FACE PROCESSING IN ADULTS WITH AUTISM SPECTRUM DISORDERS

CLARIFYING THE NATURE OF FACE PROCESSING DEFICITS IN ADULTS WITH AUTISM SPECTRUM DISORDERS

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Abstract

Individuals with autism spectrum disorder (ASD) have difficulties in many areas of social cognition including face perception. Decades of research examining face processing abilities in ASD populations have yielded equivocal results. The current thesis includes a series of experiments intended to clarify the nature of the face processing deficits seen in ASD**.** In Study 1 I examined norm-based coding of facial identity in adults with ASD. I measured identity aftereffects in adults with and without ASD and found no significant group differences. In Study 2 I examined simple (Experiment 1) and opposing (Experiment 2) figural aftereffects for male and female faces and found no significant group differences as adults with ASD. In Study 3 I examined perceptual strategies employed by adults with ASD when processing emotional facial expressions and found that adults with ASD employ a rule-based strategy. Finally, in Study 4 I examined what drives face processing deficits in adults with ASD; deficits in processing emotional information in faces or a deficit in processing socially complex information in faces. I found that adults with ASD had a deficit in discriminating basic and complex emotional facial expressions, suggesting that emotion-perception demands are associated with poor face processing in ASD. The results of the studies demonstrate that adult with ASD show typical perceptual mechanisms underlying face perception, use an atypical perceptual strategies when processing facial expressions, and have a specific deficit in processing emotional expressions.

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List of all Abbreviations and Symbols

°: Degree, unit of measurement of angles.

Φ: phi coefficient; a measure of the degree of association between two binary variables.

α: the probability of rejecting the null hypothesis when the null hypothesis is true.

η_p^2: Partial eta squared is a measure of effect size. Larger η_p^2 values indicate larger effect sizes.

ADOS-G: Autism Diagnostic Observation Schedule-Generic. Standardized psychometric tool commonly used in the clinical diagnosis of autism spectrum disorder.

ANOVA: Analysis of variance. Common statistical tests used to examine the differences across multiple group means.

ASD: Autism Spectrum Disorders. Individuals with ASD have deficits in social communication and interactions and have restricted and or stereotyped interests and behaviours.

cm: centimeter, a unit of distance or length.

***d*:** Cohen's d is a measure of effect size. Values that are closer to 1 indicate a larger effect.

***F*:** the F statistic of the F-test which evaluates differences between multiple group means.

Hz: hertz, a unit of frequency.

IQ: intelligent quotient. A numerical indication of one's cognitive abilities calculated by performance on standardized cognitive psychometric tests.

ISI: inter stimulus interval. The amount of time between the ending of the presentation of one stimulus and the beginning of the subsequent stimulus.

ITI: inter trial interval. The amount of time between the ending of one trial and the beginning of the subsequent trial.

M: mean, the average of a group of observations.

ms: milleseconds, a unit of time.

ns: not significant, usually represents p-values that's are greater that .05

p: p-value; in statistical test, the p-value represents the probability of obtaining a test statistic value that is equal to or greater then the observed value, when the null hypothesis is true.

R^2: coefficient of determination, a value that indicates how well a set of data fits with a model.

SD: standard deviation; a measure of the amount of variation from average.

SE: standard error; an estimate of the standard deviation of a specific sample.

t: the t-test statistic which is used to examine the difference between two group means.

Declaration of Academic Achievement

For Study 1, I collected and analyzed the data with the assistance of Mark Vida (graduate student). I prepared the manuscript for publication and made revisions based on the comments of my supervisor, Mel Rutherford, and my collaborators on the project Daphne Maurer (Professor, McMaster University), Gillian Rhodes (Professor, University of Western Australia), and Linda Jeffery (Professor, University of Western Australia). For Study 2 I designed the experiments with assistance from my supervisor Mel Rutherford. Mark Vida programed the experiments and I collected and analyzed the data with the assistance of Yenushka Karu (undergraduate thesis student). I prepared the manuscript for publication with the assistance of my supervisor Mel Rutherford. For Study 3 I designed the experiment with my supervisor Mel Rutherford. Mark Vida programed the experiment and I collected and analyzed the data. I wrote the paper and revised it based on comments from my supervisor Mel Rutherford. For Study 4 I designed the experiment with my supervisor Mel Rutherford. Sarah Creighton (graduate student) programed the experiment. I collected and analyzed the data with the assistance of Tatjana Popovic (undergraduate thesis student). I prepared the manuscript for publication with the assistance of my supervisor Mel Rutherford. Therefore, I was the primary contributor to all of the studies included in this thesis.

Chapter 1 – Introduction

Faces are one of the most important categories of social stimuli in our natural environment. Recognizing individuals across multiple contexts based on their facial features is a fundamental social cognitive skill. The ability to encode and interpret the meaning of a person's facial expressions is crucial for successful social interactions. Many aspects of face perception are shaped by our experiences with faces. Deficits in face perception have the potential for serious negative impacts on one's social functioning. Autism spectrum disorder (ASD) is a developmental disorder in which individuals have deficits in many aspects of social interaction and cognition, including face perception. There is a large literature devoted to understanding the specific differences in how individuals with ASD process faces, however many questions remain. Do individuals with ASD have a global face processing deficit, or is it limited to certain face perception tasks? Do individuals with ASD process faces in a different manner than typical individuals, or are they just less efficient? What drives the deficit in face processing in autism – is it a deficit in processing facial information specifically, or is it deficits in processing complex social stimuli? The objective of this thesis is to examine these questions and attempt to provide some clarification to the current literature on face perception in ASD. A clear understanding of deficits in face perception in ASD is vital for understanding one of the main behavioural manifestations of the disorder.

What is autism spectrum disorder?

Autism spectrum disorder (ASD) is a pervasive developmental disorder in which individuals display impairments in two core areas 1) social communication and interactions, and 2) repetitive and restrictive behaviours and interests. Individuals with ASD may or may not also have intellectual disabilities as well as language delays (American Psychiatric Association, 2013). In North America, the incidence rate of ASD is 1 in every 68 children and 1 in 42 boys (Baio, 2014). Autism is the second most frequently occurring developmental disorder after mental retardation (Newschaffer, et al., 2007). While early signs of autism specific deficits have been noted in the first year of development retrospectively (Baranek, 1999; Maestro et al., 2005; Osterling & Dawson, 1994; Osterling, Dawson, & Munson, 2002), many individuals are not formally diagnosed until around 3-years-of-age (Hertz-Picciotto & Delwiche, 2009; Mandell, Novak, & Zubritsky, 2005; Werner, Dawson, Osterling, & Dinno, 2000). There are no known biological or neurological markers of ASD and clinical diagnosis is done exclusively through behavioural observations, typically involving the use of the Autism Diagnostic Observation Schedule (ADOS) (Lord et al., 2003; Luyster et al., 2009; Gotham, Risi, Pickles, & Lord, 2007) or Autism Diagnostic Interview (ADI) (Lord, Rutter, & Le Couteur, 1994). There is currently no clear understanding of the cause of autism, although many believe it to be a combination of environmental and genetic components (for reviews see Fombonne, 1999; Newschaffer, et al., 2007). With the alarming increase in incidence of ASD over the past few decades (Baio, 2014), it is imperative for researchers to continue to focus on increasing our understanding of the not only the potential causes of the disorder, but to improve our understanding of the behavioural manifestations of ASD in order to improve diagnostic techniques which currently rely entirely on behavioural observations.

Social deficits in individuals with ASD

Social deficits in individuals with ASD vary in severity and may include difficulties initiating and maintaining conversations or social interactions, difficulty interpreting nonverbal communication, abnormal body language or eye contact, abnormal affect, or difficulty interpreting and expressing emotions (American Psychiatric Association, 2013). Dawson and colleagues (1998) proposed that a key deficit in individuals with autism is a *social orientating impairment,* or the failure to attend to and lack of interest in social stimuli in the environment. Furthermore, one study found that atypical joint attention and social orienting were the best predictors of autism diagnosis in a group of 3-5-year-old children (Dawson et al., 2004). Zwaigenbaum and colleagues (2005) demonstrated that as early as 12 months, children developing with autism show a measureable lack of interest in social stimuli and respond atypically to social events, such as shifting their attention when their name is called or making eye contact with others.

The ability to process and understand social information available in faces is arguably one of the most important social abilities for human social interaction. This is because faces are a rich source of social information. Faces convey important socially relevant information about an individual such as their gender, group membership, age, and their internal emotional state. The abilities of individuals with ASD to process facial information have been an area of intense focus in psychological research (for reviews see Dawson, Webb, & McPartland, 2005; Jemel, Mottron, & Dawson, 2006; Harms, Martin & Wallace, 2010; Sasson, 2006; Weigelt, Koldewyn, & Kanwisher, 2012) because individuals with ASD have been demonstrated to show less interest and fail to orient to social stimuli in the natural environment, including people and faces, from early in development (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998). Because several aspects of face processing are shaped by experience with faces (e.g., Mondloch, Le Grand, & Maurer, 2003) studying face perception in the ASD population allows researchers to examine which aspects of face perception are most affected by atypical social cognitive development and potential atypical developmental experience with faces. In addition, social deficits that are characteristic of ASD have been argued to be some of the most prevalent and distressing deficits for individuals with ASD and their caregivers, (Volkmar, Sparrow, Goudreau, Cicchetti, Paul, Cohen, 1987; Wing & Gould, 1979). Thus, understanding abnormalities in face perception in individuals with ASD helps us understand the one aspect of a primary deficit in ASD.

Face perception development in typical individuals

Faces are an extremely important class of visual stimuli and humans have a preference for faces or face-like stimuli from birth (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991; Valenza, Simion, Cassia, & Umiltà, 1996). Newborns are able to discriminate their mother's face from a stranger's face (e.g, Bushneil, Sai, & Mullin, 1989; Field, Cohen, Garcia, & Greenberg, 1984; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995; Walton, Bower, & Bower, 1992). Several perceptual skills related to processing facial identity (e.g., processing of configural or spacing information in faces) continue to gradually develop throughout early childhood (Mondloch, Le Grand, Maurer, 2002; Mondloch, Geldart, Maurer, & Grand, 2003) and facial identity recognition abilities improve dramatically throughout early childhood and into adolescence (e.g., Blaney, Winograd, 1978; Carey, Diamond, & Woods, 1980; Flin, 1980).

There are several behavioural phenomena that have been proposed to demonstrate typical individuals' perceptual expertise with upright human faces. The composite face effect is the finding that individuals have more difficulty discriminating individual features of two faces when the top and bottom halves of the faces are aligned compared to when they are misaligned (e.g., Hole, 1994; Le Grand, Mondloch, Maurer, & Brent, 2004; Young, Hellawell, D., & Hay, 1987). The composite face effect demonstrates that typical individuals process faces as a whole rather than a collection of individual features, and this holistic representation makes it difficult to process faces in a feature by feature manner, however misaligning the top and bottom halves of the face disrupts holistic processing and allows easier individual feature comparison. The composite face effect has been demonstrated with the traditional experimental paradigm in children as young as four-years-of-age (de Heering, Houthuys, & Rossion, 2007) suggesting the holistic processing of faces develops early in childhood.

The face inversion effect (Yin, 1969) is the finding that inversion has a much larger impact on accuracy for discriminating faces than for other classes of visual objects (see Valentine (1988) for review). Face inversion disrupts configural and holistic processing of faces which typical individuals rely on for processing faces (e.g., Freire, Lee, & Symons, 2000) more so than other classes of objects. The classic face inversion effect has been demonstrated in children as young as 7-years of age (Flin, 1985), however under certain testing conditions, researchers have demonstrated evidence of emerging face inversion effects in young infants (Turati, Sangrigoli, Ruely, & Schonen, 2004).

The whole-parts effect is the demonstration that typical individuals show better accuracy in discriminating and recognizing features of individual faces (e.g., that is Jim's mouth vs. John's mouth) when they are presented in the context of an intact whole face compared to when they presented in isolation. The whole-part effect has been demonstrated in children as young as 6-years-of age (Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998) providing further support that holistic processing of faces develops in early childhood. In summary, there is a large body of evidence that suggests that typical individuals are specialized at processing upright human faces, which they do so in a holistic rather than piecemeal manner, and that this holistic style of processing faces develops in early childhood.

Faces are thought to be represented as individual points in a multidimensional "face-space" in which the physical features in which faces differ (e.g., spacing between the eyes) are represented as individual dimensions (Valentine, 1991). At the centre of this face space is a representation of the average face, or prototype, which is based on our own unique experience with faces. Individual faces are thought to be encoded and represented relative to this norm (e.g., Leopold, O'Toole, Vetter, & Blanz, 2001; Rhodes, Brennan, & Carey, 1987; Rhodes & Jeffery, 2006), with more average looking faces clustering around the prototypical centre and more distinctive faces more distant from the centre. Faces that are far from the average are perceived as less attractive (e.g., Rhodes, & Tremewan, 1996) and are more easily recognized (Lee, Byatt, & Rhodes, 2000; Rhodes, Brennan, & Carey, 1987). Implicit comparison of individual faces to the prototype and implicit evaluation of how much they differ from the prototype is thought to aid facial identification (Rhodes & Leopold, 2011; Webster & McLeod, 2011). This model of face perception is known as norm-based coding and has been proposed as a model for how typical individuals are able to so accurately and efficiently distinguish faces with only subtle physical variations (Rhodes, Robbins, Jaquet, McKone, Jeffery, & Clifford, 2005).

Facial aftereffects, or face adaptation, are considered to be supportive evidence of the norm-based coding model of face perception. Face aftereffects are similar to other forms of visual adaptation in that extended exposure to a specific face, or set of faces, influences perception of subsequently viewed faces (see Webster & McLeod, 2011 for review). Adaptation to a specific face or set of faces is thought to create adaptation, or fatigue in the underlying neural coding mechanism, which creates a temporary shift in the representation of the norm or prototype and therefor biases perception of other individual faces. For example, prolonged exposure to one category of faces (e.g., male faces) leads to the perception of category-ambiguous stimuli as the opposite category (e.g. female) (Webster, Kaping, Mizokami, & Duhamel, 2004). Face aftereffects have been demonstrated for several categories of faces and facial features including emotional facial expression (e.g., Rutherford, Chattha, & Krysko, 2008; Skinner & Benton, 2010; Butler, Oruc, Fox, & Barton, 2008), facial attractiveness (e.g., Rhodes et al., 2003), race (Jaquet, Rhodes, & Hayward, 2007; Jaquet, Rhodes, & Hayward, 2008; Little, DeBruine, Jones, & Waitt, 2008), age (Lai, Oruç, & Barton, 2012; Little, DeBruine, Jones, & Waitt, 2008), gender (Bestelmeyer et al., 2008; Jaquet & Rhodes, 2008; Little, DeBruine, Jones, 2005) and facial identity (e.g., Rhodes & Jeffery, 2006; Leopold, O'Toole, Vetter, & Blanz, 2001). Facial identity aftereffects have been demonstrated in children as young as four-years of age (Jeffery et al., 2010) demonstrating that norm-based coding develops early in childhood. The facial aftereffects paradigm is a useful tool for examining the underlying perceptual coding mechanisms which facilitate face perception, and for examining how different categories of faces are represented in relation to one another.

Emotional facial expression processing in typical individuals

Interpreting facial expressions in an efficient and accurate manner is essential for successful social interactions. Other's facial expressions depict important information about their current internal emotional state and allow us to make decisions about how we will approach and interact with them. Classic research by Ekman and his various colleagues (e.g., Ekman, Friesen, 1971; Ekman, Friesen, & Ellsworth, 1972; Ekman, Sorenson, & Friesen, 1969) have identified six "basic" emotions which are most easily and reliably recognized and produced cross-culturally; happy, sad, fearful, disgust, anger, and surprise. These emotional expressions are perceived categorically, which is thought to allow fast and efficient encoding and interpretation (Etcoff & McGee, 1992). Many studies have investigated young infants' ability to discriminate basic emotions and have found that this ability develops gradually over in the first and second year of life (see de Haan, & Nelson (1998) and Nelson (1987) for reviews). Developmental research suggests that categorical perception of facial expressions develops in early childhood (Cheal &Rutherford, 2011) and possibly begins to develop during infancy (Kotsoni, de Haan, & Johnson, 2001) and that children's ability to correctly recognize and label facial expressions improves with age (e.g., Odomd & Lemond, 1972; Camras & Allison, 1985;

Tremblay, Kirouac, & Dore, 1987). Some of the basic emotions (e.g., happy and sad) are more easily recognized than others (e.g., disgust) by both adults (see Russell (1994) for review) and children (Camras & Allison, 1985). Rutherford, Chattha, & Krysko (2008) measured emotional facial expression aftereffects to explore the psychological relationships among the six basic emotions; they reported that happy was the psychological opposite of all negative basic emotions, while sad opposed happy.

Several studies have examined the role of experience in the development of facial expression discrimination abilities. For example, Pollak and Sinha (2002) reported that children who experienced physical abuse from their caregivers (and therefore presumed to have atypical experience with negative facial expressions) were much more sensitive and able to accurately identify angry facial expressions with much less visual information of the facial expressions compared to typical controls. Similarly, Pollak, Cicchetti, Hornung, & Reed (2000) reported that children who experienced significant neglect showed a response bias for sad expressions and a general difficulty for discriminating facial expression compared to controls. Together these results suggest that experiences in the natural environment with various facial expressions influences perception of facial expressions and that atypical experiences may lead to deficits in facial expression discrimination.

Attention and neural response to faces in individuals with ASD

Individuals with ASD have been demonstrated to show atypical scan path patterns of faces and bodies when viewing complex social scenes in comparison to age matched controls. Klin, Jones, Schultz, Volkmar, & Cohen (2002) found that adolescent males with ASD attend less to the eyes regions of faces and focus more on the mouth region of the face, bodies as well as inanimate objects compared to matched controls when viewing complex social scenes. Speer, Cook, McMahon, and Clark (2007) extended these findings and reported that adolescents with ASD do not show these scan path differences when viewing static complex social scenes, static images of individuals, or dynamic scenes of isolated individuals. Together, these results suggest that children and young adolescents with ASD show a typical pattern of attending to faces and social stimuli when viewing dynamic socially complex stimuli.

Typical individuals show distinct patterns of brain activity in response to upright human faces in comparison to other categories of objects. The N170 an early occurring negative event-related potential (ERP) component that has been robustly demonstrated to elicit shorter latency and larger amplitude in response to upright human faces compared to other objects (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Eimer, 2000a; see Rossion & Jacques (2011) or Eimer (2011) for reviews). The N170 is considered by some to be a marker of face expertise because as with other behavioural markers of face expertise, typical individuals show different N170 responses to inverted faces compared to upright faces, suggesting specialized processing of upright faces (e.g., Eimer, 2000b). McPartland, Dawson, Webb, Panagiotides, and Carver (2004) demonstrated that adolescents and adults with ASD show longer latencies to upright faces compared to typical controls and also did not show differences in response to inverted faces as typical controls did. Interestingly, the N170 latency was related to performance on a facial identity recognition task for the ASD participants. Hileman, Henderson, Mundy, Newell, and Jaime (2011) found a similar pattern of results with children and adolescents with ASD. McPartland and colleagues (2011) also demonstrated a lack of inversion effect on the N170 in children with ASD as well as reduced right hemisphere localization, which was reliably demonstrated in the control group for faces.

The fusiform face area (FFA) is part of the fusiform gyrus area of the occipital and temporal lobes which has been demonstrated to show increased activation in response to faces in comparison to other objects in typical individuals (see Kanwisher & Yovel (2006) for review). Pierce, Müller, Ambrose, Allen, and Courchesne (2001) reported that while adults with ASD were as accurate as controls on a face perception task, they should little or no activated of the typical brain areas typically activated during face perception tasks (e.g., FFA, superior temporal sulcus, amygdala). The authors noted that every participant with ASD showed maximal activation in areas outside of those which are maximally activate in response to faces in typical individuals. Hadjikhani, Joseph, Snyder, and Tager-Flusberg (2007) found similar results of activation outside the typical face selective areas in individuals with ASD. Schultz et al. (2000) demonstrated that individuals with ASD showed brain responses that were characteristic of typical object perception, or feature-based perceptual strategies, when viewing faces. These results suggest that while individuals with ASD are able to perform face perception tasks as accurate as matched controls, they appear to be doing so with a completely different neural circuitry than that of typical individuals.

Facial identity processing abilities in ASD

The ability to discriminate faces of various individuals and to recognize an individual across multiple contexts on the basis of facial features (i.e., facial identity recognition) are essential skills for successful social interactions. Many studies have investigated the behavioral markers of typical facial identity recognition expertise (outlined in a previous section) in ASD populations. The face inversion effect is one of the most widely excepted hallmark of typical face perception and has been measured directly in ASD populations in several studies which have reported typical patterns of worse performance with inverted faces in children (Scherf, Behrmann, Minshew, & Luna 2008) and adults with ASD (Hobson, Ouston, & Lee, 1988; Lahaie, Mottron, Arguin, Berthiaume, Jemel, & Saumier 2006; Scherf, Behrmann, Minshew, & Luna 2008). The whole-part effect is another marker of typical facial identity perception and has been demonstrated to be present in children (Jospeh & Tanaka, 2002; Lopez, Donelly, Hadwin, & Leekam, 2004; Wolf et al., 2008) and adults with ASD (Faja, Webb, Merkle, Aylward, & Dawson, 2009). Nishimura, Rutherford, and Maurer (2008) examined the composite face effect, another marker of typical face perception, in adults with ASD who demonstrated typical patterns of performance for aligned versus misaligned faces. Together, the results of studies examining behavioural hallmarks of typical face perception suggest that individuals with ASD do not process faces in a completely different manner compared to typical individuals, as they show evidence of several markers of perceptual expertise with faces.

Several studies have investigated children developing with ASD's ability to discriminate and remember facial identities. Studies investigating children and adolescents with ASD's ability to encode a set of faces and then preform a delayed old vs.

new recognition task have demonstrated that individuals with ASD have a marked deficit in their memory for recently learned faces (Boucher & Lewis, 1992; de Gelder et al., 1991; Hauck, et al., 1998; McPartland, Webb, Keehn, &Dawson, 2011) as well as familiar face, for example faces of one's teachers (Boucher, Lewis, & Collis, 1998). Interestingly, several studies have also tested children and adolescents with ASD's memory for non-face stimuli, such as visual patterns or buildings and houses, have found that deficits in memory in ASD participants are specific to faces, as there were no group differs in memory performance for non-face stimuli (Boucher et al., 1998; Hauck et al., 1998; McPartland et al., 2011).

Experiments looking at perception of faces rather than memory or faces have yielded mixed results. Behrmann and colleagues (2006) reported that while adults with ASD had much slower reaction times, they performed as accurately as matched controls on a same different facial identity task. Several studies that have measured individuals with ASD's performance on facial identity match-to-sample tasks (with no memory demand) have reported no significant group differences between individuals with ASD and matched controls suggesting that ASD participants do not have a deficit in simple face perception (Boucher & Lewis, 1992, Hauck, Fein, Maltby, Waterhouse, & Feinstein, 1998; Derulle, Rondon, Gepner, & Tardif, 2004). In contrast, Wolf and colleagues (2008) reported significantly worse performance of children with ASD on several match-to sample tasks compared to typical children. Similarly, Riby, Doherty-Sneddon, and Bruce (2009) reported significant deficits in children with ASD's performance on a match-to-sample task with upper and lower halves of faces. One study tested the same participant groups on facial identity perception tasks with and without memory demands. Gepner, deGelder, deSchonen (1996) reported no significant differences in performance on a face identity sorting task (which had no memory demand), however the same group of children with ASD performed worse compared to typical children on a delayed match to sample face identity task. Thus, while comparison across studies examining simple facial identity perception in individuals with ASD have reported conflicting results, the results from Gepner and colleagues which directly compared performance on a facial identity perception task with memory demands and one without support the notion that individuals with ASD have specific deficits in face memory rather than a global deficit in the perception and processing of facial information.

