internal/external feature distinction. *Perception, 36*(11), 1646-1659.

Bushnell, I. W., Sai, F., & Mullin, J. T. (1989). Neonatal recognition of the mother's face. *British Journal of Developmental Psychology, 7*, 3-15.

Carey, S., & Diamond, R. (1977). From piecemeal to configurational representation of faces. *Science Vol 195(4275) Jan 1977, 312-314.*

Carey, S., & Diamond, R. (1994). Are faces perceived as configurations more by adults than by children? In V. E. Bruce & G. W. E. Humphreys (Eds.), *Object and face recognition. Special issue of Visual Cognition*.

Centers for Disease Control and Prevention. (2009). Prevalence of Autism Spectrum Disorders. [Morbidity and Mortality Weekly Report]. *Surveillance Summaries, February. MMWR 2007, 58*(SS-10), 1-20.

Chakrabarti, S., & Fombonne, E. (2005). Pervasive developmental disorders in preschool children: Confirmation of high prevalence. *American Journal of Psychiatry*, *162*(6), 1133-1141.

Chiroro, P., & Valentine, T. (1995). An investigation of the contact hypothesis of the own-race bias in face recognition. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology 48A*(4), 879-894.

Cohen, L. B., & Cashon, C. H. (2001). Do 7-month-old infants process independent features or facial configurations? *Infant and Child Development*, *10*(1-2), 83-92.

Dalton, K. M., Nacewicz, B. M., Johnstone, T., Schaefer, H. S., Gernsbacher, M. A., Goldsmith, H. H., et al. (2005). Gaze fixation and the neural circuitry of face processing in autism. *Nature Neuroscience*, *8*(4), 519-526.

Davies, S., Bishop, D., Manstead, A. S. R., & Tantam, D. (1994). Face perception in children with autism and Asperger's syndrome. *Journal of Child Psychology and Psychiatry*, *35*(6), 1033-1057.

Dawson, G., Webb, S. J., & McPartland, J. (2005). Understanding the Nature of Face Processing Impairment in Autism: Insights From Behavioral and Electrophysiological Studies. *Developmental Neuropsychology*, *27*(3), 403-424.

de Gelder, B., Vroomen, J., & Van der Heide, L. (1991). Face recognition and lip-reading in autism. *European Journal of Cognitive Psychology, 3*(1), 69-86.

Deruelle, C., Rondan, C., Gepner, B., & Tardif, C. (2004). Spatial Frequency and Face Processing in Children with Autism and Asperger Syndrome. *Journal of Autism and Developmental Disorders, 34*(2), 199-210.

Diamond, R., & Carey, S. (1977). Developmental Changes in the Representation of Faces. *Journal of Experimental Child Psychology, 23*, 1-22.

Donnelly, N., & Davidoff, J. (1999). The Mental Representations of Faces and Houses: Issues Concerning Parts and Wholes. *Visual Cognition, 6*(3), 319 - 343.

Dziobek, I., Rogers, K., Fleck, S., Bahnemann, M., Heekeren, H. R., Wolf, O. T., et al. (2008). Dissociation of Cognitive and Emotional Empathy in Adults with Asperger Syndrome Using the Multifaceted Empathy Test (MET). *Journal of Autism and Developmental Disorders, 38*(3), 464-473.

Fagan, J. F. (1973). Infants' delayed recognition memory and forgetting. *Journal of Experimental Child Psychology, 16*, 424-450.

Faja, S., Aylward, E., Bernier, R., & Dawson, G. (2008). Becoming a face expert: A computerized face-training program for high-functioning individuals with autism spectrum disorders. *Developmental Neuropsychology, 33*(1), 1-24.

Fantz, R. L. (1965). Visual perception from birth as shown by pattern selectivity. *Annals of the New York Academy of Sciences, 118*, 793-814.

Fletcher-Watson, S., Leekman, S. R., Benson, V., Frank, M. C., & Findlay, J. M. (2009). Eye-movements reveal attention to social information in autism spectrum disorder.

Gallay, M., Baudouin, J.-Y., Durand, K., Lemoine, C., & Lecuyer, R. (2006). Qualitative Differences in the Exploration of Upright and Upside-Down Faces in Four-Month-Old Infants: An Eye-Movement Study. *Child Development*, *77*(4), 984-996.

Glichrist, A., & Mckone, E. (2003). Early maturity of face processing in children: Local and relational distinctiveness effects in 7-year-olds. *Visual Cognition, 10*(7), 769-793.