Emotional facial expression processing in individuals with ASD

As previously mentioned, facial expressions are an incredibly important source of social information that facilitate non-verbal communication and social interaction. There is a large literature of studies which have focused on assessing individuals with ASD's ability to process emotional facial expressions (see Harms, Martin, & Wallace (2010) for review). While some studies that have investigated performance on matching tasks (e.g., matching facial expressions to social context, matching expressions across identities) have reported deficits in ASD populations (e.g., Davies, Bishop, Manstead, & Tantam, 1994; Feldman, McGee, Mann, & Strain, 1993; Gross, 2008; Hobson, 1986; MacDonald et al., 1989; Ozonoff, Pennington, & Rogers 1990; Riby, Doherty-Sneddon, & Bruce, 2008; Rump, Giovannelli, Minshew, & Strauss, 2009; Tardif, Laine, Rodriguez, & Gepner, 2007), others have reported typical performance by ASD participants (Gepner, Deruelle, & Grynfeltt, 2001; Prior, Dahlstrom, & Squires, 1990).

Studies that have measured individuals with ASD's ability to accurately label emotional facial expressions have also yielded mixed results. Several studies have reported no group differences in accuracy of labeling facial expressions (Adolphs, Sears, & Piven, 2001; Capps, Yirmiya, & Sigman, 1992; Loveland et al., 1997; Rosset et al., 2008) but other have demonstrated deficits (Baron-Cohen et al., 1997; Celani, Battacchi, & Arcidiacono, 1999; Law Smith, Montagne, Perrett, Gill, & Gallagher, 2010; Riby et al., 2008). In their comprehensive review of emotional expression processing experiments, Harms, Martin, & Wallace (2010) suggested that demographic factors (e.g., age of participants, matching of ASD and typical groups), differences in task demands, or functioning level of ASD participants may account for discrepancies across studies.

What is the nature of face processing deficits in ASD?

Characterizing the exact nature of the face processing deficits in ASD is essential for our understanding of the behavioral manifestations of the disorder, but also to assist in the development of possible effective treatments and interventions. As discussed in previous sections, while there are a large number of studies investigating facial identity and emotional facial expression recognition and discrimination abilities in individuals with ASD, there is not a clear consensus of the underlying cause of face processing deficits in ASD. Weigelt, Koldewyn, and Kanwisher (2012, 2013) have suggested that individuals with ASD do not have a global facial identity processing deficit, rather a specific deficit in face memory. In their review paper, Weigelt and colleagues suggest that the current literature supports the hypothesis that individuals with ASD are less effective at processing facial identity, but not that they process facial identity in a completely different manner than typical individuals. As mentioned in a previous section, norm-based coding is widely accepted as the perceptual mechanism underlying and facilitating face perception and identity recognition. The facial aftereffects paradigm has been used extensively in typical populations to explore the organization of face space, relationships between different facial categories, and to characterize the perceptual mechanisms that facilitate face perception. Interestingly, this paradigm has rarely been used to examine face perception in ASD populations. Therefore, as a further test of whether individuals with ASD process facial information differently than typical people, measuring face aftereffects is a useful tool to examine if individuals with ASD show evidence of norm-based coding, or show evidence of the same perceptual coding mechanisms which underlie typical face perception as well as the organization and relationships among face categories.

Rutherford, Walsh, and Troubridge (2012) measured emotional expression aftereffects in adults with ASD and found that while adults with ASD showed evidence of emotion aftereffects, the pattern of which emotional expression opposed each other was atypical compared to typical participants. Pellicano and colleagues (2007) measured identity aftereffects in children with ASD and found that while children with ASD showed identity aftereffects, the size of the aftereffects were smaller compared to those of typical children. The authors noted that this suggests that while children with ASD show evidence of norm-based coding of facial identity, less adaptation in the ASD group may indicate that they encode facial information less efficiently. Identity aftereffects have yet to be measure in older individuals with ASD, so it is not clear if the results from Pellicano et al. (2007) reflect a developmental delay in typical adaptive coding of facial identity or if this difference is a stable deficit in ASD. Cook, Brewer, Shah, and Bird (2014) reported typical identity and emotional aftereffects in a group of high-functioning adults with ASD. The contrast of these results and those of aftereffects in children with ASD suggest that there may be a developmental delay in norm-based coding in the ASD population, however further studies are needed to confirm this hypothesis. Measuring other types of aftereffects would allow further exploration of the organization of face space in ASD populations as well as further test for evidence of norm-based coding of facial information.

What accounts for the conflicting results across studies of face processing in ASD?

As noted in previous sections, studies investigating the processing of both facial identity and emotional facial expressions in ASD have produced conflicting results. Several studies have reported deficits in children and adults with ASD in these domains, while other studies have reported typical performance (for reviews see Harms, Martin & Wallace, 2010; Sasson, 2006; Weigelt, Koldewyn, & Kanwisher, 2012). An important question that remains unanswered in the current literature is what might account for these discrepancies in results across studies. In their compressive review of studies examining facial identity recognition abilities in individuals with ASD, Weigelt and colleagues (2012) suggested that the available imperial evidence suggests that individuals with ASD have a specific deficit in face memory, rather than a global face processing deficit. The authors suggested that differences in experimental designs (i.e., whether a experimental task involves a significant memory demand or not) may account for the differences in findings across studies. Weigelt, Koldewyn, and Kanwisher (2013) directly tested whether children with ASD have a domain and process specific deficit in facial recognition and found that indeed, children with ASD have a deficit in face memory, but not face perception in general or a global memory deficit as children with ASD showed typical memory of cars and places. Based on the current literature regarding facial identity processing in individuals with ASD, there seems to be adequate evidence to support the hypothesis that individuals with ASD have a specific deficit in memory for facial identity and that this may account for variation in results across experimental designs which vary in face memory demand. It is not clear if this also applies to emotional facial expression processing, or if there may be other possible explanations for discrepancies in results across studies.

In the context of emotional expression processing, one possible explanation for differences in results across studies of face perception in ASD is that that individuals with ASD may use an alternative perceptual strategy to process facial information. As discussed in a previous section, individuals with ASD have been shown to demonstrate brain response patterns to faces that are characteristic of object, or feature-based processing in typical individuals (e.g., Schultz et al., 2000). Several behavioural studies have suggested that individuals with ASD may use a more feature focused strategy during face perception tasks, (e.g., Joseph & Tanaka, 2002; Baron-Cohen, Wheelwright, & Jolliffe, 1997, also see Behrmann, M., Thomas, C., & Humphreys, K. (2006) for review). Rutherford and McIntosh (2007) demonstrated that adults with ASD employ a rule-based feature focused strategy when processing line drawings of facial expressions. This is a different strategy compared to the more automatic prototype matching strategy that typical individuals are thought to use. Schultz and colleagues demonstrated that individuals with ASD's brain response patterns during facial discrimination tasks are similar to typical brain responses to processing visual objects. The authors suggested that this suggests that individuals with ASD use a more feature focused perceptual strategies while processing facial information. It may be that some experimental designs facilitate the use of this alternative strategy used by individuals with ASD, which would result in similar accuracy outcome measures between groups regardless of group differences in perceptual strategies employed to complete the task. Other experimental designs may hinder or make it impossible for individuals with ASD to use this alternative strategy, and therefore may find group differences in performance accuracy. It has yet to be tested directly if individuals with ASD employ a rule-based strategy when processing facial expressions in natural faces, as they appear to do so with schematic drawings of faces. Developing a clear understanding of what may account for such varying results in face processing abilities of individuals with ASD is an important research question that remains open in the current literature.

Summary and current research

Previous studies investigating identity and emotional recognition abilities in individuals with ASD have produced equivocal results some reporting worse performance on facial identity and emotional expression recognition and discrimination tasks, while others report no group differences in performance (for reviews see Weigelt, Koldewyn, &

Kanwisher, 2012; Harms, Martin & Wallace, 2010). In the context of facial identity processing, Weigelt et al. (2013) have suggested that individuals with ASD have a specific deficit in face memory, which may account for the differences among results of studies investigating identity recognition abilities as different experimental designs may or may not include face memory demands. However, there are other possible explanations for the discrepancies in previous results that have yet to be explored. It is unclear what may account for the differences in studies examining emotional facial expression processing.

One possibility is that the development of the perceptual mechanisms underlying typical face perception (e.g., norm-based coding) is atypical in individuals with ASD. In Study 1 I examined norm-based coding of facial identity in adults with ASD and controls. A previous study demonstrated that children with ASD show smaller identity aftereffects suggesting atypical adaptive mechanisms for facial identity (Pellicano, Jeffery, Burr, & Rhodes, 2007), however norm-based coding of facial identity has never been studied with an adult population of individuals with ASD, so it is unclear if these results reflect a delay in the development of typical adaptive coding mechanisms of facial identity or a deficit that remains throughout development. In Study 2 I used a figural aftereffects paradigm to examine facial adaptation and figural aftereffects in adults with ASD. I used a variation of a common figural aftereffects paradigm, which has been used extensively with typical adults and children to study norm-based coding of various face categories, but has never been use with an ASD population. This study was designed to test 1) whether individuals with ASD are sensitive to figural aftereffects and whether this research paradigm could be used with this special population to examine other aspects of norm-based coding and 2) whether adults with ASD show atypical coding of gender information of faces.

Another possible explanation for the discrepancies in results across studies of face processing in ASD is that individuals with ASD may rely on an alternative strategy compared to the one employed by typical individuals to process facial information. Rutherford and McIntosh (2007) demonstrated that adults with ASD employ a rule-based strategy when processing emotional expression information in line drawings of faces, however, this hypothesis has not been tested with natural faces. In Study 3 I extended the findings of Rutherford and McIntosh tested the hypothesis that adults with ASD rely more heavily on a rule-based strategy when processing emotional expression information in natural photographs of faces. Study 3 also added two additional control tasks to Rutherford and McIntosh's original design to further test the hypothesis that the rule-based strategy used by those with ASD to perceive emotional facial expressions is specific to categorizing expressions, and not used in face processing generally.

While some previous studies have attempted to clarify if deficits observed in face processing in individuals with ASD are specific to processing faces, or if they extend to other types of visual stimuli such as cars or 3-D shapes (Weigelt, Koldewyn, Kanwisher, 2013), few studies have examined if individuals with ASD have deficits in processing all types of facial information, or if they are more specific. In Study 4 I designed a battery of face processing tasks which ranged in social cognitive complexity, and also could be categorized as either involving facial expression processing or not. Study 4 was designed to test whether the face processing deficits in ASD are driven by a deficit in processing facial expression information, or a deficit in processing socially complex stimuli.

The experiments included in this thesis were designed to clarify the nature of face processing deficits in adults with ASD. Studies 1 and 2 tested whether adults with ASD show evidence of norm-based coding, which is proposed to be the primary mechanism underlying typical face perception. Study 3 examined whether adults with ASD use a rule-based strategy to process emotional expression as well as non-emotional information in faces. Finally, Study 4 was designed to distinguish whether adults with ASD show deficits in processing emotional expressions, or whether the deficit is in processing complex social stimuli more generally. This series of experiments was designed to test several possible explanations for the discrepancies that exist among studies in the current ASD face processing literature as well as attempt to clarify the nature of face processing deficits in adults with ASD.

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Chapter 2 – Study 1

Walsh, J. A., Maurer, D., Vida, M. D., Rhodes, G., Jeffery, L., & Rutherfod, M. D. Norm-based coding of facial identity in adults with autism spectrum disorder Submitted to *Vision Research* (August 11th, 2014)

The norm-based coding model of face perception has been proposed to explain how typical individuals are able to efficiently and accurately discriminate among hundreds of exemplars of faces that have only small physical differences between one another. Facial aftereffects provide experimental support for adaptive norm-based coding of facial information. Specifically, previous research has demonstrated that the size of identity aftereffects is modulated by the physical difference of the adapting face from the average face; the norm-based coding model predicts this pattern of results. Typical adults and young children show this pattern of results suggesting that adaptive norm-based coding of facial identity develops early in typical individuals. Previous research has demonstrated that children with ASD show evidence of facial adaptation and norm-based coding of facial identity, however they consistently show smaller aftereffects than typical children, which authors suggest indicates inefficient encoding of facial information. It is unclear if diminished facial adaptation is a developmentally stable deficit in ASD, as norm-based coding of facial identity has not been tested in adults with ASD. The current study provided this test by using a variation of a classic face adaptation paradigm. We measured identity aftereffects in both adults with and without ASD after adapting to extreme adapting faces (i.e., ones that were very different from the average face) or less extreme adapting faces (i.e., ones that were slightly different from the average face). The results of this study provide the first evidence of norm-based coding of facial identity in adults with ASD and suggest that there may be a developmental change in the atypical face adaption previously reported in children with ASD.

Abstract

It is unclear whether reported deficits in face processing in individuals with ASD can be explained by deficits in perceptual face coding mechanisms. In the current study, we examined whether adults with ASD showed evidence of norm-based opponent coding of facial identity, a perceptual process underlying the recognition of facial identity in typical adults. We began with an original face and an averaged face and then created an anti-face that differed from the averaged face in the opposite direction from the original face by a small amount (near adaptor) or a large amount (far adaptor). To test for norm-based coding, we adapted participants on different trials to the near versus far adaptor, then asked them to judge the identity of the averaged face. To rule out low-level effects, the test and adapting faces were of a different size. Consistent with the predictions of norm-based coding, high functioning adults with ASD (n = 27) and matched typical participants (n= 28) showed identity aftereffects that were larger for the far than near adaptor. Unlike results with children with ASD, the strength of the aftereffects were similar in the two groups. This is the first study to demonstrate norm-based coding of facial identity in adults with ASD.

Introduction

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder in which affected individuals have measureable anomalies in two key areas: 1) social interactions and communication and 2) restrictive and repetitive interests or behaviours (American Psychiatric Association, 2013). Developing a clear understanding of the behavioural manifestations characteristic of ASD is an important area of scientific research as current diagnosis of ASD relies completely on behavioural observations.

Individuals with ASD have been shown to orient less to social stimuli than their peers from a young age (Dawson et al., 1998; Dawson et al., 2004; Zwaigenbaum et al., 2005). As faces are considered to be one of the most important categories of social stimuli, many studies have examined potential qualitative and quantitative differences in face processing abilities of individuals with ASD (see Sasson, 2006; Harms, Martin, & Wallace, 2010; Weigelt, Koldewyn, & Kanwisher, 2012, for reviews). Few studies have examined the perceptual mechanisms underlying these face processing skills and how they may differ in the ASD population. The goal of the current study was to measure facial identity aftereffects in individuals with ASD in order to examine whether they show evidence of norm-based coding of facial identity. Norm-based coding is thought to underlie typical face perception but has not been examined in adult ASD populations.

Norm-based coding in typical face perception.

The norm-based coding model of face perception suggests that face identification involves implicit evaluation of how an individual face differs from a face prototype (Rhodes & Leopold, 2011; Webster & McLeod, 2011). This model suggests that the prototype face is refined by our experience with faces. Norm-based coding provides a model for how individuals are able to efficiently distinguish individual faces that subtly differ from one another (Rhodes, et al., 2005).

Evidence supporting a norm-based coding model of facial identity perception comes from studies that employed a variant of an adaptation paradigm. Face adaptation, like other kinds of visual adaptation, occurs when prolonged fixation on a face biases perception of subsequently viewed faces (see Webster & McLeod, 2011 for review). For example, prolonged exposure to a male face biases perception of an ambiguously gendered face in the opposite direction: it is seen as female (Webster, Kaping, Mizokami, & Duhamel, 2004). Face aftereffects have also been demonstrated for emotional expression (e.g., Rutherford, Chattha, & Krysko, 2008; Skinner & Benton, 2010; Butler, Oruc, Fox, & Barton, 2008), facial attractiveness (e.g., Rhodes et al., 2003) and facial identity (e.g., Rhodes & Jeffery, 2006; Leopold, O'Toole, Vetter, & Blanz, 2001).

Previous studies have investigated norm-based coding of facial identity using facial identity aftereffects. In a common paradigm, participants learn a set of target identities (e.g., Ted and Rob, see Figure 1), fixate on an “anti-identity”, a face which physically differs from an average face in the opposite way from the target face (e.g., anti-Ted or anti-Rob; see Figure 1), and then categorize an average face as being either like Ted or Rob (Jeffery et al., 2011; Leopold, O’Toole, Vetter, & Blanz, 2001; Rhodes & Jeffery, 2006; Robbins, McKone, & Edwards, 2007). Figure 1 depicts two target identities (Ted and Rob) and their corresponding anti-identities (anti-Ted and Rob). The anti-identities and their corresponding target faces lie on the same identity trajectory, but are on the opposite side of the average face. Weaker versions of each identity can be created by morphing the average and target face by various amounts; e.g., morphing Rob and the average face by 60% creates 60% Rob. When individuals are adapted to the anti-identities (e.g., anti-Rob) weaker identity strengths and the average face are more likely to be perceived as the original identity (e.g., Rob) (Rhodes & Jeffery, 2006). Norm-based coding theory predicts that after adapting to an anti-identity, one's average face prototype will be recalibrated in the direction of the adapting anti-identity face. This shift in the prototype has effects on the perception of faces along vectors going through the prototype such that faces on the opposite side of the prototype from the adapting face now look more distinctive (less average and more Rob-like in this example).

Notice that in our example, the average face is intermediate between the target identity and its anti-identity, and this is critical in the test for norm-based coding. Previous studies have demonstrated that although adapting to an anti-identity enhances recognition of the original identity, adapting to a non-opposite face (a face that lies on a separate identity continuum) does not facilitate recognition of the same face to the same degree (Leopold et al., 2001; Rhodes & Jeffery, 2006). This pattern provides evidence for the norm-based coding model of facial identity, as it suggests that facial identity is coded in relation to an average, or norm.

Further evidence of norm-based coding of facial identity comes from experiments looking at differences in the magnitude of facial aftereffects created by varying how much a face differs from the norm or average face (extremeness). The norm-based coding model predicts that more extreme adapting faces (i.e., adapting faces that are very different from the average face) will produce a greater amount of adaptation and hence pull the prototype of the average face more towards the direction of the adapting face, leading to a larger shift in the perception of the average face (for a detailed description of why the norm-based coding model predicts these patterns of results, see Robbins, et al., 2007; Jeffery et al., 2011). The effect of more extreme adaptors is measureable as a larger bias in perception of subsequently viewed faces. This pattern of results has been demonstrated with expression aftereffects (Skinner & Benton, 2010), with facial feature-spacing aftereffects (Robbins, et al., 2007) and with facial identity aftereffects in typical adults and children (Jeffery et al., 2011; Jeffery, Read & Rhodes, 2013)

Face perception in Autism Spectrum Disorder.

Many studies have examined individuals with ASD's ability to process facial identity, but have yielded equivocal results (see Weigelt, Koldewyn, & Kanwisher, 2012, for review). For example, several studies that examined individuals with ASD's ability to discriminate recently learned or familiar identities have reported measurable deficits compared to typical participants (e.g., Boucher & Lewis, 1992; de Gelder Vroomen & van der Heide, 1991; Hauck, Fein, Maltby, Waterhouse, &Feinstein 1998; McPartland, Webb, Keehn, & Dawson, 2011; Boucher, Lewis, & Collis, 1998). Several studies examining face identity discrimination with experimental tasks that do not have significant memory demands (e.g., match-to-sample tasks) have reported typical performance by participants with ASD (e.g., Boucher & Lewis, 1992, Hauck et al., 1998; Derulle, Rondan, Gepner, & Tardif, 2004), while others have reported significant deficits in ASD populations (Riby Doherty-Shannon, &Bruce, 2009; Scherf, Behrmann, Minshew,

& Luna, 2008; Wolf et al., 2008). It is important to examine not only the differences in performance in ASD populations on various face processing tasks, but also what may account for any reported deficits. An important question is whether the perceptual mechanisms that are thought to facilitate face perception and face identification abilities (e.g., adaptation and norm-based coding) are intact or deficient in ASD populations. Examining the perceptual mechanisms underlying face perception in ASD may provide an explanation for the underlying sources of deficits in facial identity processing that have been previously reported.

Face adaptation and facial aftereffects in ASD.

The facial aftereffects paradigm is a useful experimental tool for examining norm-based coding of facial information and categories and has been employed extensively with typical populations (for example see Webster & McLeod (2011) and Rhodes et al. (2005) for reviews), but very few studies have examined facial aftereffects in ASD populations. Three studies have examined facial aftereffects in children with ASD. Pellicano, Jeffery, Blurr, and Rhodes (2007) examined facial identity adaptation in 8- to 13-year-old children with ASD and matched typical participants. Participants learned two male identities and during the test phases were adapted to an 80% anti-identity adapting face. While the ASD group was able to learn and discriminate the two identities as well as the typical group, they showed smaller identity aftereffects in comparison to the typical children. The authors suggested that the abnormal norm-based coding of facial identity might be one explanation for other face processing deficits characteristic of autism. Ewing, Pellicano, and Rhodes (2013) measured face distortion aftereffects (Webster &

Maclin, 1999) for upright and inverted faces as well as cars, in children with ASD. The authors reported diminished figural aftereffects in the ASD group compared to the typical group for upright faces, but not the other two categories of stimuli. Ewing, Leach, Pellicano, Jeffery, & Rhodes (2013) reported diminished facial identity aftereffects in children with ASD when attention to adapting faces was controlled. Finally, Rhodes, Ewing, Jeffery, Avard, and Taylor (2014) specifically tested for evidence of norm-based coding of facial identity by measuring aftereffects for different strengths and found that children with ASD show evidence of norm-based coding of facial identity (i.e., modulation of size of aftereffects relative to strength of adapting face), but overall show smaller identity aftereffects compared to typical children. Together, the results of these studies suggest atypical face adaptation in children with ASD, for upright faces.

Although deficits in face adaption have been demonstrated in children with ASD, it is not clear if this implies a delay in the development of face adaptation, or a stable deficit characteristic of the autism phenotype. One previous study found that adults with ASD show similar sized emotion and identity aftereffects as typical participants (Cook, Brewer, Shah, & Bird, 2014). That result suggests a change in face processing mechanisms between childhood and adulthood in individuals with ASD. However, finding identity aftereffects does not in and of itself provide evidence of norm-based coding of facial identity as other models of face perception, such as the exemplar based model also offer explanations for facial aftereffects (Rhodes & Jeffery, 2006). The purpose of our study was to directly test norm-based coding of facial identity in adults with ASD.

The current study.

In the current study, we used a paradigm similar to that used in previous studies exploring norm-based coding in typical children (Jeffery et al., 2011; Jeffery, et al., 2013). Participants learned two male identities. Participants were then adapted to anti-identities, and were then asked to categorize the average face as one of the two previously learned identities. Adapting faces were either extreme adaptors, which were far from the average (i.e., 80% anti-identity) or less extreme adaptors, which were closer to the average (i.e., 40% anti-identity). To rule out adaptation based only on low-level mechanism (e.g., luminance), the test and adapting faces were of a different size. If adults with ASD have deficits in adaptive coding of facial identity similar to those found in children with ASD, we would expect group differences in the magnitude of identity aftereffects. If norm-based coding is atypical in adults with ASD, we might also expect that their aftereffects for far and near adaptors will not show a typical-sized difference. However, if individuals with ASD are simply delayed in developing typical norm-based coding mechanisms of facial identity, we would expect no group differences in the magnitude of the identity aftereffects or in the difference between aftereffects for near and far adaptors.

Method

Participants.

Participants were 27 high-functioning adults (7 females, average age 29.07 years, *SD* = 8.70, range 18 to 58) with a diagnosis of autism spectrum disorders and 28 typical adults (6 females, average age 28.14, *SD* = 7.42, range 22 to 47). Three additional participants (two ASD) were tested but not included in the final analysis as their full scale

IQ scores were more than two standard deviations below the mean (i.e., below 70). The groups did not differ in chronological age or IQ (see Table 1 for demographic information).

Participants with ASD were recruited from a local assisted-living group home and from a database of individuals who had previously participated in research. The typical participants were recruited off-campus, via online advertising. The participants with ASD had been given a diagnosis of autism or Asperger's syndrome by an independent clinician, and were also evaluated for this study in a separate testing session using the ADOS-G (Lord et al., 2000) Module 4. All ASD participants' previous diagnoses were confirmed (see Table 2). All participants had normal or corrected-to-normal vision. Participants received a small honorarium for their participation in the study.