Gower, M. W., Perez, T., Adams, N., & Sheridan, E. H. (2010). *Increasing Facial Recognition Skills in Children with Autism.* Paper presented at the International Meeting for Autism Research, Philadelphia, PA.

Haig, N. D. (1984). The effect of feature displacement on face recognition *Perception, 13*(5), 505-512.

Hernandez, N., Metzger, A., Magné, R., Bonnet-Brilhault, F., Roux, S., Barthelemy, C., et al. (2009). Exploration of core features of a human face by healthy and autistic adults analyzed by visual scanning. *Neuropsychologia, 47*(4), 1004-1012.

Hobson, R. P., Ouston, J., & Lee, A. (1988). What's in a face? The case of autism. *British Journal of Psychology, 79*(4), 441-453.

Hopkins, I. M. (2007). Demonstration and evaluation of avatar assistant: Encouraging social development in children with autism spectrum disorders. *Dissertation Abstracts International: Section B: The Sciences and Engineering, 68*(5-B), 3424.

Howard, M. A., Cowell, P. E., Boucher, J., Broks, P., Mayes, A., Farrant, A., et al. (2000). Convergent neuroanatomical and behavioural evidence of an amygdala hypothesis of autism. *Neuroreport, 11*(13), 2931-2935.

Humphreys, K. (2003). *The development of face-space: An exploration.* Unpublished doctoral dissertation, University of London, London, England.

Humphreys, K., Minshew, N. J., Leonard, G. L., & Behrmann, M. (2007). A fine-grained analysis of facial expression processing in high-functioning adults with autism. *Neuropsychologia, 45*(4), 685-695.

Hunnius, S., & Geuze, R. H. (2004). Developmental Changes in Visual Scanning of dynamic faces and abstract stimuli in infants: A longitudinal study. *Infancy, 6*(2), 231-255.

Janik, S. W., Wellens, A. R., Goldberg, M. L., & Dell'Osso, L. F. (1978). Eyes as the center of focus in the visual examination of human faces. *Perceptual and Motor Skills, 47*(3), 857-858.

Johnston, R. A., & Ellis, H. D. (1995). Age effects in the processing of typical and distinctive faces. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology 48A*(2), 447-465.

Joseph, & Tanaka. (2003). Holistic and part-based face recognition in children with autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 44*, 529-542.

Kirchner, J. C., Hatri, A., Heekeren, H. R., & Dziobek, I. (2010). Autistic Symptomatology, Face Processing Abilities, and Eye Fixation Patterns. *Journal of Autism and Developmental Disorders*.

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry, 59*(9), 809-816.

Klin, A., Sparrow, S. S., de Bildt, A., Cicchetti, D. V., Cohen, D. J., & Volkmar, F. R. (1999). A normed study of face recognition in autism and related disorders. *Journal of Autism and Developmental Disorders, 29*(6), 499-508.

Lahaie, A., Mottron, L., Arguin, M., Berthiaume, C., Jemel, B., & Saumier, D. (2006). Face perception in high-functioning autistic adults: Evidence for superior processing of face parts, not for a configural face-processing deficit. *Neuropsychology 20*(1), 30-41.

Langdell, T. (1978). Recognition of faces: An approach to the study of autism. *Journal of Child Psychology and Psychiatry, 19*(3), 255-268.

Leo, I. (2006). Visual preference for faces: A comparison between children and adults. *Giornale Italiano di Psicologia*, *33*(1), 199-206.

Light, L. L., Kayra-stuart, F., & Hollander, S. (1979). Recognition memory for typical and unusual faces. *Journal of Experimental Psychology: Human Learning and Memory, 5*, 212-228.

Lopez, B., Donnelly, N., Hadwin, J. A., & Leekam, S. R. (2004). Face processing in high-functioning adolescents with autism: Evidence for weak central coherence. *Visual Cognition, 11*(6), 673 - 688.

Lord, C., Rutter, M., DiLavore, P. C., & Risi, S. (2003). *Autism Diagnostic Observation Schedule (ADOS)*. Los Angeles, CA: Western Psychological Services.

Luria, S. M., & Strauss, M. S. (1978). Comparison of eye movements over faces in photographic positives and negatives. *Perception 7*(3), 349-358.

Marcus, D. J., & Nelson, C. A. (2001). Neural bases and development of face recognition in autism. *CNS Spectrums*, *6*(1), 36-59.

Mauer, D. (1985). Infants' perception of facedness. In T. N. Field & N. Fox (Eds.), *Social Perception in Infants*. Norwood, NJ: Ablex.

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. [Review]. *Trends in Cognitive Sciences, 6*(6), 255-260.

McKone, E., & Boyer, B. L. (2006). Sensitivity of 4-year-olds to featural and second-order relational changes in face distinctiveness. *Journal of Experimental Child Psychology*, *94*(2), 134-162.

Merin, N., Young, G., Ozonoff, S., & Rogers, S. (2007). Visual fixation patterns during reciprocal social interaction distinguish a subgroup of 6-month-old infants At-risk for autism from comparison infants. *Journal of Autism and Developmental Disorders, 37*(1), 108-121.

Minear, M., & Park, D. C. (2004). A lifespan database of adult facial stimuli. *Behavior Research Methods, Instruments, & Computers, 36*(4), 630-633.

Mondloch, Dobson, K. S., Parsons, J., & Maurer, D. (2004). Why 8-year-olds cannot tell the difference between Steve Martin and Paul Newman: Factors contributing to the slow development of sensitivity to the spacing of facial features. *Journal of Experimental Child Psychology, 89*(2), 159-181.

Mondloch, Le Grand, R., & Maurer, D. (2002). Configural face processing develops more slowly than featural face processing. *Perception, 31*, 553-566.

Mondloch, Lewis, T. L., Budreau, D. R., Maurer, D., Dannemiller, J. L., Stephens, B. R., et al. (1999). Face perception during early infancy. *Psychological Science, 10*(5), 419-422.

Mondloch, Maurer, D., & Ahola, S. (2006). Becoming a Face Expert. *Psychological Science, 17*(11), 930-934.

Mondloch, Pathman, T., Maurer, D., Le Grand, R., & de Schonen, S. (2007). The composite face effect in six-year children: Evidence of adult-like holistic face processing. *Visual Cognition, 15*(5), 564-577.

Morton, J. (1993). Mechanisms in infant face processing. In B. d. Boysson-Bardies (Ed.), *Developmental neurocognition: Speech and face processing in the first year of life* (pp. 93-102). Norwell, MA: Kluwer Academic Publishers.

Morton, J., & Johnson, M. H. (1991). Conspec and conlearn: A two process theory of infant face recognition. *Psychological Review, 98*, 164-181.

Mottron, L., Dawson, M., Soulieres, I., Hubert, B., & Burack, J. (2006). Enhanced Perceptual Functioning in Autism: An Update, and Eight Principles of Autistic Perception. *Journal of Autism and Developmental Disorders, 36*(1), 27-43.

Neumann, D., Spezio, M. L., Piven, J., & Adolphs, R. (2006). Looking you in the mouth: abnormal gaze in autism resulting from impaired top-down modulation of visual attention. *Social Cognitive and Affective Neuroscience, 1*(3), 194-202.

Newell, Best, C. A., Gastgeb, H., Rump, K. M., & Strauss, M. S. (in press). The development of categorization and facial knowledge: Implications for the study of autism. In L. M. Oakes, C. H. Cashon, M. Casasola & D. H. Rakison (Eds.), *Early Perceptual and Cognitive Development*. New York: Oxford Press.

Newell, F. N., Chiroro, P., & Valentine, T. (1999). Recognizing unfamiliar faces: The effects of distinctiveness and view. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology 52A*(2), 509-534.

Norbury, C. F., Brock, J., Cragg, L., Einav, S., Griffiths, H., & Nelson, K. (2009). Eye-movement patterns are associated with communicative competence in autistic spectrum disorders. *Journal of Child Psychology and Psychiatry, 50*, 834-842.

Pellicano, E., Rhodes, G., & Peters, M. (2006). Are preschoolers sensitive to configural information in faces? *Developmental Science, 9*(3), 270-277.

Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B. D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders, 32*(4), 249-261.

Perlman, S. B., Hudac, C. M., Pegors, T., Minshew, N. J., & Pelphrey, K. A. (2010). Experimental manipulation of face-evoked activity in the fusiform gyrus of individuals with autism. *Social Neuroscience*, 1747-1927.

Rakover, S. S. (2002). Featural vs configurational information in faces: A conceptual and empirical analysis. *British Journal of Psychology*, *93*(1), 1-30.

Rakover, S. S., & Cahlon, B. (2001). *Face Recognition: Cognitive and computational processes*. Philadelphia: John Benjamins

Riby, D. M., Doherty-Sneddon, G., & Bruce, V. (2009). The eyes or the mouth? Feature salience and unfamiliar face processing in Williams syndrome and autism. *The Quarterly Journal of Experimental Psychology*, *62*(1), 189-203.