Materials.

The experiment consisted of two training phases and an experimental adaptation phase, during which aftereffects were tested. In the training phases, participants learned two male identities ("Ted" and "Rob") first at full strength and then at weaker identify strengths. The test phase was designed to measure participants' identity aftereffects. All face stimuli were presented as greyscale images and were created using Gryphon Morph (see Rhodes & Jeffery, 2006).

The faces used in the training phases consisted of two male faces, referred to as "Ted" and "Rob," and two weaker identity strengths (40% or 60% Ted; 40% or 60% Rob). These weaker identity faces were created by morphing each original identity (Ted or Rob) with the average face, which was constructed by vector averaging across 20 individual male faces (see Figure 2a). The resulting weaker identities are then intermediate between the original identity and the average.

The experimental adaptation phase included adapting faces and test faces. Adapting face stimuli were "anti-identities" created by extrapolating beyond the average face away from the target along the same identity trajectory. The resulting anti-identity face differs from the average face in a way that is opposite to how the target deviates from the average. For example, if the target has thinner than average lips the anti-face will have thicker than average lips. There were two types of adaptors: near adaptors (40% anti-Ted and anti-Rob faces) and far adaptors (80% anti-Ted and anti-Rob) (see Figure 2b). The test faces consisted of an average male face or an 80% identity face of either Ted and Rob (see Figure 2a). The 80% identities were included to verify that participants remembered the identities. Only the data from the average face were used to measure the strength of identity aftereffects.

All the faces used in the current experiment have been validated and used in other identity aftereffect experiments (e.g., Fiorentini et al., 2012; Jeffery et al., 2011; Nishimura et al., 2008; Pellicano et al., 2007; Pimperton, Pellicano, Jeffery, & Rhodes, 2009). Test stimuli were 5.1 cm (height) by 4.8 cm (width) and subtended a visual angle of 5.9° x 5.5° when viewed at a distance of 50 cm. Adapting stimuli were 6.4 cm by 6.4 cm and subtended a visual angle of 7.3° x 7.3°. The size change was included to reduce low-level visual adaptation effects.

Procedure.

Participants were tested individually on a 17-inch desktop Macintosh Dual 2.7

GHz PowerPC G5 computer with OS X operating system. Participants used a chin rest to maintain a constant viewing position of 55 cm. The lights in the testing room were on throughout the experiment and an experimenter sat behind a divider out of the participant's sight throughout the experiment.

The experiment consisted of three phases: two training phases and an experimental adaptation phase, which were all presented in the context of a game. Participants were told that the experiment was originally designed for children but that we were interested in validating it with adults.

Training Phases. The first training phase was designed to ensure that participants learned and were able to accurately identify the two male identities (Ted and Rob) at full identity strength. The second training phase was designed to allow participants to practice categorizing weaker identity strengths of Ted and Rob, so that they understood how to respond to weak impressions of each identity. The latter was necessary to ensure participants could respond appropriately when experiencing an aftereffect while viewing an average test face (i.e. experiencing only a weak impression of identity).

During the first training phase, participants were presented with the 100% identity strength Ted and Rob faces side by side. They were told that Ted and Rob were both police team captains who specialize in catching robbers. Participants were allowed to look at the two identities until they felt they could tell them apart. Participants were then presented one 100% identity strength face at a time, either of Ted or Rob, and were asked to identify if it was Ted or Rob. The face remained on the screen until the participant made his or her response by pressing the "x" key for Ted or the "." key for Rob. These keys were labeled with stickers reading “T” and “R” respectively. Participants were instructed to press the spacebar to begin the next trial. Feedback for each practice trial was given to participants in both training phases. Participants completed six of these practice trials (3 for each identity) in randomized order. Had any participant not been 100% correct on these trials, he or she would have repeated another six trials; no participant in either group needed to repeat the trials. Next participants completed 12 training trials that presented one of the 100% identity strength faces for 400 ms and then were prompted to identify whether the face was Ted or Rob. Had any participant been incorrect on more than two trials, he or she would have been asked to complete an additional six trials; no participants in either group had to complete additional trials.

In the second training phase, participants were shown “Team Ted” and “Team Rob.” Each team consisted of two weaker identity strength faces (40% and 60%) as well as the 100% identity strength faces of either Ted or Rob. They were told that the weaker identity strength faces were other members of Ted/Rob’s police team. Participants were presented with one “team” until they felt they could identify all the team members. Participants were instructed that they did not need to be able to tell the team members apart, but only be able to recognize that they were all on the same team. Once the participant felt they knew the first team, they were shown the second team. Participants completed 12 training trials in which one of the six identities was presented until the participant responded. Participants were instructed to press the spacebar to begin the next trial. If participants were incorrect on four or more of these training trials, they would have been asked to complete an additional 12 practice trials. No participants in either group had to complete additional trials. Next participants completed another 12 trials in which one of the six identities was presented for 400 ms.. If participants had been incorrect on four or more of these trials, they would have been asked to complete an additional 12 practice trials. No participants in either group had to complete additional trials.

Experimental Adaptation Phase. Once participants had completed both training tasks, they proceeded to the experimental adaptation task. Participants were first shown the two "robbers", who were the anti-identities. Participants were instructed to identify the test face that followed as belonging to which team (Ted or Rob), as this was the team that caught the robber. Each trial began by presenting one of the robber's faces (an adapting face) displayed for 5000 ms, followed by a 150 ms ISI and finally a test face displayed for 400 ms. The next trial began immediately after the participant pressed the spacebar. Participants were told to watch the robber's face carefully, but they were only to identify whose team the second face belonged to. No feedback was given to participants during this phase. Participants completed a total of 120 adapting trials; 80 in which the test face was the average face (0% identity), and 40 in which the test face was either 80% Rob or 80% Ted (equally likely). The trials were divided into five pseudo-randomized blocks of 24 trials each, constrained so that no more than two adapting faces of the same identity (e.g. anti-Ted) appeared sequentially, to avoid accumulating adaptation to one anti-face. All participants received the same pseudo-random order. The adapting faces were either near (40% anti-Ted or anti-Rob) or far (80% anti-Ted or anti-Rob) from the average face, with each type of adaptor appearing on 30 trials in the same/different random order for each participant. Together, the two training phases and experimental adaptation phase took approximately 30 minutes to complete.

Results

To assess participants' ability to identify the two target identities (i.e., "Ted" and "Rob"), we compared ASD participants' and typical participants' proportion of correct responses on trials where the target face was at 80% identity strength during the test. An independent samples t-test revealed no difference between the ASD group (*M*= .97, *SD* = .064) and the typical group (*M* = .99, *SD* = .022), *t*(53) = 1.26, *p* = .213; indicating an equally high level of recognition of the target identities during the test in the two groups

The size of the aftereffect was calculated for each participant using responses to the 0% identity strength faces. The proportion of "Ted" responses after adapting to "anti-Rob" were subtracted from the proportion of "Ted" responses after adapting to "anti-Ted" for each adapting condition (near vs. far) separately. An aftereffect in the predicted direction would yield a positive difference, since adapting to anti-Ted should make the average face look more like Ted while adapting to anti-Rob should make the average look more like Rob and less like Ted.

A 2 (strength of adaptor; near vs. far) by 2 (Group; ASD vs. typical) repeated measures mixed-model ANOVA was conducted on the size of participants' aftereffects. The results revealed a significant main effect of strength of adaptor; *F*(1,53) = 53.70, *p* < .001, η_p^2 = .503. Across the two groups, participants showed a larger aftereffect for far (80% adapting faces), *M* = .31, *SD* = .24, compared to near (40% adapting faces), *M* = .09, *SD* = .19. Figure 3 illustrates this effect. The main effect of group was not significant, *F*(1,

53) = 2.40, p = .13, η_p^2 = .043 and neither was the interaction between strength of adaptor and group, $F(1, 53)$ = .35, p = .56, η_p^2 = .007. Figure 3 displays the mean size of identity aftereffects for each position of adapting anti-identities (80% (far) and 40% (near)) for the typical and ASD groups.

We conducted separate one sample t tests for each group to test whether the near and far aftereffects were significantly greater than zero. For the typical group, both the far, $t(27)$ = 10.69, $p < .001$, d = 2.91, and the near, $t(27)$ = 3.16, $p < .01$, d = .84, aftereffects were significantly greater than zero. For the ASD group, the far aftereffect was significantly greater than zero, $t(26)$= 4.76, $p <.001$, d = 1.31, but the near aftereffect was not, $t(26)$ = 1.56), p = .13, d = .42.

In addition, we conducted a difference of proportions test (Blalock, 1972), to compare the proportion of participants who showed an aftereffect across the two adapting conditions. Any participant whose calculated size of aftereffect was greater than zero was regarded as showing an aftereffect for this analysis. For the typical participants, 27 out of 28 participants showed an effect in the far condition, while 20 out of 28 showed an aftereffect in the near condition, a significant difference in proportions ($z(27)$ = 2.55, p =.005, Φ = .34). Similarly, for the ASD group, 22 out of 27 participants showed an aftereffect in the far condition, while 17 out of 27 showed an aftereffect in the near condition, a significant difference ($z(26)$ = 1.79, p =.04, Φ = .24). Finally, the difference of difference of proportions test (Blalock, 1972) showed no group by condition interaction; the two groups performed similarly on the two types of adapting trials (z (53) = .43, *ns*).

Discussion

The goal of the current experiment was to measure the extent to which adults with ASD show evidence of norm-based coding of facial identity. Employing a commonly used aftereffects paradigm, participants were adapted to two anti-identity strengths, which varied in how much they differed from the average face. The norm-based model of face perception predicts that more extreme anti-identity adaptors will lead to larger aftereffects in comparison to less extreme adaptors. The results of the current study suggest that high-functioning adults with autism spectrum disorder use norm-based coding in face identification, and that this norm-based coding functions similarly to that of the typical group. Participants in both groups showed larger identity aftereffects when adapted to more extreme adapting faces (i.e., 80% anti-identity faces) compared to when they were adapted to less extreme adapting faces (i.e., 40% anti-identity faces). This pattern of results is predicted by the norm-based model of face perception (Robbins et al., 2007) and has been previously demonstrated in typical adults (Robbins et al., 2007; Skinner & Benton, 2010) and typically developing children (Jeffery, 2011; Jeffery, Read, and Rhodes, 2013). The current study is the first to demonstrate this pattern of results in a group of adults with ASD.

The finding that adults with ASD show similar sized identity aftereffects to those observed in typical adults is similar to that of Cook and colleagues (2014). They reported typical identity and emotional expression aftereffects in high-functioning adults with ASD. Together, the results of the current study and those reported by Cook et al. suggest that high-functioning adults with ASD show typical face adaptation and use of norm-based coding of facial identity. Therefore, by adulthood, there appears to be no qualitative difference between typical adults and high-functioning adults with ASD in the adaptive coding mechanisms that underlie face identity perception. These results contrast those of previous studies examining facial adaptation (Pellicano et al., 2007; Ewing et al., 2013; Ewing, Pellicano, & Rhodes, 2013) and norm-based coding of facial identity (Rhodes et al., 2014) in children with ASD which all reported smaller aftereffects, or diminished adaptation, in children with ASD.

There are several possible explanations for the differences in results between the current study and that of previous studies demonstrating diminished aftereffects in ASD populations. (Pellicano et al., 2007; Ewing et al. 2013, Ewing, Pellicano, & Rhodes, 2013; Rhodes et al., 2014). Perhaps the most obvious difference between the current study and the previous studies is the age of the participants. It may be that the reduced facial adaptation reported in previous studies reflects a developmental delay in facial adaptation of their young participants with ASD. It may be that reduced attention to faces early in development in children with ASD leads to a delay in the maturation of typical face adaptation. Previous studies have demonstrated that children with ASD orient to social stimuli, including people, less than typical children (Dawson et al., 1998; Dawson et al., 2004). Although this difference continues into adulthood (Sasson et al., 2007), it may be that eventually individuals with ASD accumulate enough experience with faces to develop typical face adaptation. It is important to note that while studies with children with ASD have reported diminished face aftereffects, they all demonstrate that children with ASD show evidence of face adaptation or norm-based coding of facial identity, just not to the same extent as typical children. Alternatively, it may take longer for them to develop an accurate norm on which to centre face processing because the norm is not updated as efficiently as in typical children, in part, because the child with ASD attends less often to faces. More sensitive developmental studies, with either a larger range of age groups, or a longitudinal design are needed to map out the developmental trajectory of norm-based coding in ASD from childhood through to adulthood.

It is unlikely that differences in attention during the task can account for differences in facial adaptation between children and adults with ASD. As with other types of visual adaptation, face aftereffects are modulated by attention to the adapting face stimulus (e.g., Moradi, Koch, & Shimojo, 2005). Rutherford, Troubridge, and Walsh (2012) recorded eye-tracking data from adults with ASD and typical participants during an emotion aftereffects experiment and reported no group differences in attention to adapting faces. While previous studies examining face adaptation in children with ASD did not include eye-tracking data, Ewing, et al. (2013) manipulated attention to adapting faces by including a facial feature change detection task in addition to measuring identity aftereffects. Although children with ASD were as accurate at detecting changes in the lips or eyes of the adapting stimuli, indicating that they attended well to the adapting faces, they still showed reduced identity aftereffects in comparison to typical children. These results suggest that reduced attention to adapting faces is not likely to account for diminished face aftereffects in children with ASD.

It is interesting to note the group difference in the results of the single-sample t-tests for each aftereffect. While the typical group showed non-zero aftereffects for both the far (80% anti-identity) and near (40% anti-identity) adapting faces, the ASD group only had a significant aftereffect after adapting to the far adapting faces. The size of aftereffects for the less extreme adapting faces was not significantly different from zero at the group level for the ASD group. However, the difference of proportions analysis suggested that there were no differences between groups in the proportion of participants who showed significant aftereffects for either the near or far adapting conditions.

The results of the current study are consistent with the conclusions of Weigelt, Koldewyn, and Kanwisher (2012) who argue that there is little evidence for a qualitative difference between typical individuals and those with ASD in facial identity processing abilities. Specifically, they suggest that previous studies examining facial identity processing in ASD support the notion that individuals with autism may process facial identity less efficiently, but not in a completely different manner, than typical individuals. If the deficits in facial identity processing that are characteristic of ASD are related to reduced efficiency rather than a different manner of processing as Weigelt and colleagues suggested, then we would expect the basic coding mechanisms of facial identity to be similar to those of typical individuals. In the current study we found no evidence for a qualitative difference in the coding mechanisms underlying face identification, as there were no group differences in the pattern of identity aftereffects. The results of the current study suggest that adults with ASD use norm-based coding of facial identity, just as typical adults do.

In conclusion, the current study provides evidence that high-functioning adults with ASD use norm-based coding in a facial identity task. ASD participants showed larger aftereffects for more extreme anti-identity adapting faces compared to less extreme adapting faces, a pattern of results that has been previously demonstrated in typical populations and is taken as evidence for norm-based coding. This is the first study that has explored norm-based coding of facial identity in an adult population of individuals with ASD. The results of the current study suggest that previously reported deficits in facial identity processing in adults with ASD are not likely to arise from deficits in the norm-based perceptual coding mechanisms that underlie these face- processing abilities.

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Tables

Table 1

Chronological age and IQ of participants.

	ASD (n = 27)			Typical (n = 28)			Group Difference	
	Mean	SD	Range	Mean	SD	Range	t(37)	p
CA (years)	29.07	8.70	18-58	28.14	7.41	21-47	.428	.67
Verbal IQ	97.19	13.6	76-134	95.29	13.4	70-118	.523	.603
Performance IQ	98.63	14.29	69-138	99.32	16.24	70-125	-.168	.868
Full Scale IQ	97.33	11.6	83-121	97.36	14.5	70-120	-.007	.995

CA = chronological age

Table 2

ADOS scores for ASD participants

	Mean	SD	Range
Communication	4.26	2.41	0-9
Reciprocal Social Interaction	8.67	2.75	3-16
Imagination/Creativity	1.52	0.8	0-3
Stereotyped Behaviours and Restricted Interests	0.41	1.05	0-2

Figures

Figure 1

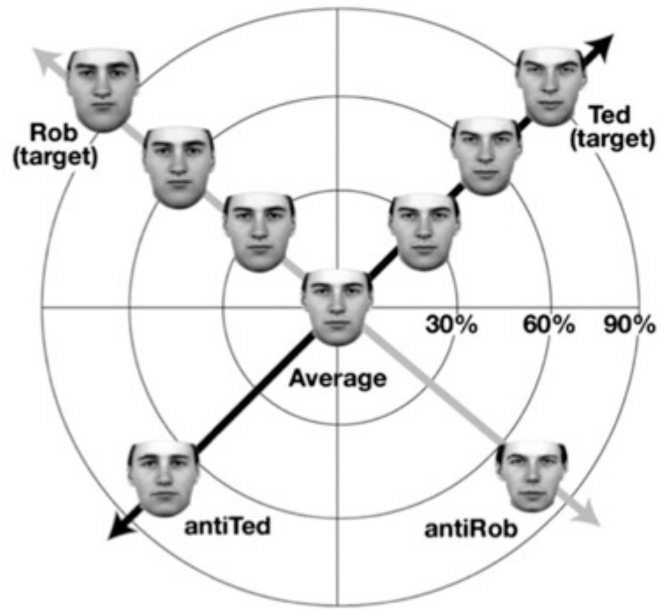

Figure 1. Figure 1 illustrates two target identities (Ted and Rob) and the anti-identities, which lie on the same identity trajectory but on the opposite side of the average. "Weaker" identity strengths of the target identities are created by morphing the average face and target face by varying amounts (e.g., 60% to create 60% Ted). Norm-based coding model predicts that adapting to an anti-identity will bias perception of the weaker identity targets, as well as the average face, towards the original identity target (i.e., adapting to anti-Ted will lead to the perception of the average face as Ted).

Figure 2

80% Ted Average 80% Rob

Figure 2a. Test stimuli used in the experimental adaption phase. The 80% identity strength test faces were created by morphing between the average (0% identity) and the original (100% Ted/Rob) identity.

Near (40%) anti-Rob Far (80%) anti-Rob Near (40%) anti-Ted Far (80%) anti-Ted

Figure 2b. Anti-faces were used as adapting faces in the experimental adaptation phase. Near adaptors were 40% anti-identities and far adaptors were 80% anti-identities.

Figure 3

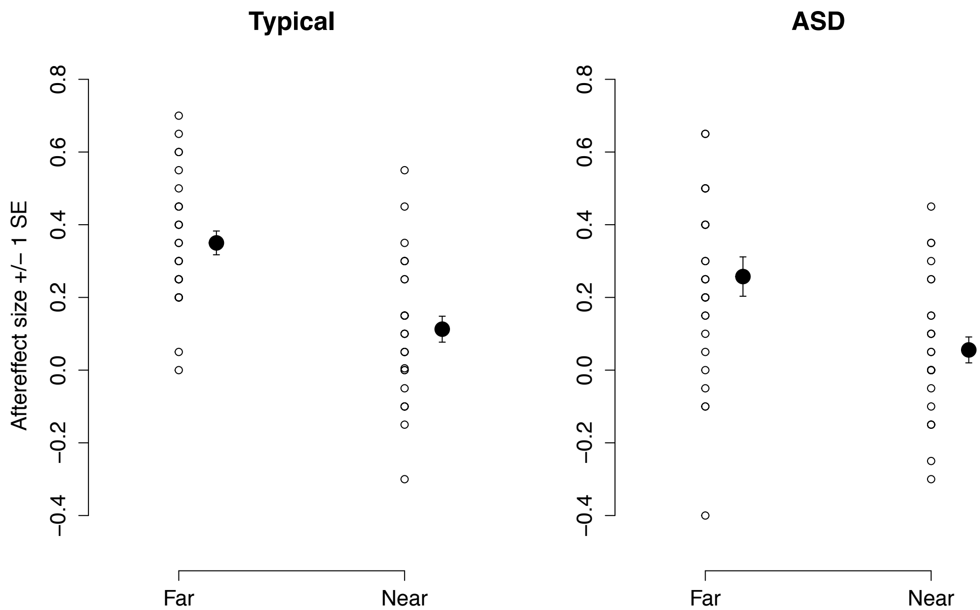

Figure 3. Aftereffects for near (40% anti-identity) and far (80% anti-identity) adaptors for the ASD and typical groups. The unfilled circles represent the individual participant scores, while the filled black circles represent the group means. Error bars represent the standard error of the mean.

Chapter 3 – Study 2

Walsh, J. A., Vida, M. D., & Rutherfod, M. D. Adults with autism spectrum disorder use norm-based coding and encode different prototypes for male and female faces**.** Submitted to *Vision Research* (August 15th, 2014)

Understanding how facial information is encoded and how categories of faces are represented in relation to one another is important for our general understanding of typical face perception. Figural aftereffects have been used to examine norm-based coding of facial categories and whether different categories of faces (e.g., male and female faces) are coded by separate or overlapping neural populations. Previous research has demonstrated both simple aftereffects (adaptation to distorted faces from one gender creates aftereffects for that gender but not the other) and opposing aftereffects (adaptation to both genders in opposite directions creates separate opposing aftereffects for each gender) for male and female faces. The figural aftereffects paradigm is a well-established research paradigm with typical populations, but has yet to be used with adults with ASD. The current study employed a variation of the previously used figural aftereffects paradigm and measured both simple (Experiment 1) and opposing (Experiment 2) gender aftereffects in both adults with and without ASD in order to examine whether adults with ASD 1) are sensitive to figural face distortions which results in significant figural aftereffects and 2) show evidence of norm-based coding. In Experiment 1 we measured the shift in participants' normality ratings of faces before and after being adapted to either male or female faces that had either extremely contracted features or extremely expanded features. In Experiment 2, we used the same procedure except participants were adapted to male contracted faces and female expanded faces simultaneously in order to probe for opposing aftereffects. The results of the current study provide further evidence of intact face aftereffects and norm-based coding in adults with ASD and have important implications for our understanding of face processing deficits in ASD populations.

Abstract

The norm-based coding model of face perception posits that face perception involves an implicit comparison of observed faces to a representation of an average face (prototype), which is shaped by experience. Observers with autism spectrum disorder (ASD) have shown atypical face perception given some methods, but preserved face perception with others. Here, we tested whether adults with ASD show evidence of norm-based coding of faces, and whether they encode separate prototypes for male and female faces, as typical observers do. Following prolonged exposure to distorted faces that differ from the stored prototype, typical adults show aftereffects: the prototype shifts in the direction of the adapting face. We measured aftereffects following adaptation to either one distorted gender (Experiment 1) or each gender distorted in opposite directions (Experiment 2). Adults with ASD showed norm based coding, and separable male and female face prototypes similar to typical participants. This is the first study to examine figural aftereffects in adults with ASD. The results of this study are similar to a previous study examining aftereffects in adults with ASD, but contrast with studies showing diminished adaptation in children with ASD.

Introduction

Autism spectrum disorder (ASD) are characterized by: 1) deficits in social communication and interactions and 2) repetitive and restrictive behaviors and interests (American Psychiatric Association, 2013). The ability of individuals with ASD to process social information in faces has been an area of focus in recent decades, but there is still not a clear understanding of the specific face processing deficits in the current literature. While many studies have focused on measuring performance accuracy on various face perception tasks, relatively few studies have examined the perceptual mechanisms underlying face perception. Face adaptation and norm-based coding are proposed to facilitate typical face perception, however only one study has examined face adaptation in adults with ASD. Examining face adaptation and norm-based coding in ASD will provide a direct test of whether face perception processes are the same in individuals with ASD compared to typical observers.

Norm-based face processing in typical individuals.

Typical adults are expert face processors and show superior performance on face-based visual perception over other categories of visual stimuli (see Maurer, LeGrand, & Mondloch (2002) for review). The norm-based coding model of face perception (Rhodes & Leopold, 2011; Webster & MacLeod, 2011) suggests that the perception of faces involves an implicit comparison of perceived faces to a prototypical or average face (Rhodes, Robbins, Jaquet, Jeffery, & Clifford, 2005; Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003). This average face is thought to be dynamic and constantly updated by an individual's experience with faces.

Face aftereffects.

Previous studies have used an aftereffects paradigm to examine norm-based coding of faces. A face aftereffect occurs when the perception of faces are influenced by prolonged exposure to another face (or group of faces; see Webster & McLeod, 2011 for review). In order to test the hypothesis that individuals' face prototype can be calibrated by recent visual experiences, several researchers have measured the results of exposure to artificially distorted faces, an approach known as figural face aftereffects (e.g., Webster & Maclin, 1999; Watson & Clifford, 2003; Rhodes et al., 2003; Rhodes, et al., 2004; Little, DeBruine, & Jones, 2005; Jaquet & Rhodes, 2008; Watson & Clifford, 2006**;** Jaquet, Rhodes, & Hayward, 2007; Little, DeBruine, Jones, & Waitt, 2008). The figural face aftereffects paradigm involves recalibrating individuals' average face representation by exposing them to a series of faces that are distorted in a similar manner (e.g., extreme spacing between the eyes and mouth, expansion or contraction), which is thought to create neural adaptation and to shift the observer's average face representation in the direction of the distortion (MacLin & Webster, 2001; Rhodes, et al., 2003). By measuring individuals' normality ratings of a range of faces before and after adaptation, an experimenter is able to infer the change in facial characteristics that are perceived as most normal. This is taken to be an index of changes in the average face representation.

The figural aftereffects paradigm has also been used to explore whether various categories of faces are encoded by overlapping neural populations. If two categories of faces (e.g., male and female) are coded by separate neural populations, then adapting participants to distorted faces from one category should induce aftereffects for the same category without affecting the other category. In contrast, if the two categories of faces are coded by common or overlapping neural populations, then adapting participants to one category of faces should create measureable aftereffects for both categories. Furthermore, if discrete neural populations code the two categories of faces, then it should be possible it should be possible to recalibrate the average representation for each category in opposite directions, leading to aftereffects in opposite directions for the two categories (e.g. contracted versus expanded) (Rhodes et al., 2003). Figural face aftereffects have been demonstrated for race (Jaquet et al., 2007; Jaquet, Rhodes, & Hayward, 2008, Little, et al., 2008), and gender (Little et al., 2005; Jaquet & Rhodes, 2008) and are seen even with inverted faces (Rhodes, et al., 2004; Watson & Clifford, 2006),

Separate encoding of prototypes for each gender.

Little and colleagues (2005) used the simple (e.g., aftereffect created and measured within a gender category) and opposing (e.g., male and female faces adapted to opposite distortions) figural aftereffects paradigms together to examine whether male and female face prototypes are encoded with distinct or overlapping neural populations. Across a set of three experiments, participants displayed sex-contingent simple and opposing aftereffects, which the authors interpreted as evidence for distinct neural representations of male and female faces. Jaquet and Rhodes (2008) used similar methods as well as a more sensitive measure and found similar sex contingent aftereffects, but the authors also reported transferring of aftereffects to the opposite gender of test faces that participants were adapted to, a pattern suggesting common neural underpinnings for male and female faces. Taken together, these studies suggest that male and female faces are encoded with partly, but not fully, overlapping neural populations.

Face aftereffects in individuals with autism spectrum disorder.

Previous research has provided conflicting results regarding deficits in face processing in ASD. Some studies report atypical performance on specific face processing tasks such as emotion or identity recognition, while others report typical performance (see Jemel, Mottron, & Dawson, 2006; Sasson, 2006; and Weigelt, Koldewyn, & Kanwisher, 2012 for reviews). Face aftereffects paradigms can be used to explore the psychological relationships among face categories, such as emotional expressions (Rutherford, Chattha, Krysko, 2008). Rutherford, Troubridge, and Walsh (2012) used an aftereffects paradigm to examine the psychological organization of facial expressions in adults with ASD and found atypical psychological organization of the six basic emotions. Aftereffects can also be used to test for reduced or abnormal norm-based coding of face information. Pellicano, Jeffery, Blurr, and Rhodes (2007) employed an identity aftereffects paradigm and demonstrated that norm-based coding of facial identity was atypical in children with ASD. Ewing, Pellicano, and Rhodes (2013) demonstrated that children with ASD show smaller figural aftereffects for upright faces, but not inverted faces or cars, suggesting selective deficits for adaptation for upright faces. Similarly, Ewing, Leach, Pellicano, Jeffery, and Rhodes (2013) reported that children with ASD show reduced identity aftereffects when attention to adapting faces is controlled suggesting that diminished adaptation is not likely due to inattention to adapting stimuli.

Only one study has used the aftereffects paradigm to examine opponent coding and face adaption in adults with ASD. Cook, Brewer, Shah, and Bird (2014) examined identity and expression aftereffects in adults with ASD and reported no group differences in the size of either type of aftereffect, indicating intact adaptation to facial identity and expression. The difference between these results and those of experiments showing atypical face adaptation in children with ASD may indicate a developmental delay in face adaptation in the ASD population, however this needs to be explored further. The figural aftereffects paradigm has yet to be used to examine norm-based coding in adults ASD populations. As this paradigm is well established in typical populations and considered a useful experimental tool for examining face adaptation and norm-based coding, we will use this paradigm here to test whether 1) adults with ASD show evidence of norm-based coding just as typical observers do, and 2) whether adults with ASD encode overlapping but separaable prototypes for male and female faces, just as typical observers do.

The current research.

Two experiments were designed to examine the extent to which high-functioning adults with ASD show evidence of norm-based coding and show distinct neural representations of male and female faces. Both experiments employed a figural face aftereffects paradigm, which is well-established for measuring face aftereffects but has never been used with an ASD population. In Experiment 1, we tested whether adults with ASD would show evidence of simple gender aftereffects. In Experiment 2, we tested whether adults with ASD would show evidence of opposing gender aftereffects. If adults with ASD encode gender information as typical individuals do, we would expect participants to show distinct aftereffects for male and female faces. If adults with ASD encode gender information of faces in an atypical manner, we might find group differences in either the size or the direction of the aftereffects.

Experiment 1

Methods.

Materials.

Stimuli were colour photographs of 15 Caucasian male and 15 Caucasian female faces with neutral expressions. All faces were cropped around the contour of the face with an oval mask as shown in figure 1. The faces were distorted by applying the spherize tool of Adobe Photoshop. This application distorted the faces by shifting the internal facial features towards the center of the face (i.e., contracted) or away from the center of the face (i.e., expanded).

Pre- and Post-Adaptation Test Stimuli. Test images were derived from photographs of five male and five female faces. Each model's face was distorted in increments of 15% to create a continuum ranging from 60% contracted to 60% expanded (9 images total for each model). Test images were presented at 900 x 1200 pixels, or 13.5 x 18cm. See Figure 1a.

Adapting stimuli. Adapting images were derived from 10 male and 10 female faces that were different from those used to develop the adaptation stimuli. Each model's photograph was distorted 60% contracted and 60% expanded. Adapting images were presented at 1300 x 1800 pixels, or 16 x 21cm. The size change between adapting and test stimuli was intended to reduce low-level visual adaptation effects. See Figure 1b.

All stimuli were presented and data was compiled in MatLab Student Version 7.4 on the same Apple Macintosh mini Dual 2.7 GHz PowerPC G5 computer with OS X operating system with a 17-inch LCD monitor set to a resolution of 1280 x 1024 and a refresh rate of 60Hz.

Participants.

Participants were 20 high-functioning adults (13 males, average age 26.8 years, range 18 to 39) with a diagnosis of ASD and 20 typical adults (17 males, average age 29.5, range 20 to 40). The groups did not differ in chronological age or IQ (see Table 1 for demographic information). Four additional participants (2 ASD) were excluded because of technical error (1 ASD, 2 typical participants) or inattentiveness (1 ASD participant).

Participants with ASD were recruited from a local assisted living home as well as from a database of individuals who had previously participated in research in the lab. They had received a diagnosis of autism or Asperger's by outside agencies, and were also evaluated using the ADOS-G (Lord et al., 2000) Module 4 in a separate testing session to confirm diagnosis for this study. Results are shown in Table 2. They were free from other medical or psychiatric diagnoses. The typical participants were recruited from off-campus, via online advertising. All participants had normal or corrected to normal vision. Participants were given a small honorarium for their participation in the study. The current research was carried out in compliance with the McMaster Research Ethics Board guidelines for research with human subjects and complied with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

Procedure.

There were three phases: a pre-adaptation rating task, an adaptation phase, and a post-adaptation rating task. Participants were assigned to one of four adapting conditions: male contracted, male expanded, female contracted or female expanded. Participants in the male contracted condition (for example) were only exposed to contracted male faces during the adaptation phase. Five participants from each group (ASD and typical) were in each condition.

For all three tasks, participants sat and used a chin rest. Viewing distance was 60 centimeters from the monitor. Before the pre-adaptation task, participants were given verbal instructions. They were told that they would see one face at a time and would be asked to rate how normal each face looked on a scale from 1 (unusual) to 9 (normal) by pressing one of nine computer keys. Male and female test faces were presented individually, in random order, and participants rated how normal each looked. Faces appeared centrally on the screen for 1s, then disappeared. After a 200ms inter stimulus interval (ISI), the response screen appeared, prompted participants and remained on the screen until participants responded. The next trial began after a 200ms ISI. This task was a single block of 90 trials.

In the adaptation phase, participants were told that they would see a variety of faces during this task and that they were only to watch each one carefully. Each adaptation face was presented centrally on the screen for 4s with a 200ms ISI between each face. Each model was repeated four times and there were 40 trials total in this phase.

Immediately following the adaptation task, participants completed post adaptation rating task. The procedure was identical to the pre-adaptation task with the addition of 6 "top-up" adaptation trials that were presented before each test face in order to maintain the adaptation effects produced during the adaptation task. The 6 top-up images (each from the set presented during the adaptation phase) were presented individually for 1s with a 200ms ISI between faces. The test face was presented with a red border to indicate which face they were to rate. The entire experiment took approximately 40 minutes.

Results.

The size of the aftereffect was the shift along the continuum from the image that were rated most normal in the pre-adaptation to that rated most normal in the post-adaptation task, (see Jaquet & Rhodes, 2008, Rhodes et al, 2004, 2003). To determine which image was rated most normal, we first plotted participants' normality ratings of the test faces as a function of distortion level (for male and female faces and for pre and post adaption faces separately). As in Jaquet & Rhodes (2008), we fit a third-order polynomial (cubic) function to each participant's data (illustrated in Figure 2). The fits for each group were good for both genders pre and post-adaptation ratings, see Table 3 for details. We conducted a 2 (gender of test face) x 2 (test time point) x 2 (group) mixed model repeated measures ANOVA on participants' R^2 scores for the data fits. Results indicated no significant main effects (all $p > .10$) and no significant interactions (all $p > .18$) demonstrating that the fits for both groups were equally good. See Table 3.

The distortion level corresponding to the peak of the function was calculated in order to determine the distortion level that was rated as most normal. This was done for each participant separately and for male and female faces pre- and post-adaptation separately. The size of the aftereffect was estimated by the difference between the distortion level rated most normal pre-adaptation from the distortion level rated most normal post-adaptation. Positive scores indicated an increase in normality ratings for expanded faces, whereas negative scores indicated an increase in normality ratings for contracted faces.

Do adults with ASD show evidence of norm-based coding?

We conducted separate one-sample t-tests for the same-gender and opposite-gender aftereffects for each distortion type (contracted and expanded) for the ASD group to test whether they show evidence of face adaptation. For ASD participants adapted to expanded male or female face, the size of the aftereffect for same gender of test faces (M = 21.76, SD = 18.16) was significantly different from zero, $t(9) = 3.79$, $p = .004$, $d = 1.69$, but the aftereffect for opposite gender of test faces (M = 1.24, SD = 19.61) was not significantly different from zero, $t(9) = .20$, $p = .85$, $d = .09$. For ASD participants adapted to contracted male or female faces, the aftereffect for same gender of test faces (M = -30.51, SD = -28.84) was significantly different from zero, $t(9) = -3.35$, $p = .009$, $d = -1.40$, and the aftereffect for opposite gender of test faces (M = -38.14, SD = 25.52) was also significantly different from zero, $t(9) = -4.73$, $p = .001$, $d = -2.11$.

Do typical adults and adults with ASD encode separate prototypes for male and female faces?

We conducted a 2 (Adaptation distortion; expanded vs. contracted) x 2 (Test gender difference; adaptation gender same or opposite) x 2 (Group) mixed model repeated measures ANOVA on the size of the aftereffect. Results revealed a significant main effect of adaptation distortion, $F(1, 34) = 69.14$, $p <.0001$, $\eta_p^2 = .658$. Across groups and test gender differences, participants adapted to contracted faces showed larger aftereffects ($M = -33.11$, $SD = 15.61$) compared to participants adapted to expanded faces ($M = 9.78$, $SD = 8.72$). See Figure 3. All other main effects and interactions were not significant (all $p > .14$). These results indicate that gender of adapting faces did not influence the formation of aftereffects, but rather the type of distortion of the adapting faces did.

Aftereffects for the expanded adaptation and contracted adaptation conditions.

To test whether contracted and expanded distortions created significant aftereffects for the same and opposite gender of test faces, we conducted separate one-sample t-tests for same gender and opposite gender aftereffects for each adaptation distortion type (contracted and expanded) across groups to evaluate whether each aftereffect was significant from zero. We collapsed across ASD and typical participants, since the ANOVA revealed no significant effect of group. For participants adapted to expanded faces, the aftereffect for same gender test faces ($M = 15.59$, $SD = 21.99$) was significantly different from zero, $t(19) = 3.17$, $p = .00$, $d = .71$, but the aftereffect for opposite gender faces ($M = 3.97$, $SD = 19.68$) was not, $t(19) = .90$, $p = .378$, $d = .20$. In contrast, participants adapted to contracted faces showed significant aftereffects for same gender test faces ($M = -29.73$, $SD = 32.88$), $t(19) = -4.04$, $p = .001$, $d = .-90$ and opposite gender test faces ($M = -36.50$, $SD = 21.80$), $t(19) = -7.49$, $p <.001$, $d = -1.67$. These results indicate that across groups, participants in the expanded adaptation conditions showed the results that were expected based on previous work (e.g., Jaquet & Rhodes, 2008):

significant aftereffects for test faces with the same gender as the adapting face, but not for test faces with the opposite gender. In contrast, participants in the contracted conditions showed significant contracted aftereffects for both genders.

Discussion.

In Experiment 1 we used a distortion aftereffects paradigm to test for norm-based coding of face stimuli, and to measure transfer of aftereffects across gender of model in adults with ASD and typical controls. Participants were adapted to one gender distorted in one direction (i.e., expanded or contracted) and we measured the change in their normality ratings for expanded and contracted faces separately and for each gender, to estimate the size of the aftereffect. The results of Experiment 1 suggest that adults with ASD display figural gender aftereffects similar to those of typical adults. There were no group differences in size or direction of aftereffects. This is the first study to demonstrate figural aftereffects in adults with ASD. This result suggests that face processing deficits previously reported in observers with ASD are not likely to arise from abnormal norm-based coding of facial information. The fact that adults with ASD are sensitive to the figural distortions and show similar aftereffects as typical adults indicates that they are coding gender information in a similar way as typical individuals.

Some of the current results contrast those of previous studies exploring distortion gender aftereffects in typical adults, and raise some interesting methodological questions. In the current study there was a significant main effect of distortion type. Across groups, participants who were adapted to expanded faces displayed significant aftereffects for the same gender of test face that they were adapted to but not for the opposite gender of test face. These are the expected results based on previous studies examining norm-based coding of gender (Jaquet & Rhodes, 2008; Little, DeBruine, & Jones, 2005). In contrast, participants who were adapted to contracted faces showed significant aftereffects for both genders. This contrast in results between the expanded and contracted adaptation conditions suggests that the effect of adaptation to contracted faces is not equivalent to the effect of adaptation to expanded faces, as previous studies have assumed. One possible explanation may be that the contracted distortion creates adaptation for the neural populations coding for common characteristics between the two categories of faces, while the expanded distortion only creates adaptation for the neural populations that are unique to each category.

Experiment 2

In Experiment 2, we examined whether adults with ASD show evidence of opposing gender aftereffects, as stronger test of whether separate prototypes are encoded for male and female faces. When typical adults are simultaneously adapted to male and female faces that are distorted in opposite ways (e.g., males with wide eye spacing and females with small eye spacing), participants show significant aftereffects in opposite directions for male and female test faces (Little, DeBruine, and Jones, 2005; Jaquet and Rhodes, 2008) This suggests that male and female faces are encoded at least somewhat independently. In Experiment 2 we adapted both participants with ASD and typical controls to contracted male faces and expanded female faces. If adults with ASD encode gender information as typical adults do, we would expect them to show separate and opposite aftereffects for male and female faces. In contrast, if adults with ASD process gender information of faces atypically, we might see group differences in the direction or size of the aftereffects.

Method.

Materials.

Stimuli for Experiment 2 were created in the same manner as in Experiment 1. Stimuli were colour photographs of 10 Caucasian males and 10 Caucasian females displaying neutral expressions. Ten faces were used as testing stimuli and 10 were used as adapting stimuli. All faces were cropped around the contour of the face with an oval black mask. The faces were distorted by applying the spherize tool of Adobe Photoshop.

Pre- and Post-Adaptation Test Stimuli. Stimuli consisted of five male and five female faces. Each individual's face was distorted in increments of 15% to create a continuum ranging from 60% contracted to 60% expanded (9 faces total). Test faces were presented at 900 x 1200 pixels, or 13.5 x 18cm.

Adapting stimuli. Adapting faces consisted of 5 male and 5 female faces that were different from the test faces. Each male face was distorted to 60% contracted and each female face was distorted to 60% expanded. Adapting faces were presented at 1300 x 1800 pixels, or 16 x 21cm. The size differed between adapting and test stimuli to reduce low-level visual adaptation.

All stimuli were presented and data was compiled in MatLab Student Version 7.4 on the same Apple Macintosh mini Dual 2.7 GHz PowerPC G5 computer with OS X operating system with a 17-inch LCD monitor set to a resolution of 1280 x 1024 and a refresh rate of 60Hz.

Participants.

Participants were 22 adults (5 females, average age 28.5, range 19-58) with a diagnosis of ASD and 22 control participants (7 females, average age 29.41, range 20-50). Groups did not differ in age, verbal IQ, performance IQ, and full scale IQ. See Table 4 for demographic information. Several participants who participated in Experiment 1 participated in Experiment 2, however these studies were conducted at different time points, several months apart.

Participants with ASD were recruited from a local assisted living home as well as from a database of individuals who had previously participated in research in the lab. They had received a diagnosis of autism or Asperger's by outside agencies, and were also evaluated using the ADOS-G (Lord et al., 2000) Module 4 to confirm diagnosis for this study. Results are shown in Table 5. They were free from other medical or psychiatric diagnoses. The typical participants were recruited off-campus, via online advertising. Those with ASD were free from other medical conditions. One ASD participant had a clinical diagnosis of ASD but was not available to complete an ADOS for this study. Participants had normal or corrected to normal vision. Participants were given a small honorarium for their participation in the study. The current research was carried out in compliance with the McMaster Research Ethics Board guidelines for research with human subjects and complied with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

Procedure.

The procedure for Experiment 2 was identical to that of Experiment 1.

Results.

The size of the aftereffect was calculated as in Experiment 1. The fits for each group were good for both genders and for both Pre and Post-Adaptation (see Table 6 for details). We conducted a 2 (gender of test face) x 2 (test time point) x 2 (group) mixed model repeated measures ANOVA on participants' R^2 scores for the fits. Results indicated no significant main effects (all $p < .32$) and no significant interactions (all $p < .17$), indicating that the fits for both groups were comparable.

As in Experiment 1, the distortion level corresponding to the peak of the function was calculated in order to determine the distortion level that was rated as most normal. This was done for each participant separately for male and female faces and for pre and post-adaptation.

Does adaptation to male and female faces distortion in opposite directions create opposing aftereffects in those with and without ASD?

We tested whether simultaneous adaptation to male contracted faces and female expanded faces create opposing aftereffects (e.g., aftereffect for male test faces in the expanded direction and aftereffect for female test faces in the contracted direction). We conducted a 2 (Gender of test face) x 2 (Group) mixed model repeated measures ANOVA on the size of the aftereffects. The results revealed a marginally significant main effect of gender of test face, $F(1, 42) = 3.40$, $p = .07$. Across both groups, participants showed larger contracted aftereffects for male test faces ($M = -25.09$, $SD = 32.09$) compared to aftereffects for female test faces ($M = -12.91$, $SD = 31.33$). The main effect of group was not significant, nor was the interaction between gender of test face and group (both *p*s

<.72). See Figure 4. Both the male aftereffect, $t(43) = -5.19$, $p>.001$, $d = -.78$ and the female aftereffect, $t(43) = -2.73$, $p=.009$, $d = -.041$, were significantly different from zero (tested across groups as there was no significant effect of group). See Figure 4. Together, these results suggest that participants with ASD show similar aftereffects, in terms of size and direction, to typical participants. However, these results do not provide strong evidence of opposing aftereffects, as there was no effect of gender of test face, and both the aftereffects for male and female test faces were significantly different from zero, indicating no difference in aftereffects for male versus female test faces.

Do adults with ASD show evidence of norm-based coding?

We conducted separate one-sample t-tests for the male and female aftereffects for the ASD group to test whether they show evidence of norm-based coding. The aftereffect for male test faces was significantly different from zero, $t(21) = -4.56$, $p <.001$, $d = -1.37$, but the aftereffect female test faces was not significantly different from zero, $t(21) = -1.79$, $p = .09$, $d = -.54$.

Discussion.

The results of Experiment 2 suggest that adults with ASD show similar size and direction of figural aftereffects as typical individuals do. The ASD group showed evidence of norm-based coding, as the aftereffect for male faces was in the contracted direction and significantly different from zero. As with Experiment 1, the results of the contracted adaptation were not what would be expected based on previous research. Using the same procedure but different stimuli, Jaquet and Rhodes (2008) adapted participants to male and female faces distorted in opposite directions (e.g., male contracted and female expanded). Participants showed significant aftereffects in the contracted direction for the gender of test faces that was contracted in adaptation (e.g. male) but not the other gender (e.g. female). In contrast, participants in the current study showed significant aftereffects in the contracted direction for both genders of test faces, even though they were adapted to male contracted faces and female expanded faces. This result suggests that the unexpected difference between contracted and expanded aftereffects in Experiment 1 is reliable. This suggests that the contracted distortion is adapting common characteristics between male and female faces, while the expanded adaptation is not.

General Discussion

These experiments tested, for the first time, figural face aftereffects in adults with ASD. We used a figural face aftereffects paradigm, which has been used to study the extent to which norm-based coding of the two genders is distinct (Jaquet & Rhodes, 2008) and similarly the extent to which other categories of faces are encoded separately (Rhodes et al., 2004; Jaquet et al., 2008) in typical individuals. In Experiment 1 we measured the transfer of figural aftereffects across gender of models: Participants were adapted to one gender of models distorted in one direction and aftereffects were then tested for aftereffects using both genders of models. In Experiment 2, we measured opposing gender aftereffects: Participants were adapted to faces of each gender distorted in opposite directions and aftereffects were then measured for each gender.

There were no significant group differences in either experiment, in terms of the direction or magnitude of aftereffects for either male or female faces. Although we did not find the expected results of sex-contingent aftereffects in all adaptation conditions, the results of the expanded condition in Experiment 1 replicate findings of previous studies examining norm-based coding of gender in typical populations. Across groups, participants in the expanded condition showed significant aftereffects for the gender of test face they were adapted to, but not the opposite gender, which is evidence of sex contingent aftereffects. This result suggests at least some distinct coding of male and female faces. These results suggest that adults with ASD do not encode gender information in faces in a significantly difference manner compared to typical individuals. The figural aftereffects paradigm is used widely for examining norm-based coding of faces, but has not before been used with individuals with ASD. The current study demonstrates that the figural aftereffects paradigm can be effectively used to examine norm-based coding in ASD.