Rouse, H., Donnelly, N., Hadwin, J. A., & Brown, T. (2004). Do children with autism perceive second-order relational features? The case of the Thatcher illusion. *Journal of Child Psychology & Psychiatry*, *45*(7), 1246-1257.

Rump, K. M., Giovannelli, J. L., Minshew, N. J., & Strauss, M. S. (2009). The Development of Emotion Recognition in Individuals With Autism. *Child Development, 80*(5), 1434-1447.

Rutherford, M. D., Clements, K. A., & Sekuler, A. B. (2007). Differences in discrimination of eye and mouth displacement in autism spectrum disorders. *Vision Research, 47*(15), 2099-2110.

Rutter, M., LeCouteur, A., & Lord, C. (2003). *Autism Diagnostic Interview, Revised (ADI-R)*. Los Angeles, CA Western Psychological Services.

Sasson, N. J. (2006). The Development of Face Processing in Autism. *Journal of Autism and Developmental Disorders, 36*(3), 381-394.

Schwarzer, G. (2002). Processing of facial and non-facial visual stimuli in 2-5-year-old children. *Infant and Child Development*, *11*(3), 253-269.

Serra, M., Althaus, M., de Sonneville, L. M. J., Stant, A. D., Jackson, A. E., & Minderaa, R. B. (2003). Face Recognition in Children with a Pervasive Developmental Disorder Not Otherwise Specified. *Journal of Autism and Developmental Disorders, 33*(3), 303-317.

Shepherd, J. W., Gibling, F., & Ellis, H. (1991). The effects of distinctiveness, presentation time and delay on face recognition. *European Journal of Cognitive Psychology 3*(1), 137-145.

Simion, F., Cassia, V. M., Turati, C., & Valenza, E. (2001). The Origins of Face Perception: Specific Versus Non-specifi Mechanisms. *Infant and Child Development, 10*, 59-65.

Spezio, M. L., Adolphs, R., Hurley, R. S. E., & Piven, J. (2007). Analysis of face gaze in autism using "Bubbles". *Neuropsychologia, 45*, 144-151.

Tantam, D., Monaghan, L., Nicholson, H., & Stirling, J. (1989). Autistic children's ability to interpret faces: A research note. *Journal of Child Psychology and Psychiatry, 30*(4), 623-630.

Thompson, P. (1980). Margaret Thatcher: A new illusion. *Perception*, *9*(4), 483-484.

Trepagnier, C., Sebrechts, M. M., & Peterson, R. (2002). Atypical face gaze in autism *CyberPsychology & Behavior, 53*(3), 213-217.

Valentine, T. (1988). Upside-down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology 79*(4), 471-491.

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology 43A*(2), 161-204.

Valentine, T., & Bruce, V. (1986a). The effects of distinctiveness in recognising and classifying faces. *Perception 15*(5), 525-535.

Valentine, T., & Bruce, V. (1986b). Recognizing familiar faces: The role of distinctiveness and familiarity. *Canadian Journal of Psychology, 40*(3), 300-305.

Valentine, T., & Endo, M. (1992). Towards an exemplar model of face processing: The effects of race and distinctiveness. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology 44A*(4), 671-703.

Valenza, E., Simion, F., Cassia, V. M., & Umilta, C. (1996). Face preference at birth. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 892-903.

van der Geest, J. N., Kemner, C., Verbaten, M. N., & van Engeland, H. (2002). Gaze behavior of children with pervasive developmental disorder toward human faces: A fixation time study. *Journal of Child Psychology and Psychiatry, 43*(5), 669-678.

Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence (WASI).* San Antonio: The Psychological Corporation.

Weissman, M. M., Wickramaratne, P., Adams, P., Wolk, Verdeli, & Olfson. (2000). *Brief screening for family psychiatric history*. *Archives of General Psychiatry 57*, 675-682.

Wilcox, B. M. (1969). Visual preferences of human infants for representations of the human face. *Journal of Experimental Child Psychology, 7,* 10-20.

Wilkinson, G. S., & Robertson, G. J. (2006). *Wide Range Achievement Test, 4th Edition (WRAT4).* Lutz, FL: Psychological Assessment Resources.

Yin, R. K. (1969). Looking at upide-down faces. *Journal of Experimental Psychology: General July, 81*(1), 141-145.