The current results differ from that of previous studies examining face adaptation and norm-based coding in children with ASD. Using a different face aftereffects paradigm, Pellicano, Jeffery, Blurr, and Rhodes (2007) examined norm-based coding of facial identity in children with ASD, who showed smaller aftereffects overall compared to typical children, a finding which the authors interpreted as evidence of reduced norm-based coding of identity in children with ASD. Ewing, Pellicano, and Rhodes (2013) reported that children with ASD show smaller figural aftereffects for upright faces compared to typical children. Ewing and colleagues (2013) also reported diminished identity aftereffects in children with ASD in an experiment that controlled attention to adapting stimuli. The most obvious difference between the current study and those that have reported atypical face adaptation in ASD is the age of participant groups. Previous studies with typical children have demonstrated norm-based coding of identity in children as young as four years (Jeffery, Read, & Rhodes, 2013) and figural aftereffects in children as young as five (Short, Hatry, & Mondloch, 2011). It is possible that the development of norm-based coding is delayed in autism, possibly because of reduced orienting to faces (Osterling & Dawson, 1994; Baranek, 1999; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Dawson et al., 2004). Indeed, Cook and colleagues also reported no group differences in identity and expression aftereffects in adults with ASD. While all of these studies use different methods to examine face adaptation (which makes direct comparison of results across studies difficult), the clear difference in findings between studies with children versus adults with ASD warrants further investigation. It may be that there is a delay in the development of norm-based coding in individuals with ASD. Further experiments with a diverse age range of individuals with ASD are needed to better understand the developmental trajectory of norm-based coding in autism.

The results of both Experiment 1 and 2 raised some interesting methodological questions. In Experiment 1, participants in both groups who were adapted to contracted faces showed larger aftereffects compared to those who were adapted to expanded faces. This finding has been demonstrated in previous studies employing the figural aftereffects paradigm (Jaquet et al., 2008; Short, Hatry, & Mondloch, 2011). The contracted and expanded distortions are thought to be physically equal amounts of opposite distortion, however these results suggest that they are not psychologically equally distorted. Perhaps the contracted distortion is a more extreme distortion perceptually. In addition, the contracted adaptation conditions reliably created aftereffects for the same gender of test faces as well as the opposite gender, but this was not the case for expanded adaption. In Experiment 1 participants who were adapted to expanded faces showed significant aftereffects for the same gender of test faces, but not the opposite. In Experiment 2, participants were adapted to both expanded and contracted faces, but showed large contracted aftereffects for both male and female faces. These results as well as those of previous studies employing similar methods suggest that contracted distortions create larger and more robust aftereffects than expanded distortions.

In keeping with the norm-based coding model of figural aftereffects, the finding that the contracted and expanded figural distortions create different patterns of aftereffects suggest that the contracted distortion creates adaptation in the neural populations common to both categories of faces, while the expanded distortion does not. Other studies have used expanded and contracted distortions in adaptation paradigms and found distinct expanded and contracted aftereffects (Jaquet et al, 2007; Jaquet et al, 2008; Anzures, Mondloch, & Lackner, 2009; Short et al, 2011). The results of the current experiments, which used identical methods as the previously mentioned studies to create the expanded and contracted stimuli, warrant further investigation into the methodological utility of these distortions for examining whether two categories of faces are encoded with separate or distinct neural populations.

Conclusions.

The current study employed a figural face aftereffects paradigm to examine face adaptation and norm-based coding of face categories in high-functioning adults with autism. In two experiments, ASD participants showed aftereffects in the direction and magnitude as typical participants for male and female faces. These are the first experiments to use the figural face aftereffects paradigm with a group of adults with ASD, and results demonstrate that this experimental tool, which has been widely used with typical populations, may be used to explore norm-based coding in this special population known to have deficits in several areas of face processing. The results of the expanded condition in Experiment 1 provide some evidence that adults with ASD show separate aftereffects for male and female faces just as typical individuals do, suggesting distinct neural coding of these two face categories. In both experiments the interesting difference in results between the expanded and contracted distortions suggests that these two manipulations do not create equal adaptation effects.

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Tables

Table 1

Chronological age and IQ of participants.

	ASD (n = 20)			Typical (n = 20)			Group Difference	
	Mean	SD	Range	Mean	SD	Range	$t(38)$	p
CA (years)	26.8	5.29	18-39	29.5	7.38	20-47	-1.31	.20
Verbal IQ	95.90	13.51	76-125	97.00	12.92	70-120	-.26	.79
Performance IQ	100.35	13.48	81-138	96.70	17.41	63-125	-.74	.46
Full Scale IQ	97.25	11.36	77-117	97.60	14.01	73-116	-.09	.93

CA = chronological age

Table 2

ADOS scores for ASD participants

	Mean	SD	Range
Communication	4.3	2.30	2-9
Reciprocal Social Interaction	8.35	3.18	2-16
Imagination/Creativity	1.4	0.87	0-3
Stereotyped Behaviours and Restricted Interests	0.55	1.61	0-7

Table 3

R^2 values for polynomial fits for male and female faces pre- and post-adaptation.

	ASD (n=20)	Typical (n=20)
	Mean R^2 (SD)	Mean R^2 (SD)
Male Faces Pre-Adaptation	0.77 (0.18)	0.80 (0.21)
Male Faces Post-Adaptation	0.76 (0.23)	0.87 (0.12)
Female Faces Pre-Adaptation	0.76 (0.20)	0.76 (0.27)
Female Faces Post-Adaptation	0.81 (0.17)	0.85 (0.15)

Table 4

Chronological age and IQ of participants.

	ASD (*n* = 22)			Typical (*n* = 22)			Group Difference	
	Mean	SD	Range	Mean	SD	Range	*t*(42)	*p*
CA (years)	28.5	8.04	19-58	29.41	9.00	20-50	.353	.73
Verbal IQ	98.73	13.24	75-125	93.95	12.97	70-117	1.21	.23
Performance IQ	99.64	13.60	81-138	99.36	16.31	70-125	.06	.95
Full Scale IQ	97.77	11.41	77-117	96.95	14.14	73-118	.211	.83

Table 5

ADOS scores for ASD participants

	Mean	SD	Range
Communication	4.86	2.33	2-9
Reciprocal Social Interaction	8.14	3.17	2-16
Imagination/Creativity	1.43	.87	0-3
Stereotyped Behaviours and Restricted Interests	.57	1.57	0-7

Table 6

R^2 values for polynomial fits for male and female faces pre- and post-adaptation.

	ASD (n=22)	Typical (n=22)
	Mean R^2 (SD)	Mean R^2 (SD)
Male Faces Pre-Adaptation	0.75 (0.20)	0.74 (0.21)
Male Faces Post-Adaptation	0.73 (0.27)	0.76 (0.20)
Female Faces Pre-Adaptation	0.71 (0.23)	0.78 (0.22)
Female Faces Post-Adaptation	0.65 (0.24)	0.74 (0.22)

Figures

Figure 1

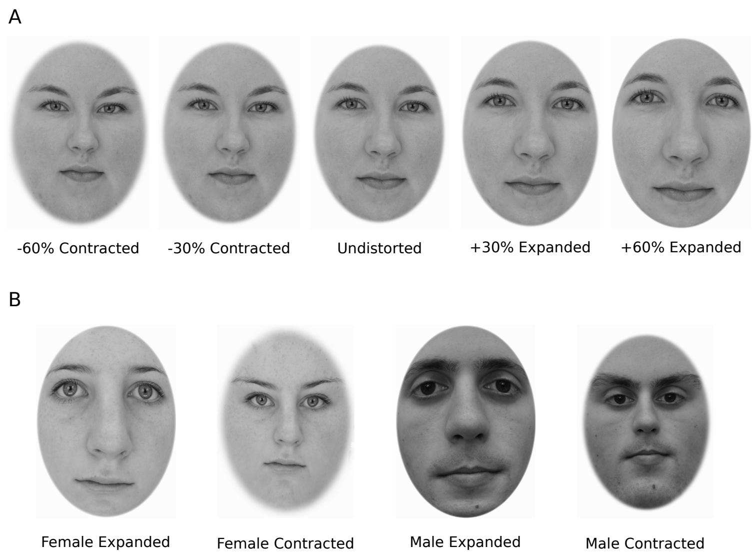

Figure 1. A) Example of faces used in the pre- and post-adaptation test phases. For each of the five male and five female models, nine different distortion levels were created (-60%, -45%, -30%, -15%, 0%, +15%, +30%, +45%, +60%). B) Example of faces used in each adaptation condition. Each condition consisted of one gender that was distorted in one direction. Participants were adapted to only one condition of faces.

Figure 2

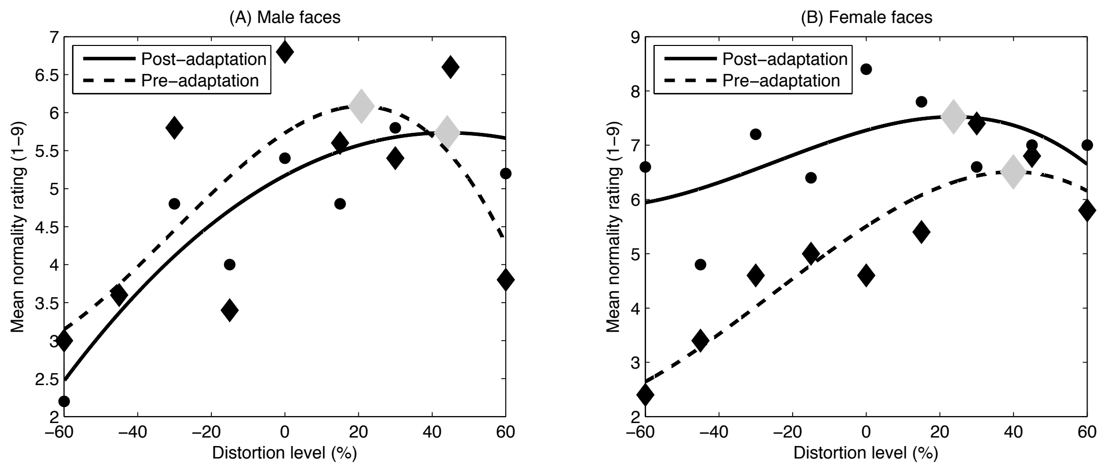

Figure 2. An example of mean Pre- and Post-Adaptation ratings for male and female faces for one ASD participant. Participants rated 10 individuals at each distortion level (average rating for each distortion level represented by black diamonds for pre-adaptation and circles for post-adaptation). The third-order polynomial function curve is shown. Mean pre- and post-adaptation ratings (i.e., the peak of the curve) were calculated and a third-order polynomial function was fit for each participant individually for males and females separately (represented by grey diamonds).

Figure 3

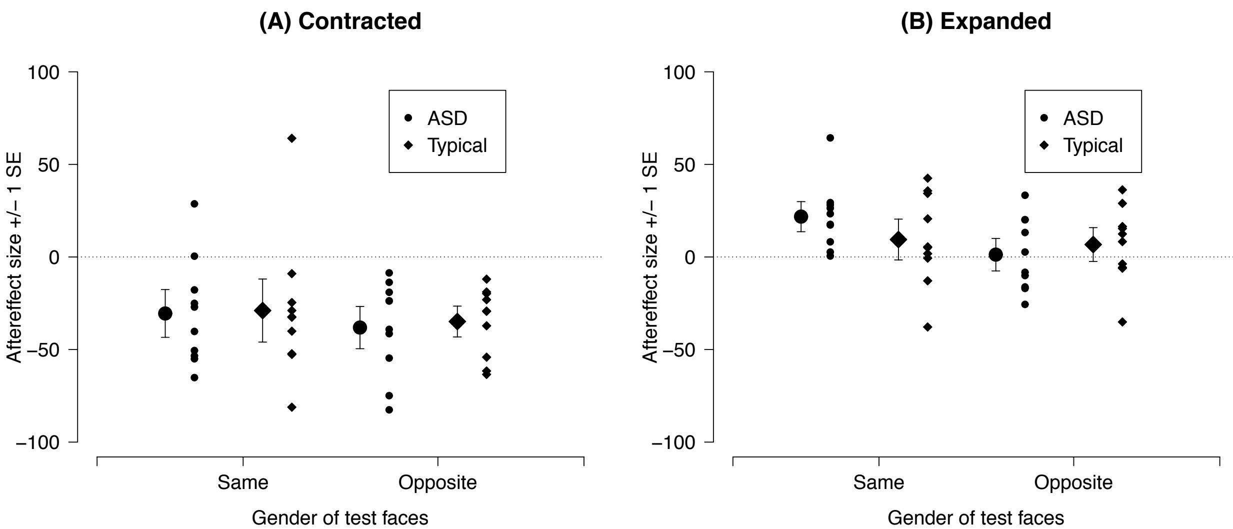

Figure 3. Aftereffects for same gender of test faces as adaptation faces and opposite gender of test faces as adaptation faces for expanded and contracted adaptation conditions. The dotted line represents zero change between pre-adaption normality ratings and post-adaptation normality ratings. Positive aftereffects indicated an increase in normality ratings for expanded faces, while negative aftereffects indicated an increase in normality ratings for contracted faces. Error bars represent the standard error of the mean.

Figure 4

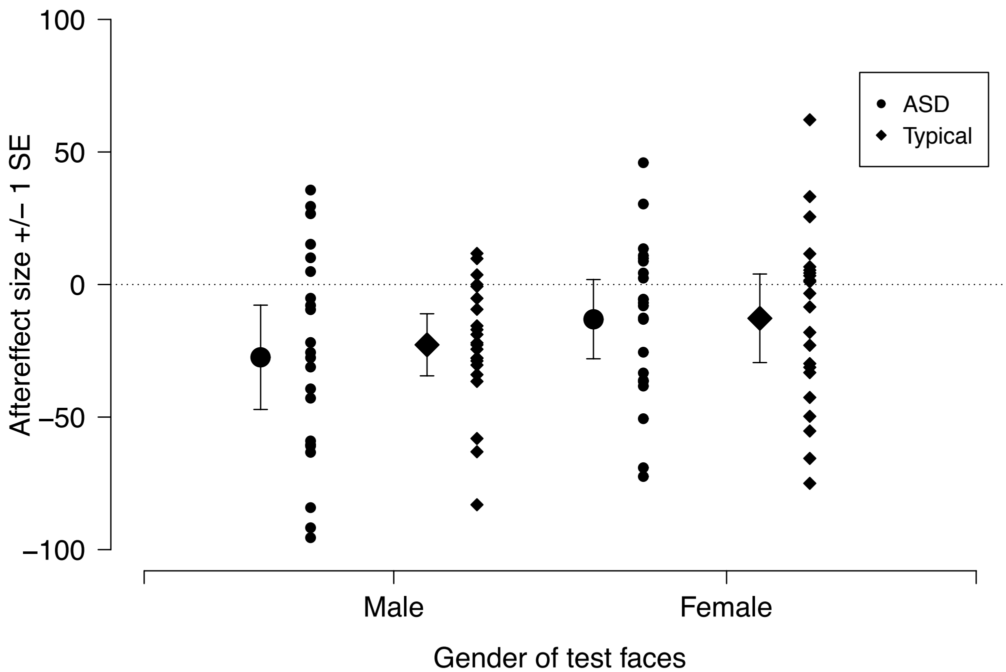

Figure 4. Aftereffects for female and males faces. The dotted line represents zero change between pre-adaption normality ratings and post-adaptation normality ratings. Positive aftereffects indicated an increase in normality ratings for expanded faces, while negative aftereffects indicated an increase in normality ratings for contracted faces. Error bars represent the standard error of the mean.

Chapter 4 – Study 3

Walsh, J. A., Vida, M. D., & Rutherford, M. D. (2014). Strategies for Perceiving Facial Expressions in Adults with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *44*, 1018-1026.

The ability to perceive and interpret other's facial expressions is essential for successful social interactions. Individuals with ASD have been shown to have a lack of interest in social stimuli from an early age and difficulties identifying and discriminating facial expressions. Previous research has demonstrated that adults with ASD employ an alternative perceptual strategy when processing line drawings of facial expressions; they appear to use a rule-based strategy (e.g., when the corners of the lips are turned down, that is a sad face) rather than the template matching strategy (e.g., this new face is similar to my representation of an average sad face, therefore it is a sad face) that typical adults are thought to employ. This hypothesis has yet to be examined with natural faces so it is unclear if adults with ASD also use an atypical rule-based strategy when processing emotional expressions in real faces. The current study measured adults with and without ASD's tolerance of exaggerated facial expressions. A rule-based strategy would lead to higher tolerance for exaggerated facial expressions because exaggerating the facial expression also exemplifies the rule. In contrast, a template matching strategy would be less tolerant of exaggeration as this creates expressions that are too dissimilar to the average representation that they are perceived as grotesque. Participants saw two happy or sad faces that differed in the level of exaggeration (from 100% to 300%) and were asked to choose which one looked like what real people look like when they feel happy or sad. In a separate task participants saw the same pairings of faces but we asked them to choose which face was more realistic. Finally, participants completed a discrimination task to assess their ability to discriminate the different levels of exaggeration. The results of this study provide evidence that adults with ASD rely more heavily on a rule-based strategy when processing emotional expressions, but not other types of facial information, such as how realistic a face is. These results may provide an explanation for why there are discrepancies between previous studies examining emotional expression processing abilities in ASD populations.

Abstract

Rutherford and McIntosh (2007) demonstrated that individuals with autism spectrum disorder (ASD) are more tolerant than controls of exaggerated schematic facial expressions, suggesting that they may use an alternative when processing emotional expressions. The current study was designed to test this finding using photographs of real people. In addition, two control tasks were added to eliminate alternative explanations. We replicated the findings of Rutherford and McIntosh (2007) and also demonstrated that adults with ASD do not show this tolerance when evaluating how realistic the expressions are. These results suggest adults with ASD employ a rule-based strategy to a greater extent than typical adults when processing facial expressions but not when processing other aspects of faces.

Introduction

Individuals with autism spectrum disorder (ASD) display deficits in three main areas; communication, social interaction, and restrictive and repetitive behaviours and interests (American Psychiatric Association, 2002). The social deficits that are characteristic of ASD are perhaps the most devastating (Volkmar, Sparrow, Goudreau, Cicchetti, Paul, Cohen, 1987; Wing & Gould, 1979). Disturbances in emotion understanding and perception exemplify such social deficits. Understanding the perception of facial expressions in individuals with ASD thus helps us understand the primary deficits in ASD. The current study focuses on the strategies used in the perception of emotional facial expressions.

There is not currently a consensus regarding strengths and deficits in emotional face processing in autism (see Jemel, Mottron, & Dawson, 2006, for review). Some studies have reported deficits in matching facial expressions (Celani, Battacchi, & Arcidiacono, 1999) or intermodal perception of expressions (Loveland et al., 1995). Individuals with ASD appear to scan expressive faces differently than typical individuals (Pelphrey et al., 2002) and may focus more on individual features than typical individuals do (Klin, Jones, Schultz, Volkmar & Cohen, 2002). Gross (2004) demonstrated that children with ASD focused on the lower portions of the face when processing facial expressions, and performance of children with ASD did not improve when the whole face, rather than isolated parts, was presented, as it did for typical children. Spezio, Adolphs, Hurley & Piven (2007) reported that although high-functioning adults with ASD correctly identified facial expressions in a "Bubbles" task, which presents faces with only randomly selected visible parts, they used an abnormal strategy to complete the task. As a whole, this evidence suggests that individuals with ASD may rely on the individual features to a greater extent than typical individuals when processing emotional facial expressions.

Others have not found any group differences in expression processing (e.g., Ozonoff, Pennington, & Rogers, 1990; Gepner, Deruelle, & Grynfeltt, 2001). One possibility for the discrepancies in results across studies is that while typical individuals use specialized, automatic perceptual processes, those with ASD may employ an alternative, more deliberate strategy for processing faces and emotional facial expressions (see Harms, Martin, and Wallace, 2010, for review). McParland, Dawson, Webb, Panagiotides, and Caver (2004) reported that individuals with ASD showed longer latencies for the face sensitive N170 ERP component for faces compared to objects, indicating slower information processing speed specific for faces. Behrmann et al. (2006) reported that while there were no group differences in accuracy between ASD participants and controls for identity and gender face processing tasks, the ASD participants had slower reaction times even though the authors employed several methods to control for overall group differences in processing speed. Capps, Yirmiya, and Signman (1992) reported that although children with ASD did not demonstrate difficulties on tasks involving labeling emotions, they took longer to answer and their answers sounded rehearsed. Taken together, these studies suggest that individuals with ASD may use an atypical, less automatic strategy when processing facial expressions.

If typical emotion perception involves specialized perceptual processes such as an intuitive and automatic prototype matching strategy, while those with ASD lack this intuitive and automatic perception of facial expressions, those with ASD might rely on an alternative compensatory strategy to process facial expressions. For example, those with ASD might use a rule-based strategy whereby memorized lists of characteristics define emotional expressions, leading them to look for the presence of these specific characteristics when performing emotional perception tasks. For example, if the “rules” for sadness (corners of the mouth turned down, lowered eyebrows) are present in a face display, then the face is labeled sad. The more of these rules that are present or the more intense they are, the more likely it is to be perceived as a better representation of a sad face.

An experimental design that manipulates the level of exaggeration in emotional facial expressions has been used to test the idea that individuals with ASD employ a rule-based strategy when processing emotional expressions, while typical individuals do not. Rutherford and McIntosh (2007) presented participants with stylistic drawings of faces displaying each of the six basic emotions (happy, sad, fear, anger, disgust, surprise). The faces within each emotion category varied on level of intensity, and included unnaturally exaggerated expressions. Participants were presented with pairs of faces displaying the same emotion at different levels of intensity and asked to choose the face that looked like a real person would if they were really feeling that emotion. The results indicated that participants with ASD were more likely than typical participants to choose the most exaggerated faces. The authors suggested that participants with ASD were employing a deliberate rule-based emotion perception strategy whereas the typical participants were employing an intuitive prototype matching strategy. For participants with ASD, the more exaggerated faces better exemplified the "rules" or feature characteristics for each emotion and therefore were likely accepted as a better representation of the given emotion.

The current experiment is designed to replicate the findings of Rutherford and McIntosh (2007) using more ecologically valid stimuli and to provide stronger evidence that individuals with ASD use an alternative strategy when processing facial expressions. Specifically, we used a task similar to that of Rutherford & McIntosh (2007) here called the Emotions Task, to examine whether typical individuals and those with ASD employ the same types of strategies when perceiving emotional expressions of photographic images of faces. In addition, the current study has two new control tasks that are designed to further test the hypothesis that the rule-based strategy used by those with ASD to perceive emotional facial expressions is specific to categorizing expressions, and not used in face processing generally. In the Realism Task, we use the same photographs and procedure as the Emotions Task, but we ask participants to judge how realistic the faces are. We expect results in the Realism Task to differ from those in the Emotions Task, because the rule-based strategy, by hypothesis, is used to categorize emotions and would not be relevant to the Realism Task despite the fact that the faces show emotional expressions. We also added a Discrimination Task to ensure that all participants, particularly the ASD group, are able to discriminate between all the faces used in the experiment. Results from this control task will allow us to ensure that any group differences found in the Emotions and Realism Tasks are not a result of ASD participants not being able to discriminate among the levels of expression exaggeration.

Method

Materials.

Photographs were taken of 3 male and 3 female undergraduate students displaying happy, sad, and neutral facial expressions. Using PsychoMorph face morphing software (Tiddeman, Burt & Perrett, 2001; Tiddeman, Burt & Perrett, 2005) composite faces comprised of all six faces were created for each facial expression. The composite faces were created by first placing many individual point-landmarks on each individual face, then averaging the position of each landmark across the individual faces to create an average face shape, and finally averaging the colour content across the individual faces. From these composite, or 100% expression, photographs, a continuum of varying intensity levels was created for each emotion. These were created by calculating the physical difference between the neutral and happy/sad composite faces and then extrapolating beyond the 100% face in 50% increments to create the different levels of exaggerated faces (Calder, Rowland, Young, Nimmo-Smith, Keane, & Perrett, 2000). Each continuum included 5 images; 100%, 150%, 200%, 250%, and 300%. The eye and mouth areas from these faces were pasted onto the same neutral face outline to create face images used in the experiment (see Figure 1) so as not to change the contour of the face between individual faces. The final set of stimuli was comprised of 10 greyscale images, cropped to 950 by 450 pixels. All tasks were presented and data was compiled in MatLab Student Version 7.4 on the same 17-inch desktop Macintosh Dual 2.7 GHz PowerPC G5 computer with OS X operating system. Participants sat with their chin in a chin rest 60cm from the monitor.

Participants.

Participants were 20 high-functioning adults (13 males, average age 26.85 years, range 18 to 39) with a diagnosis of autism or Asperger's syndrome and 19 typical adults (16 male, average age 28.95, range 20 to 40). The groups did not differ in chronological age and IQ (see Table 1 for demographic information).

Participants with ASD were recruited from a local assisted living group home as well as from a database of individuals who had previously participated in research studies in our lab. The typical participants were recruited off-campus, via online advertising. Those with ASD were free from other medical conditions. The participants with ASD had been given a diagnosis of autism or Asperger's by outside agencies, and were also evaluated using the ADOS-G (Lord et al., 2000) Module 4 to confirm diagnosis and group membership for this study, see Table 2. All participants had normal or corrected to normal vision. Participants were given a small honorarium for their participation in the study.

Procedure.

Each participant completed the following tasks, in the following order: the Emotions task, the Realism Task, and the Discrimination task. For the Emotions task, participants completed a forced-choice key press task for two side-by-side face images depicting two different levels of intensity of the same emotion. For the test trials, happy and sad faces were presented in separate blocks and the order of blocks was counter balanced across participants. Participants saw each possible pair of the 100%, 150%, 200%, 250%, and 300% images twice, to balance the side each level of exaggeration was presented on. In total there were 20 trials presented in a pseudo-random order for each block. For each trial, two images displaying the same expression were displayed side-by-side and the question *"Which one looks like a REAL person looks if they feel happy/sad?"* appeared at the top of the computer screen. Participants pressed the "A" key, which was labeled "Left" with a removable paper label for the face on the left and the "L" key, which was labeled "Right" for the face on the right. The images remained on the screen until the participant made their response, and then the next trial immediately began. Participants were told that all the faces were created by the computer, so none of them were actual real people's faces, but they should chose the one that was closest to what real people look like when they feel that emotion.

Prior to the test trials, participants completed 16 practice trials consisting of happy, sad, and neutral faces each paired with each other and paired with each test question. Participants were required to obtain 75% accuracy before moving onto the test trials and were allowed up to three attempts to reach this criterion. These trials were included to ensure that participants understood the question being asked and the key press procedure. All participants in both groups met the criterion on the first or second attempt.

The Realism task was identical to the Emotions task except that participants were asked; *"Which face is the most realistic?"*

The Discrimination task was designed to evaluate whether participants were able to discriminate between the various levels of exaggeration. Participants completed a forced-choice key press task for three images that were displayed in a triangle configuration. The three faces displayed the same emotion, however two images were the same intensity level (e.g., 100%) and one target image was a different level of intensity (e.g., 200%). The location of the target image (the different exaggeration level) was randomly selected. The question *"Which one is different from the other two?"* appeared at the top of the computer screen. Participants pressed 1, 2, or 3 on the number pad. The face images remained on the screen until the participant made their response. The next trial immediately began after the participant made their response. Each intensity level was paired with each other level twice, once as the target face and once as the distractor, for a total of 20 trials for each block. Happy and sad images were presented in separate blocks and the order of blocks was the same as the participants had completed the Emotions and Realism tasks and was counterbalanced across participants. The entire session lasted approximately 30 minutes.

Results

We analyzed responses to happy and sad facial expressions separately for the Emotions and Realism tasks. The analysis was conducted on the number of trials participants chose a selection of the exaggerated faces; 150%, 200%, 250%, and 300% faces across all trials that each face was presented. Although our main focus was the influence of exaggeration of facial expressions on participants' responses, we also analyzed participants' election of the non-exaggerated faces (100%) separately. This analysis was done to test our prediction that the ASD group would be more tolerant of exaggerated facial expressions in the Emotions Task, but not the Realism Task. We predicated that there would be group differences in the selection of the 100% faces in the Emotions task, but not the Realism task. Specifically, we predicted that the typical participants would choose the 100% face more often compared to the ASD participants. Because of the forced-choice design with every level paired with each other, each measure was not independent and therefore we could no conduct a single analysis including all levels.

Emotions Task.

A 2 (expression) x 4 (exaggeration level) x 2 (group) repeated measures mixed-model ANOVA was conducted on the number of times participants chose each exaggerated face (150%, 200%, 250%, and 300%) during the Emotions Task (a maximum of 8 trials). The results indicated a significant main effect of exaggeration level, $F(1,37) = 63.67$, $p < .001$, as well as a significant interaction between exaggeration level and group, $F(1, 37) = 9.32$, $p = .004$; see Figure 2. Follow up paired-samples t-tests were conducted between groups, collapsed across emotions, corrected for multiple comparisons with a Bonferroni correction ($\alpha = .0125$). These comparisons revealed significant group differences for the 150% faces $t(37) = -3.159$, p = .003, where typical participants chose this face on more trials ($M = 6.40$, $SD = .86$) than the ASD participants did ($M = 5.13$, $SD = 1.54$), as well as the 300% faces ($t(37) = 2.979$, $p = .005$) where the ASD participants chose these faces on more trials ($M = 2.45$, $SD = 2.81$) than the typical participants did ($M = .45$, $SD = .83$).

We conducted a linear trend analysis on participants' responses for the exaggerated faces. We tested the hypothesis that participants' responses followed the linear trend of decreasing as exaggeration level increased, which would indicate intolerance for exaggeration in the facial expressions. After confirming that both groups' linear contrasts were significantly different from zero, i.e., changing across exaggeration levels (all $p < .05$), we conducted a 2 (expression) x 2 (group) mixed model repeated-measures ANOVA on the contrast scores associated with the linear comparison. The results indicated a significant effect of group, such that the typical group had significantly higher contrast scores (*M* = 9.88, *SD* = 2.78) compared to the ASD group (*M* = 4.60, *SD* = 7.04), $t(37) = -3.05$, $p < .005$, indicating that the typical groups' responses were a closer fit to the expected linear trend. All other main effects and interactions were not significant.

We also examined the proportion of trials that participants chose the more exaggerated face of the pair across all 25 trials. A 2 (expression) x 2 (group) repeated measures mixed-model ANOVA revealed a significant main effect of group, $F(1,37) = 7.726$, $p = .009$, but not emotion, $F(1,37) = .646$, *ns*. Across emotions, ASD participants chose the more exaggerated face on more proportion of trials (*M* = .36, *SD* = .36) compared to the typical participants (*M* = .11, *SD* = .13); see Figure 3. The interaction between group and emotion was not significant.

Additionally, we examined whether the number of participants in each group who were using a rule-based strategy more exclusively during the Emotions Task (i.e., choosing the more exaggerated face on .8 or more proportion of trials) for either happy or sad faces differed between the ASD and typical groups. Seven out of 20 ASD participants chose the more exaggerated face on .8 or more trials for either the happy or sad task compared to one out of 19 typical participants. A difference of proportions test (Blalock, 1972) showed a significant difference between the two groups ($z = -2.10$, $\Phi = .37$, $p = .01$).

We also examined possible group differences in the number of times participants chose the non-exaggerated (100%) faces. A 2 (expression) x 2 (group) mixed model repeated-measures ANOVA revealed a significant effect of group, $F(1,37) = 5.62$, $p = .023$. Typical participants chose the 100% face on more trials ($M = 6.45$, $SD = 1.69$) compared to the ASD participants ($M = 4.45$, $SD = 3.28$).

Realism Task.

Parallel analyses were conducted on data from the realism task. A 2 (expression) x 4 (exaggeration level) x 2 (group) repeated measures mixed-model ANOVA was conducted on the number of times participants chose each exaggerated face during the Realism Task (maximum of 8 trials). The analysis revealed a significant main effect of level of exaggeration, $F(1,37) = 11491.06$, $p <.0001$); see Figure 4. All other main effects and interactions were not significant.

We conducted a linear trend analysis on participants' responses for the exaggerated faces. We tested the hypothesis that participants' responses followed the linear trend of decreasing as exaggeration level increased, which would indicate intolerance for exaggeration in the facial expressions. After confirming that both groups linear contrasts were significantly different from zero (all $p < .05$), we conducted a 2(expression) x 2 (group) mixed model repeated-measures ANOVA on participants contrast scores. The results indicated no significant main effects or interactions, all $p > .364$.

We examined possible group differences in the number of times participants chose the non-exaggerated (100%) faces. A 2(expression) x 2(group) mixed model repeated-measures ANOVA revealed no significant main effects or interactions (all $p > .149$).

Additionally, we examined whether the number of participants in each group who were using a rule-based strategy more exclusively during the Realism Task (i.e., choosing the more exaggerated face on .8 or more proportion of trials) for either happy or sad faces differed between the ASD and typical groups. No participants in either group chose the more exaggerated face on more than .8 percent of trials. In fact the highest proportion of trials that any participant in either group chose the more exaggerated face during the realism task was .5.

We also examined the proportion of trials that participants chose the more exaggerated face of the pair across the 25 trials (including those with the 100% faces). A 2 (emotion) x 2 (group) repeated measures mixed-model ANOVA revealed no significant main effects or interactions.

Reaction times on Emotions and Realism tasks.

To examine possible group differences in reaction time on the Emotions and Realism Tasks we compared participants' median response time. One participant from the ASD group was excluded from this analysis for having median responses times more than 3 SDs above the group mean, leaving 18 ASD participants and 19 typical participants in this analysis. A 2 (task type) x 2 (emotion) x 2 (group) repeated measures mixed model ANOVA revealed a significant main effect of task type, $F(1, 35) = 7.98$, $p = .008$; see Figure 5. Across the two groups and emotions, participants were significantly faster at the Realism Task ($M = 1.78$, $SD = .768$) compared to the Emotions Task (M = 2.82, $SD = 1.06$). The main effects of emotion and group were not significant, neither was the interaction between task type, emotion, and group (all $p > .328$).

Discrimination Task.

Participants' accuracy scores on the discrimination task were the proportion of trials on which they correctly chose the target image. A 2 (emotion) x 2 (group) repeated measures mixed model ANOVA was conducted on participants' accuracy scores. This analysis revealed no significant main effect of emotion, $F(1, 37) = 3.46$, $p = .071$, or group, $F(1, 37) = .026$, p = .872. The interaction between emotion and group was also not significant $F(1, 37) = 1.594$, $p = .215$.

We collapsed participants' accuracy scores across groups and conducted separate one-sample t-tests for happy and sad faces to see if participants' performed above chance, which would have been a proportion of .333. Participants' accuracy scores were significantly different from chance for both happy ($M = .956$, $SD = .075$; $t(38) = 52.26$, $p < .001$) and sad ($M = .94$, $SD = .078$; $t(38) = 48.01$, $p < .001$)

Discussion

The results of this study show that individuals with ASD are more tolerant of exaggeration when asked to identify happy and sad facial expressions. In the Emotions Task, when participants were asked which face was a better representation of what people actually look like when they feel happy or sad, individuals with ASD chose the most exaggerated (300%) face on more trials than the typical individuals and were also more likely to choose the more exaggerated face across all test trials than typical individuals. These results were present for happy and sad facial expressions. The linear trend analysis of participants' responses for the exaggerated faces (150%-300%) also revealed group differences in tolerance for exaggeration. Typical participant's responses showed a stronger linear trend compared to ASD participants' responses, indicating that the typical participants' responses decreased more with increased exaggeration compared to the ASD group. The results from the difference of proportion analysis demonstrated that while not every participant in the ASD group chose the more exaggerated face on every trial, a greater number of participants in the ASD group chose the exaggerated face on 80% or more trials, consistent with the idea that they were employing a more rule-based strategy, and doing so reliably. Taken together, the results of the current study are consistent with Rutherford and McIntosh's (2007) results with schematic drawings of facial expressions.

There is at least one important difference between our results from the Emotions Task and the results reported by Rutherford and McIntosh (2007), who found that ASD participants' responses consistently increased with increased exaggeration of facial expressions. In the current study, ASD participants' responses decreased with exaggeration, though significantly less than controls' responses decreased. Although ASD participants chose the more extremely exaggerated faces on more trials compared to typical participants, they did not exclusively chose the more exaggerated face as a better representation of the emotion expression. The differences between the two studies are most likely due to differences in stimuli: Rutherford and McIntosh used schematic line drawings, while we used photographs of real people, which are much more realistic than schematic line drawings.

The increased tolerance of exaggeration in happy and sad faces in the ASD group is consistent with the idea that these individuals rely to a greater extent than typical individuals on an explicit, rule-based strategy for processing these expressions. Such a strategy could lead an individual to base their judgments on the extent to which a particular defining feature, or rule, is present in the expression (e.g., the corners of the lips turned upward for happy expressions). Exaggerating the facial expression amplifies the presence of these defining characteristics, and would therefore make it a better example of that expression. If ASD participants are employing this type of strategy we would expect them to be more tolerant of the exaggerated facial expressions, choosing them more often than the control group does. Although the ASD group displayed this pattern of results for the Emotions Task, it is important to note that there were individual differences within the ASD group; not every participant chose the more exaggerated face on the majority of trials. However, more individuals in the ASD group appeared to be relying on this strategy, as revealed by the difference of proportion analysis, compared to typical individuals.

In contrast, if one is using a prototype matching strategy, then the more exaggerated faces will be further from the prototype and not consistent with what a typical happy or sad face would look like. After a certain level of exaggeration, the participants would reject the faces as being an appropriate representation of what people actually look like when they feel that particular emotion, because the exaggerated face is not compatible with their prototype for that expression. The typical participants appeared to use a prototype matching strategy, as they were less likely to choose the more exaggerated face of a trial pair in the Emotions Task.

Importantly, the current study revealed no group differences in performance in the

Realism Task. The Realism task was designed to examine whether individuals with ASD use an alternative rule-based strategy to process faces in a face perception task that does not require emotion perception, or if instead the rule-based processing is specific to expression processing. This task included the same faces as the Emotions Task, but required participants to choose the more realistic face. In this task, both groups were similarly intolerant of exaggeration, suggesting that the ASD individuals recognize that the more exaggerated faces are not realistic. The contrasting results of the Emotions and Realism tasks further supports the hypothesis that more individuals with ASD are using a rule-based strategy when processing the emotional content of faces, but not other aspects of the face such as how realistic it is.

The results of the Discrimination Task provide further evidence that the group differences in the Emotions Task are not an artifact of the autism group not being able to perceive the physical differences between the levels of exaggeration. For both happy and sad faces, the ASD and typical participants were able to successfully discriminate between each level of exaggeration. These results give further support that the results of the Emotions Task are due to each group employing qualitatively different strategies rather than an inability to discriminate the stimuli.

The notion that individuals with ASD develop an alternative compensatory strategy for processing facial expressions is in line with the current models of the social deficits characteristic of ASD, such as the social orienting hypothesis (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998). The social orienting hypothesis suggests that individuals developing with ASD fail to attend to social stimuli in their environment (e.g., faces) from an early age. This leads to these individuals missing crucial social information necessary for more complex social cognitive processes that emerge later in development, such as the perception of facial expressions. If individuals with ASD lack the early social experience that lead to the ability to automatically process facial expressions as typical individuals do, they maybe able to develop an alternative strategy that relies on explicitly learning the "rules" for each facial expression. For example, over time one might learn that happy faces always have the corners of the lips turn up, whereas sad faces always have the corners of the lips turned down. Although the current study did not directly examine why individuals with ASD use a rule-based strategy or why it develops in individuals with ASD, the results clearly show that they use this alternative strategy when processing the emotional content of faces, but not other information, such as how realistic a face is. These findings may be useful for those developing treatment and intervention focused on improving facial expression processing skills, as they suggest that explicit teaching of the characteristics of each facial expression may be necessary for those with ASD.

The idea that individuals with ASD use a different type of strategy to process facial expressions may explain, at lest to some extent, why some studies have found group differences in emotional perception (Celani, Battacchi, & Arcidiacono, 1999) and others have not (Castelli, 2005; Spezio, Adolphs, Hurley & Piven, 2007). In their review of dozens of studies examining facial expression processing in individuals with ASD, Harms, Martin, and Wallace (2010) noted that along with demographic factors, differences in task demands across studies might account for the majority of discrepancies in results. Experimental paradigms that make expression processing more difficult (e.g., short presentation time, or presenting inconsistent information) may limit individuals' ability to use more practiced, cognitive based strategies, which may exaggerate group differences in performance. In contrast, other paradigms may facilitate ASD participants' use of their alternative strategy and show similar results in performance as typical individuals.

One might expect that if individuals with ASD rely to a greater extent than typical individuals on a rule-based strategy to process facial expressions, the greater cognitive demands of such a strategy would lead to greater response times in the ASD group. However, we observed no group differences in response times in the current study. It may be the case that with sufficient experience applying this strategy to process facial expressions, high functioning adults with ASD become very efficient employing this strategy. One possible limitation in the current study is that although the stimuli used in this study were created from photographs of real people, the final stimuli only displayed the internal features of the face, which may not match the way faces are typically viewed in the real world. Future research could repeat the current study using faces that include the hair and external contour of the faces in order to more closely match the way faces are seen in the real world. Although we would not predict that excluding these features would influence individuals' processing of the facial expressions, it would be an important follow up to ensure the results truly generalize to how faces are processed in the real world. Also, the faces in the current study were static photographs. To further improve the ecological validity, future studies should examine whether the same results are found with dynamic faces.

In summary, the current study demonstrated that individuals with ASD are more tolerant of exaggeration in happy and sad facial expressions of naturalistic faces. Participants with ASD were more likely than typical participants to choose the most extreme exaggerated facial expression (300%) as an accurate representation of what people actually look like when they feel happy or sad. The ASD group's tolerance for exaggeration could result from greater reliance on a rule-based strategy to complete the task compared to typical participants. Interestingly, when asked about how realistic the same faces were, there were no group differences; both groups were intolerant of exaggeration of the facial expressions. This result suggests that group differences in strategies employed during face perception are limited to tasks that focus on the emotional content of faces rather than other physical characteristics.

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Tables

Table 1

Chronological age and IQ of participants.

	ASD (*n* = 20)			Typical (*n* = 19)			Group Difference	
	Mean	SD	Range	Mean	SD	Range	*t*(37)	*p*
CA (years)	26.85	5.33	18-39	28.95	5.93	20-40	-1.16	.252
Verbal IQ	96.6	13.16	75-125	98.53	14.54	77-122	-.434	.831
Performance IQ	100	13.74	81-138	95.16	15.08	63-121	1.05	.301
Full Scale IQ	97.75	10.91	77-117	96.16	15.08	77-121	.141	.889

CA = chronological age

Table 2

ADOS scores for ASD participants.

	Mean	SD	Range
Communication	4.15	2.48	0-9
Reciprocal Social Interaction	8.65	2.83	3-16
Imagination/Creativity	1.5	.89	0-3
Stereotyped Behaviours and Restricted Interests	.25	.55	0-2

Figures

Figure 1

Figure 1. 100%, 150%, 200%, 250% and 300% happy and sad faces

Figure 2

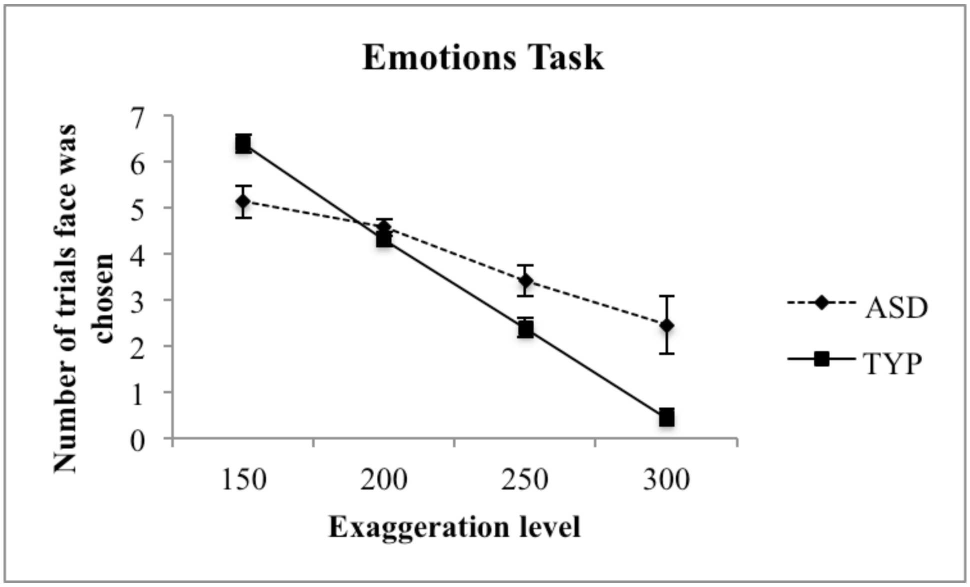

Figure 2. Number of trials participants chose each exaggerated face during Emotions Task, collapsed across happy and sad emotions. Error bars represent standard error of the mean.

Figure 3

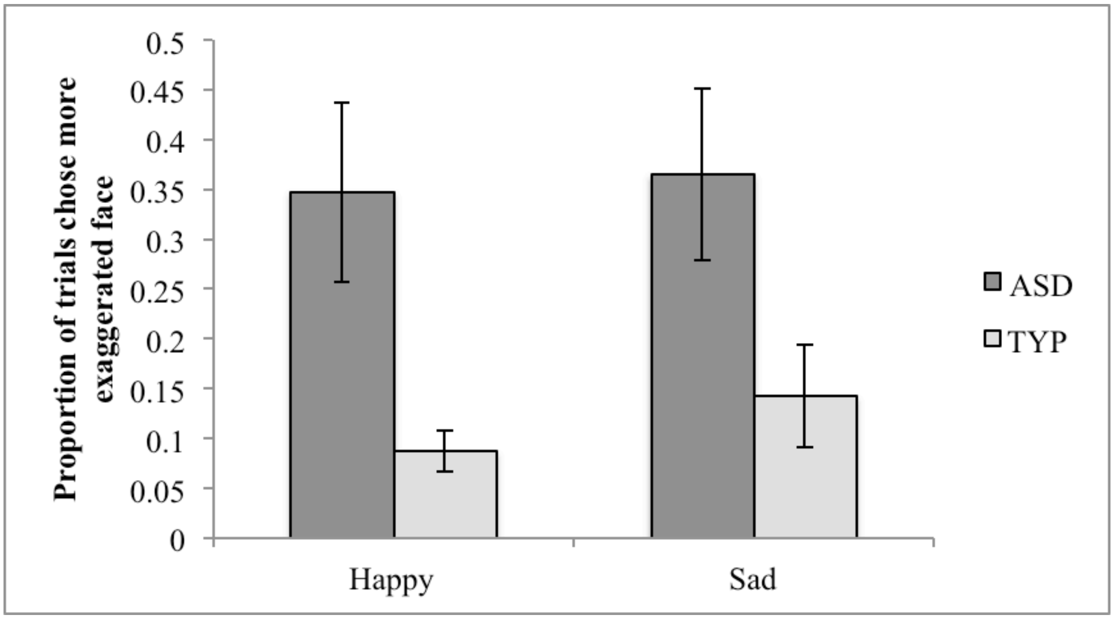

Figure 3. Proportion of trials participants chose the more exaggerated face during the Emotions Task. Error bars represent standard error of the mean.

Figure 4

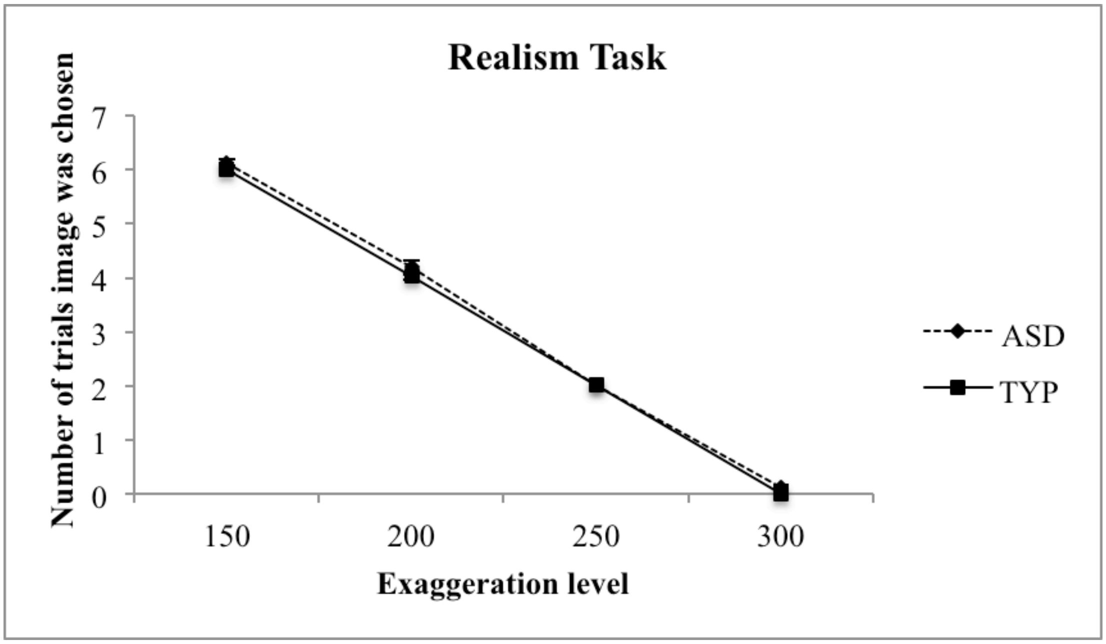

Figure 4. Number of trials participants chose each exaggerated face during Realism Task, collapsed across happy and sad emotions. Error bars represent standard error of the mean.

Figure 5

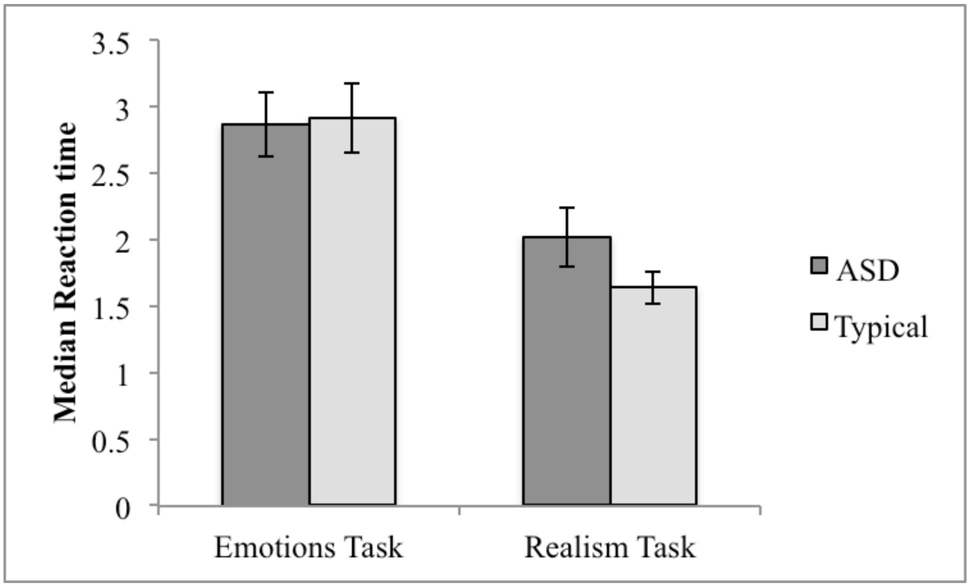

Figure 5. Median response times, collapsed across emotions. Error bars represent standard error of the mean.

Chapter 5 – Study 4

Emotion perception or social cognitive complexity: What drives face processing deficits in autism spectrum disorder? Walsh, J. A., Creighton, S. E., & Rutherford, M. D.

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Faces convey a wealth of socially relevant information such as one's sex, identity, age, ethnic group, and internal emotional state. Typical individuals are experts at encoding and interpreting facial information. Individuals with ASD have been shown to have difficulties with social communication and interactions and there has been a great scientific focus on examining individuals with ASD's ability to processing facial information. Still after decades of research there is not a clear consensus as to what the core deficits in face processing are characteristic of ASD. The current study examined whether the anomalies in face processing seen in adults with ASD are better explained by a deficit in processing facial expression information, or a deficit in processing complex social stimuli. Participants completed a battery of face processing tasks that either did or did not involve processing facial expressions, and also varied in the level of social cognitive complexity of the task. The results of the current study suggest that adults with ASD have a deficit limited to processing facial expressions, but are able to processing other types of facial information, such as identity and trustworthiness, typically. This study is an important contribution to the literature as it tested a relatively large sample of adults with ASD on a battery of face processing tasks with nearly identical task demands that assessed both emotional expression and non-emotional expression processing abilities which allows for comparison across tasks in order to assess the nature of the core deficit in face processing in ASD.

Abstract

Some, but not all, relevant studies have revealed face processing deficits among those with autism spectrum disorder (ASD). In particular, deficits are revealed in face processing tasks that involve emotion perception. The current study examined whether either deficits in processing emotional expression or deficits in processing social cognitive complexity drive face processing deficits in ASD. We tested adults with and without ASD on a battery of face processing tasks that varied with respect to emotional expression processing and social cognitive complexity. Results revealed significant group differences on tasks involving emotional expression processing, but typical performance on a non-emotional but socially complex task. These results support an emotion processing rather than a social complexity explanation for face processing deficits in ASD.

Introduction

Autism Spectrum Disorder (ASD) is defined by deficits in two areas: 1) Social communication and interactions, and 2) restricted patterns of behaviours and interests (American Psychiatric Association, 2013). Deficits in social communication comprise of a wide range of difficulties such as initiating and maintaining conversations, making appropriate eye contact, and understanding and interpreting social information. Faces provide a wealth of social information and typical adults are experts at processing facial information (see Maurer, LeGrand, & Mondloch (2002) for review).

Face processing in ASD.

There is a large literature that has focused on deficits in individuals with ASD in processing facial identity (see Weigelt, Koldewyn, & Kanwisher (2012) for review) and in processing emotional facial expressions (see Harms, Martin, & Wallace (2010) for review). With respect to processing facial identity, many studies have demonstrated that children and adults with ASD show several of the behavioural phenomena that are considered hallmarks of expert face processing in typical individuals (see Maurer, LeGrand, & Mondloch (2002) for review for behavioural markers of typical face processing expertise). For example, those with ASD have been shown to display typical face inversion effects (Lahaie et al., 2006; Rutherford, Clements, & Sekuler, 2007; Scherf, Behrmann, Minshew, & Luna 2008), whole-part effects (Joesph & Tanaka, 2003; Wolf et al., 2008; Faja, Webb, Merkle, Aylawrd, & Dawson, 2009), and composite face effect (Nishimura et al., 2008). In addition, Weigelt, Koldewyn,and Kanwisher (2013) demonstrated that individuals with ASD have a specific deficit in remembering face identities, however when memory demands are relieved, ASD participants perform similar to typical individuals. Together, these studies do not support the idea that individuals with ASD process facial identity in a qualitatively atypical way, although they may be less efficient at processing facial identity.

In contrast to facial identity processing, studies examining emotional facial expression processing have reported atypical performance in individuals with ASD. Rutherford, Troubridge, and Walsh (2012) reported that adults with ASD show atypical emotional expression aftereffects, suggesting that the psychological organization of emotional expressions is atypical in adults with ASD. Several studies have demonstrated that adults with ASD perform more poorly at labeling emotional expressions in comparison to typical adults (Howard et al., 2000; Dziobek, Fleck, Rogers, Wolf & Convit, 2006; Cordon, Chilvers, & Skuse, 2008; Bal et al., 2010). Walsh, Vida, and Rutherford (2014) examined cognitive strategies employed by adults with and without ASD while processing emotional expressions and reported that adults with ASD rely on an atypical rule-based strategy whereas typical individuals use the expected implicit template-matching strategy. Together the results of these studies, which examined emotional expression processing in adults with ASD, suggest atypical and poorer performance on behavioural tasks that involve emotional expression processing.

What drives deficits in emotional expression perception in ASD?

It may be that individuals with ASD have face processing deficits that are specific to processing emotional expression information in faces. However, processing emotional expressions can be considered a more socially cognitive complex task compared to processing other aspects of facial information, such as identity. Here we refer to social cognitive complexity as the degree to which a face processing task recruits higher-order social cognitive skills, such as evaluating and interpreting the internal state of a person, or assessing a social trait such as trustworthiness based on a photograph of a person. Some face processing tasks are less socially cognitive complex compared to others. For example, identity recognition, while computationally complex (recognizing an identity from hundreds previously encountered), is not as socially cognitive complex as emotional expression discrimination or recognition, which requires one to analyze a given facial expression , compare it to previous representations of facial expressions, and critically to infer the underlying internal emotional state.

The current literature does not definitively identify the source of the face processing deficit in ASD; it could be driven by a deficit in processing emotional expression information, or a deficit in processing socially complex information. Adolphs, Piven, and Sears (2001) examined adults with ASD's discrimination and intensity rating of basic emotional facial expressions (happy, sad, fear, disgust, surprise, and anger) as well as their ratings of trustworthiness and approachability. The authors reported that while the participants with ASD were able to discriminate and rate the intensity of facial expressions as well as typical participants were, their judgments of trustworthiness were atypical suggesting deficits in making certain social judgments of faces. The conclusions of this study are limited by the small sample size and the fact that the tasks for each type of face processing differed significantly from each other making it difficult to compare results across tasks. Also, there was no simple face identity task included, so one can not make conclusions about whether individuals with ASD have deficits in all tasks involving face processing, or deficits exclusively in tasks related to processing social information in faces. The current study used a relatively large sample of individuals with ASD to compare performance on several face processing tasks that varied with respect to emotion perception and social cognitive complexity.

The current study.

The current study was designed to test whether the facial expression content of the task or the level of social cognitive complexity drives deficits in face processing abilities in adults with ASD. We designed a battery of face processing tasks which ranged in social cognitive complexity, and also could be categorized as either involving emotional expression processing or not. Participants completed four tasks in the same order: Identification Task, Basic Expression Recognition Task, Complex Expression Task, and Trustworthy Perception Task. The Identification and Basic Expression Recognition tasks were relatively simple in terms of social cognitive complexity compared to the Complex Expression Recognition and Trustworthy Perception tasks. If the deficit in face processing in ASD is driven by deficits in expression processing, then the ASD group would perform worse than the typical group on the Basic and Complex Expression Recognition tasks, but show typical performance on the Identification and Trustworthy perception tasks. If, in contrast, the deficits are driven by the social complexity of the task, the ASD group would show poorer performance on the Complex Expression Recognition and Trustworthy tasks compared to the control group, but show typical performance on the Identification and Basic Expression Recognition tasks.

Methods

Materials.

Identification Task. Thirty-two greyscale images of eight male and eight female faces (two images of each of eight models with different lighting (e.g., direct vs. peripheral), one used as the model image and the other displayed as an option in the response screen) were used in this task. Half were used in the practice blocks and the other half were used in the experimental task. Each photo consisted of the model's face cropped with an oval mask to remove external features. Model images were displayed at a visual angle of 15.19° by 10.76° at a viewing distance on 60 cm. Response screen faces were displayed at a visual angle of 5.72° by 3.81° at a viewing distance of 60 cm.

Basic Expression Recognition Task. Thirty-two greyscale images of four male and four female models (different from above) each displaying four expressions (angry, fear, sad, happy) were used in this task. Images were taken from an established face database and had been validated in previous studies (Tottenham et al., 2009). The mean percent agreement across models for each expression was .93 for angry, .62 for fearful, 1 for happy and .82 for sad (Palermo & Coltheart, 2004). Each image was displayed at a visual angle of 15.19° by 11.42° at a viewing distance of 60 cm.

*Complex Expression Recognition Task***.** Thirty-two greyscale images of four male and four female models each displaying four expressions (arrogant, bored, flirtatious, and thoughtful) were used in this task (See Figure 1 for examples). The models wore the same shirt in all the photographs which were cropped just below the shoulders and included external facial features. Images were selected from a larger set of photographs based on percent agreement for each model across expressions. The mean percent agreement across models for each expression were calculated based on responses from 15 participants (4 males; mean age = 22 years) who did not participate in the current study and was .89 for arrogant, .84 for bored, .97 for flirtatious, and .95 for thoughtful. Each image was displayed at visual angle of 15.19° by 12.17° at a viewing distance of 60 cm.

Trustworthy Perception Task. Fourteen images of male models were used in this task. Images were selected from a larger set of photographs based on percent agreement for each model. The mean percent agreement for each category were calculated based on responses from 16 participants (5 males; mean age = 23.9 years) who did not participate in the current study and was .77 for trustworthy faces and .90 for untrustworthy faces. Each image was displayed at a visual angle of 15.19° by 12.37° at a viewing distance of 60 cm.

All stimuli were presented and data was compiled in MatLab Student Version 7.4 on the same Apple Macintosh mini Dual 2.7 GHz PowerPC G5 computer with OS X operating system with a 17-inch LCD monitor set to a resolution of 1280 x 1024 and a refresh rate of 60Hz.

Participants.

Participants were 23 high-functioning adults (5 females, average age 30.8 years, range 20 to 60) with a diagnosis of autism or Asperger's syndrome and 23 typical adults (5 female, average age 28.4, range 20 to 50). The groups did not differ in chronological age and IQ (see Table 1 for demographic information). Due to equipment failure, data was not saved for three ASD participants for the Identification Task, one ASD participant for the Basic Emotion Task, and two ASD participants for the Trustworthy perception Task. As a result the number of ASD participants varies across the four tasks.

Participants with ASD were recruited from a local assisted living group home as well as from a database of individuals who had previously participated in research studies in our lab. The participants with ASD had been given a diagnosis of autism or Asperger's by outside agencies, and were also evaluated using the ADOS-G (Lord et al., 2000) Module 4 to confirm diagnosis and group membership for this study, see Table 2. The typical participants were recruited off-campus, via online advertising. Participants were given a small honorarium for their participation in the study.

Procedure.

Prior to beginning the computer tasks, participants were asked to match the category labels used in the experimental tasks (i.e., anger, fear, happy, sad, arrogant, bored, flirtatious, thoughtful, trustworthy, and untrustworthy) with the correct definition. If a participant made a mistake, the experimenter corrected them and elaborated of the meaning of the word that was incorrectly matched. Once the participant understood all of the category labels, he or she began the experimental tasks. All participants completed the four experimental tasks in the same order: Identification Task, Basic Expression Recognition Task, Complex Expression Recognition Task, Trustworthy Perception Task. All four tasks were completed with participants seated such that their eyes were 60cm from the monitor with the lights on. The entire experiment took approximately 60 minutes to complete

For the Identification Task, participants completed a practice block in order to familiarize them with the task. Each trial began with a 500ms central fixation point. A single test face was displayed centrally on the screen for 250ms and then disappeared. A response screen appeared immediately with eight faces (four males and four females) each labeled with a number 1 through 8. Participants were asked to identify the face that they had seen via key press with unlimited response time. The next trial began after a 500ms intertrial interval (ITI). During the practice block, participants received feedback on their performance on each trial; a tone was emitted for each correct response, but not for incorrect responses. Each practice block consisted of 16 trials. If a participant was correct of 80% or more trials, the experimental task began. If their accuracy was below 80%, participants repeated the practice block for a maximum of three attempts. In the ASD group, one participant completed one practice block, five completed two practice blocks, and 14 completed three practice blocks. In the typical group, four participants completed one practice block and 19 completed three practice blocks. After three practice blocks, the experimental task began regardless of participants' accuracy. The experimental task consisted of the same trial sequence as in the practice block, however eight novel faces were used and no feedback was given to participants. The task consisted of 160 trials total; eight models appeared as the target identity 20 times. Trials were presented in a randomized order.

For the Basic Expression Recognition Task, each trial began with a 500ms fixation point, followed by a single face displayed for 250ms. Participants were asked' "*Which label best represents this facial expression?"* The labels angry, fearful, sad, and happy were written at the top of the response screen and participants responded via key press. The word labels remained on the screen until the participant made his or her response and then the next trial began after a 500ms ITI. The task consisted of 128 trials total; eight models for each of four expressions with each image repeated four times. Trials were presented in a randomized order.

For the Complex Expression Recognition Task, each trial began with a 500ms fixation point, followed by a single face displayed for 250ms. Participants were asked' "*Which label best represents this facial expression?"* The labels bored, flirtatious, thoughtful and arrogant were displayed at the top of the response screen and participants responded via key press. Word labels remained on the screen until the participant made his or her response and then the next trial began after a 500ms ITI. The task consisted of 128 trials total; eight models for each of four expressions with each image repeated four times. Trials were presented in a randomized order.

For the Trustworthy Perception Tasks, each trial began with a 500ms fixation point, followed by a single face displayed for 250ms. Participants were asked' "*Is this person trustworthy or untrustworthy?"* The labels trustworthy and untrustworthy were written at the top of the response screen and participants responded via key press. The word labels remained on the screen until the participant made his or her response and then the next trial began after a 500ms ITI. The task consisted of 140 trials total; 7 models from each category with each image repeated 14 times. Trials were presented in a randomized order.

Results

We calculated each participant's overall accuracy (the proportion of correct trials) for each of the four tasks. To compare performance between the ASD and typical groups we conducted a 4 (task type) x 2 (group) repeated measures mixed-model ANOVA, depicted in Figure 2. The results revealed significant main effects of task type, $F(3, 44) = 20.98$, $p<.001$, $\eta_p^2 =$, and group, $F(1,44) = 10.95$, $p = .002$. However, these main effects were qualified by a significant interaction between task type and group, $F(3,44) = 5.38$, $p = .002$. Follow up independent samples t-tests were used, corrected for multiple comparisons with a Bonferroni correction ($\alpha = .0125$). These comparisons revealed no significant group differences for the Identification Task, $t(44) = 1.33$, $p = .19$, or the Trustworthiness Perception Task, $t(44) = .93$, p = .36. For the Basic Expression Recognition Task, the ASD group ($M = .87$, $SD = .11$) were significantly less accurate compared to the typical group ($M = .94$, $SD = .03$), $t(44) = 3.06$, $p = .004$. Similarly, for the Complex Expression Recognition Task, the ASD group ($M = .69$, $SD = .19$) was significantly less accurate compared to the typical group ($M = .87$, $SD = 07$), $t(44) = 4.26$, $p <.001$.

Discussion

The current study was designed to examine whether face processing deficits in adults with ASD are driven by deficits in perceiving emotional expressions, or deficits in processing social cognitive complexity. If face processing deficits in ASD are restricted to tasks involving processing emotional expressions, the ASD group would perform poorly on the Basic and Complex Expression Recognitions tasks compared to the typical group, but no group differences in performance on the Identification and Trustworthy Perception tasks would be found. In contrast, if face processing deficits in ASD are driven by deficits in processing social cognitive complexity, there would be no group differences in performance on the Identification and Basic Expression Recognition tasks, which require relatively simple social judgments, but poorer performance in the ASD group on the Complex Expression Recognition and Trustworthy Perception tasks which involve more complex social cognitive judgments. The results of the current study supported our first hypothesis: participants with ASD showed poorer performance on the two expression recognition tasks. Conversely, we found no support for the second hypothesis: we found typical performance on the Identification and Trustworthy Perception tasks. This suggests that adults with ASD do not have a global face processing deficit, rather a restricted deficit in processing facial expression information in faces.

The results of the Identification Task in the current study contrast with the results of several previous studies, which used a similar delayed-match to sample tasks (although with fewer response options) and found poorer performance of the ASD participants compared to typical participants (Gepner, deGelder, & deSchonen, 1996; Scherf, Behrmann, Minshew, & Luna, 2008; Wilson, Brock, & Palermo, 2010). One key difference between the current study and previous studies is the ages of the participant groups. It may be that facial identity processing is atypical in children with ASD but reaches typical levels by adulthood. This may be a true developmental delay in ASD. Future studies should employ longitudinal designs in order to investigate the developmental trajectory of facial identity processing deficits in individuals with ASD.

The current study demonstrated that individuals with ASD were able to make perceptual judgments of the trustworthiness of faces similar to that of typical adults.

These results contrast with those of Adolphs, Piven, and Sears (2001) who reported that adults with ASD gave abnormally high trustworthiness rating to those faces that were consistently rated as most negative by other typical individuals. There are several differences between the current Trustworthiness Perception Task and the task used by Adolphs and colleagues. First the previous study only included five ASD participants, so the generalizability of the results is questionable. Another key difference between the two studies is the nature of the experimental tasks. In the current study, participants were asked to make a forced choice response indicating if they thought each face was trustworthy or untrustworthy. Adolphs, Piven, and Sears (2001) had participants rate the trustworthiness each face. It may be that this type of task is too unclear to the ASD participants, whereas a forced-choice type of task constrains responses, making the task more tractable. Interestingly, in the Adolphs, Piven, and Sears (2001) study participants also rated the approachability of the same set of faces and there were no group differences in these ratings. This discrepancy between trustworthiness and approachability, which one would assume should be closely related, may suggest that the ASD participants' trustworthiness ratings are not reliable or valid. Perhaps they did not understand the task.

In the current study, adults with ASD showed poorer performance on both the Basic Expression and Complex Expression Recognition tasks. Previous studies measuring expression recognition in individuals with ASD have produced mixed results (see Harms, Martin, and Wallace (2010) for review). Some studies have found typical recognition abilities for basic emotions (e.g., Capps, Yirmiya, & Sigman, 1992; Adolphs, Piven, & Sears, 2001, Baron-Cohen, Wheelwright, & Jolliffe, 1997; Robel et al., 2004; Castelli, 2005; Loveland et al., 1997;) while others have found measurable deficits in recognition abilities (e.g. Bormann-Kischkel et al., 2005; Kuusikko et al., 2009, Phillp et al., 2010). Baron-Cohen and colleagues (1997) reported typical performance in recognition of basic emotional expression, but poorer recognition of complex facial expressions such as thoughtful, guilt, or scheming. The participants with ASD in the current study showed poorer performance in the recognition of both simple and complex emotional facial expressions.

There is no clear explanation in the current literature for the discrepancies in results among studies examining emotional expression recognition in individuals with ASD. Two studies have investigated the perceptual strategies employed by individuals with ASD when processing basic facial expression. Rutherford and McIntosh (2007) and Walsh, Vida, and Rutherford (2013) both found that adults with ASD rely on a deliberate, rule-based perceptual strategy when processing emotional information in faces, whereas typical participants use an intuitive, prototype-matching strategy to categorize emotional facial expressions. It may be that certain experimental designs facilitate the atypical perceptual strategy favored by those with ASD and therefore do not reveal group differences in labeling emotional expression perception. In this case, there would be no group differences in accuracy, even if the two groups were employing different perceptual strategies to complete the task. Other experimental designs may not allow the use of a learned rule-based strategy (e.g., because of time limits, or using complex and less common facial expressions) and therefore find significant group differences in recognition accuracy.

The findings of Baron-Cohen, Wheelwright, and Jolliffe (1997) indirectly support this explanation, as they found no group difference in recognition of basic emotional expression, but group differences in recognizing complex facial expression. It may be that adults with ASD are able to use an alternative rule-based strategy to recognize basic emotions and therefore are as accurate in recognizing these expressions, However, complex emotional expressions are less frequently encountered and have overlap between exemplars making it difficult to develop an explicit rule-based perceptual strategy to recognize these expressions. While the current study was not a direct test of this hypothesis, it does provide indirect support as both emotional recognition tasks would have made it difficult for ASD participants to employ an alternative learned perceptual strategy because of the brief stimulus presentation time and the use of complex and less common expressions.

Conclusions

The current study directly compared the performance of a relatively large sample of adults with ASD and a matched control group on four comparable face perception tasks that involved identity, basic emotional expression, complex emotional expression, and trustworthiness perception. The performance of adults with ASD diverged from the typical group as emotion perception demands increased, but did not diverge as social complexity increased. These results suggest that face processing deficits, when seen in ASD populations, result from deficits in emotion perception, not in social complexity.

Future studies should focus on exploring the developmental trajectories of face processing deficits in individuals with ASD. It will be important to use similar face processing test batteries with children and adolescents with ASD in order to examine whether a similar pattern of face processing deficits is present throughout development for individuals with ASD. Future research should also examine the ability to process other non-emotional but social information in faces other than trustworthiness, such as attractiveness or friendliness, to further test whether adults with ASD have a global deficit in processing social information in faces.

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Tables

Table 1

Chronological age and IQ of participants.

	ASD (n = 23)			Typical (n = 23)			Group Difference	
	Mean	SD	Range	Mean	SD	Range	$t(44)$	p
CA (years)	30.8	8.54	20-60	28.39	9.33	20-50	.91	.37
Verbal IQ	97.39	12.09	75-114	94.83	14.01	70-127	.67	.51
Performance IQ	98.48	12.80	81-135	98.83	14.80	74-118	-.09	.93
Full Scale IQ	97.43	11.02	77-118	97.39	13.09	73-116	.01	.99

CA = chronological age

Table 2

ADOS scores for ASD participants

	Mean	SD	Range
Communication	4.64	2.46	1-9
Reciprocal Social Interaction	8.64	3.00	3-16
Imagination/Creativity	1.41	0.91	0-3
Stereotyped Behaviours and Restricted Interests	0.36	0.66	0-2

Figures

Figure 1

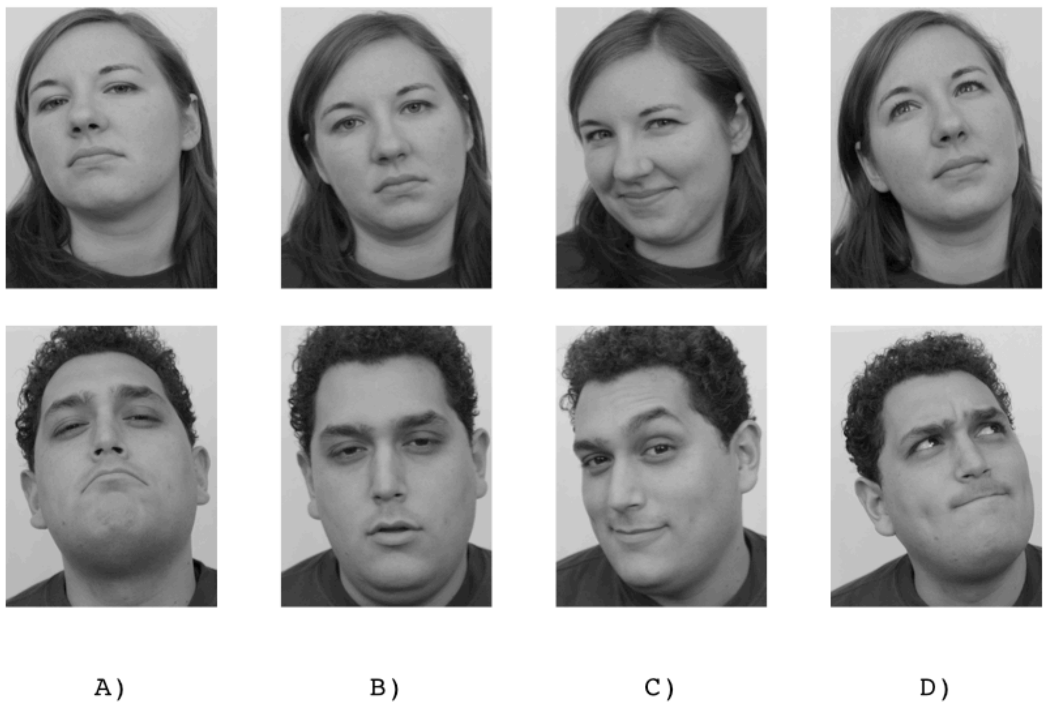

Figure 1. Examples of stimuli used in the Complex Expression Recognition Task. The Complex Expression Recognition Task included greyscale images of four males and four females display each of the following expressions: A) arrogant, B) bored, C) flirtatious, D) thoughtful.

Figure 2

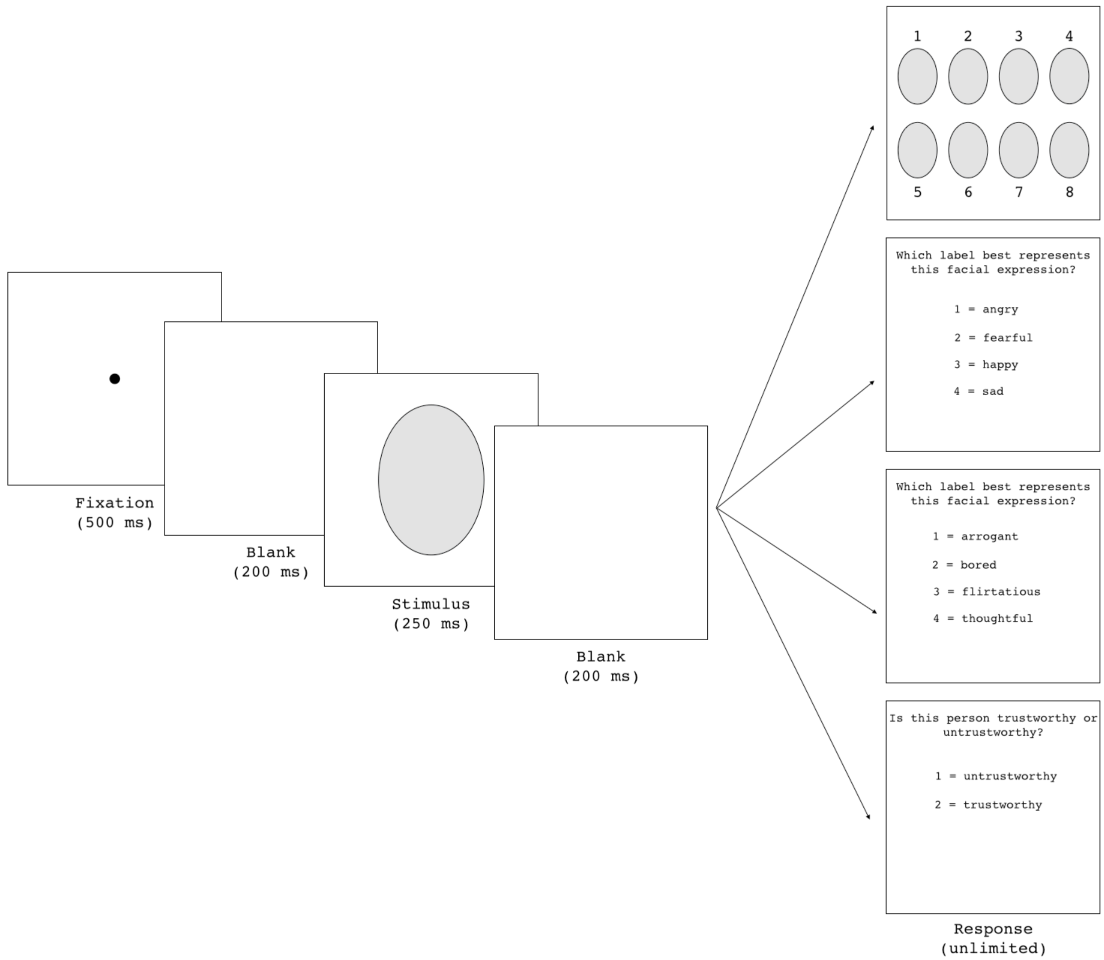

Figure 2. Trial sequence for the experimental tasks. All four tasks had the same trial sequence, however the response screen differed for each task.

Figure 3

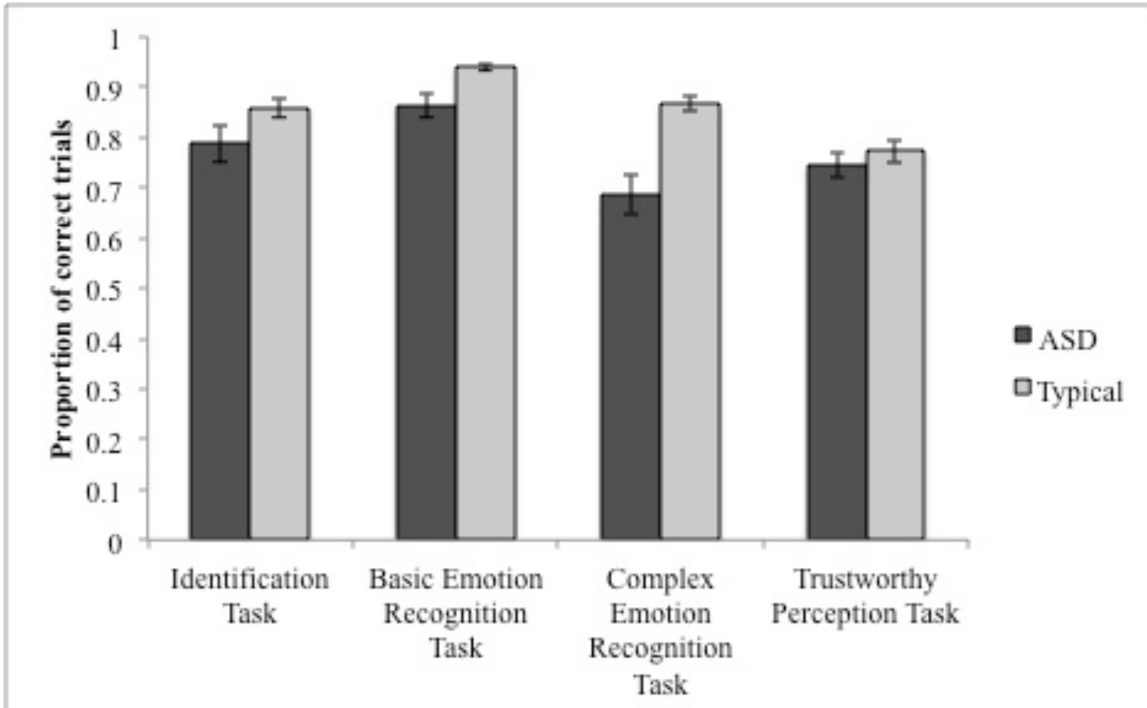

Figure 3. Accuracy across tasks. Proportion of overall correct trials for the Identification, Basic Expression Recognition, Complex Expression Recognition, and Trustworthy Perception tasks for adults with ASD and age and IQ matched typical adults. Results indicated no significant differences between groups in performance on the Identification and Trustworthy Perception tasks, but worse performance on the Basic and Complex Expression Recognition tasks for the ASD group compared to the typical group. Error bars represent the standard error of the mean.

Chapter 6 –Discussion

Summary

The series of experiments included in this thesis were designed to examine the nature of face processing deficits in adults with autism spectrum disorder (ASD). To test whether visual adaptation to faces and mechanisms that underlie face perception are atypical in adults with ASD, I examined norm-based coding of facial identity (Study 1) and gender (Study 2). In Study 1, I used a face identity aftereffects paradigm to measure identity aftereffects for adapting faces (i.e., anti-identities) that were either far from the average and therefore more extreme, or close to the average and therefore less extreme. This experimental design specifically tests for evidence of norm-based coding of facial identity, as the norm-based coding model would predict larger identity aftereffects for more extreme adapting faces in comparison to less extreme adapting faces. I found that adults with ASD show the same modulation in the size of identity aftereffects as a function of the eccentricity of the adapting face (i.e., larger aftereffects for extreme adapting faces compared to less extreme adapting faces), just as typical individuals do. These results provide the first evidence of norm-based coding of facial identity in adults with ASD.

In Study 2, I measured simple (Experiment 1) and opposing (Experiment 2) figural aftereffects for male and female faces in adult observers with ASD and matched typical participants. Previous research has demonstrated that these two categories of faces (male and female) have separable coding mechanisms, and therefore one can induce both simple and opposing aftereffects for male and female faces. In Experiment 1, participants were adapted to one of four adapting categories; contracted male faces, expanded male faces, contracted female faces, or expanded female faces. In Experiment 2, participants were adapted to contracted male faces and expanded female faces. In Experiment 1, both ASD and typical participants in the two expanded conditions showed the expected results; larger aftereffects in the expanded direction for the same gender of test faces that were seen during adaptation. However, both ASD and typical participants in the contracted conditions showed similar-sized aftereffects in the contracted direction for both genders of test faces. This difference in aftereffects for the contracted conditions was replicated in Experiment 2, as both ASD and typical participants showed significant contracted aftereffects for male and female test faces, even though they were adapted to contracted male faces and expanded female faces. While the results of these experiments raise interesting methodological questions about the use of the contracted figural distortion in facial aftereffects paradigm, the finding most relevant to thesis is that adults with ASD show significant figural aftereffects and no significant differences in the size and direction of simple and opposing gender aftereffects compared to typical participants, indicating that they are processing male and female faces in a similar manner as typical individuals.

In Study 3, I examined the extent to which adults with ASD employ an alternative rule-based strategy when processing facial expressions. Participants were shown pairs of happy or sad faces that differed in the level of exaggeration. In the Emotions Task, they were asked to choose the face that looked like what real people look like when they feel either happy or sad. In the Realism Task, they were asked to choose which face was more realistic. I measured how tolerant participants were of the exaggerated facial expression by examining the number of trials they chose each level of exaggeration in both tasks. I found that adults with ASD do appear to rely more heavily on this alternative strategy, as evidenced by their increased tolerance for exaggerated facial expressions. Interestingly, they appear to only rely on this alternative strategy when processing emotional information in faces, but not other types of facial information such as how realistic a face appears. The results of the Discrimination Task demonstrated that adults with ASD were as accurate as typical participants in discriminating between the various levels of exaggeration. This was the first study to examine the use of an alternative perceptual strategy during face perception tasks with photographs of real faces.

In Study 4, I tested whether the known face processing deficits in adults with ASD, deficits that are specific to emotion perception and not face perception more generally, are attributable to deficits in emotional expression processing or rather to deficits in processing socially complex stimuli. I tested adults with and without ASD on a battery of four face perception tasks that either did or did not require emotional expression processing, and also ranged in the level of social cognitive complexity: the Identification Task, Basic Expression Recognition Task, Complex Expression Recognition Task, and the Trustworthy perception task. The results indicated that adults with ASD showed significantly worse performance on the Basic and Complex Expression Recognition tasks, but typical performance on the Identification and Trustworthy Perception tasks. This pattern of results supports the hypothesis that adults with ASD have a specific deficit in processing emotional expression information in faces, but not other types of social and non-social facial information.

Taken together the results of this set of experiments suggest that the perceptual mechanisms underlying non-emotion based face perception (i.e., adaptation and norm-based coding) are intact in adults with ASD, and therefore they likely do not process facial information in a qualitatively different manner than typical individuals. Adults with ASD also appear to rely more heavily on an atypical rule-based strategy when processing emotional facial expressions, but not other aspects of facial information such as how realistic a face appears. Finally, adults with ASD appear to have a limited deficit on processing emotional facial expressions, but not other types of basic or socially complex facial information such as identity or trustworthiness.

Norm-based coding of facial information in adults with ASD

One of the main contributions of this thesis is the finding of intact figural aftereffects and norm-based coding of facial information in the ASD groups, which suggest typical adaptation and coding of facial information in adults with ASD. In Study 1, participants with ASD showed the same modulation of the size of identity aftereffects relative to the strength of adapting face. This pattern of results is predicted by the norm-based coding model of face perception (Rhodes & Leopold, 2011; Webster & McLeod, 2011) and has been demonstrated in typical children (Jeffery Rhodes, McKone, Pellicano, Crookes, & Taylor, 2011) and adults (Jeffery, Read, and Rhodes, 2013). In Study 2, adults with ASD showed the same size and direction of figural aftereffects for male and female faces as typical participants did. The results of Study 1 contrast those of previous research investigating adaptation and aftereffects for facial identity in children with ASD.

Pellicano, Jeffery, Burr, and Rhodes (2007) found that young boys with ASD showed significant, but diminished identity aftereffects in comparison to matched typical children. Similarly, Ewing, Pellicano, and Rhodes (2013) found that children with ASD show smaller figural aftereffects for upright faces, but not inverted faces or cars. Ewing, Leach, K., Pellicano, Jeffery, & Rhodes, (2013) reported that children with ASD show reduced facial identity aftereffects when attention to adapting faces is controlled. Additionally, Rhodes, Ewing, Jeffery, Avard, &Taylor (2014) used the same paradigm that we used in Study 1 and found that while children with ASD showed the same pattern of modulation in the size of aftereffects as a function of the strength of adapting face, overall they showed diminished aftereffects in comparison to typical children. Thus, the results of studies examining facial aftereffects in children with ASD suggest reduced adaptation, but intact norm-based coding.

There appears to be a developmental delay in typical facial adaptation between children and adults with ASD. The results of Study 1 and 2 are parallel to those reported by Cook, Brewer, Shah, and Bird (2014) who found that adults with ASD show typical aftereffects for emotional facial expressions and facial identity. This difference in results between studies examining face aftereffects in children versus adults with ASD suggest that there may be a delay in the development of typical face adaptation in ASD populations. This suggests that the participant age group may be an important factor in face adaptation research with ASD populations and that findings with either child or adults ASD populations may be specific to that age group and do not generalize to the other.

In Study 2 I demonstrated that adults with ASD show figural aftereffects for male and female faces that are similar to the aftereffects seen in typical participants. This is an important finding as it shows that adults with ASD are sensitive to figural distortions of faces and show adaptation to figural manipulations of facial features just as typical adults do. The figural aftereffects paradigm has been used extensively with typical populations (e.g., Little, DeBruine, & Jones, 2005; Little, DeBruine, Jones, & Waitt, 2008; Jaquet & Rhodes, 2008; Jaquet, Rhodes, & Hayward, 2007; Rhodes et al., 2003; Rhodes, et al., 2004; Watson & Clifford, 2003; Watson & Clifford, 2006; Webster & Maclin, 1999) but only one study has used this this paradigm to examine adaptation in children with ASD (Ewing et al., 2013). This is a valuable research paradigm and future studies may use it to explore adaption of other face categories (e.g., race, age, species) in ASD populations.

Perceptual strategies for face perception in adults with ASD

The results of Study 3 demonstrated that adults with ASD rely more heavily on an alternative rule-based perceptual strategy when processing emotional information in faces. This was first suggested by Rutherford and McIntosh (2007) who demonstrated that adults with ASD were more tolerant of exaggeration in facial expressions depicted in line drawings of faces. Study 3 replicated this finding with photographs of natural faces. The finding that adults with ASD use an alternative perceptual strategy to process emotional facial expressions may explain why some studies report deficits in emotional expression perception (e.g., Celani, Battacchi, & Arcidiacono, 1999) and others have not (e.g. Castelli, 2005; Spezio, Adolphs, Hurley, & Piven, 2007). It may be that some experimental designs allow participants with ASD to use an alternative strategy to complete the task, and thus fail to reveal group differences in accuracy. For example, shorter display of face stimuli may not allow enough time for participants to effectively use an alternative rule-based strategy, and therefore lead to group differences in accuracy. Indeed, some experiments with relatively short stimulus presentation times (e.g., Celani et al., 1999 as well as both the Basic and Complex Expression Recognition tasks in Study 3) found significant group differences in accuracy in discriminating facial expressions, but experiments with longer or unlimited presentation times did not (e.g., Castelli, 2005; Spezio, et al., 2007) reported typical performance.

Alternatively, it may be that certain tasks involve processing facial expression information for which individuals with ASD have not developed an alternative strategy for processing, perhaps because they have less experience with certain types of expressions. For example, Baron-Cohen, Wheelwright, and Jolliffe (2007) tested adults with ASD's ability to discriminate both simple (e.g., happy, sad, fearful) and complex (e.g., arrogant, guilt, preoccupied) facial expressions. Adults with ASD were significantly worse at discriminating complex, but not simple expressions compared to typical participants. It may be that participants with ASD do not have a rule-based strategy for processing complex expressions as they do for basic expressions, which they may be have more experience with. While Study 3 did not explicitly test this hypothesis, it is interesting to consider and could be directly tested in future research.

What drives the deficits in face perception in ASD?

Despite years of intense scientific focus, there is still not a clear consensus of what is the core face perception deficit in ASD. Some researchers have proposed that a domain and process specific deficit in face memory is the core face perception deficit, (Weigelt, Koldewyn, & Kanwisher, 2012; Weigelt, Koldewyn, & Kanwisher, 2013) however these researchers have focused on face identity processing and not emotional expression processing. The results of Studies 1 through 3 revealed group differences in processing facial expression information, but not other types of facial information such as identity or gender. However, one can consider gender and identity information to be more basic information available in faces, while facial expressions are more complex and require more social cognitive processing. Based on the results from Studies 1, 2 and 3, it was unclear if adults with ASD had a deficit in processing facial expressions specifically, or rather a deficit in processing social cognitively complex information. The purpose of Study 4 was to attempt to clarify this by examining if adults with ASD's performance on a battery of tasks that either required facial expression processing or did not, as well as ranged in the level of social cognitive complexity. The results of Study 4 suggest hat adults with ASD have a specific deficit in processing facial expressions (either basic or complex) as they showed typical performance on tasks related to identity discrimination and trustworthy perception, but worse performance on two tasks requiring emotional expression processing.

Limitations and future directions

Some limitations of these studies are worth mentioning. The primary limitation of these results is that they may only apply to adults and not children with ASD. As noted in Chapter 2, there is a clear difference in findings between studies examining face adaptation in children versus adults with ASD. This may reflect a developmental delay in the development of typical face adaptation and suggests that the age group of participants is likely an important factor for the generalizability of results. While the results of Studies 1 and 2 add to the building amount of evidence suggesting typical adaptation in adults with ASD (e.g., Cook et al, 2014), there have yet to be any studies that employ longitudinal designs to sensitively measure the developmental trajectory of the development of facial adaptation in ASD populations. This will be an important area for future research. Similarly, the results of Study 3 suggest use of atypical perceptual strategies when processing facial expression information in adults with ASD, however it is unclear if this is a stable difference in ASD beginning in early childhood or if it develops later in adolescence or early adulthood. Again, sensitive longitudinal experimental designs are needed to clarify the developmental trajectory of the use atypical perceptual strategies in ASD populations.

The results Experiments 1 and 2 of Study 2, which investigated figural aftereffects for male and female faces, revealed unexpected differences between contracted and expanded adapting conditions and raise interesting methodological questions. In Experiment, participants who were adapted to contracted faces showed larger aftereffects compared to those who were adapted to expanded faces. Furthermore, participants who were adapted to one gender of contracted faces showed significant contracted aftereffects for both genders of test faces, while participants who were adapted to expanded faces only showed significant expanded aftereffects for the same gender of test face. In Experiment 2, participants showed significant contracted aftereffects for both male and female test faces, even though they were adapted to contracted male faces and expanded female faces. We used identical methods as previous studies examining figural (Jaquet et al, 2007; Jaquet & Rhodes, 2008; Jaqet et al., 2008) aftereffects to produce the stimuli for both experiments, however the results of both experiments differ from several previous studies that have reported distinct contracted and expanded aftereffects (e.g., Jaquet et al, 2007; Jaquet & Rhodes, 2008; Jaqet et al., 2008; Anzures, Mondloch, & Lackner, 2009; Short, Hatry, & Mondloch, 2011).

This difference in findings between Study 2 and previous studies using the same methodologies warrants further investigation. The results of the current study suggest that the contracted and expanded distortions are not psychological equivalent to one another. It may be that the contracted distortion is perceptually a more extreme distortion and therefore creates larger adaptation and aftereffects. It may also be that the contracted distortion creates adaptation of the neural populations that encode information common to both categories of faces more so compared to the expanded distortion. While this question is beyond the scope of Study 2, future research should further investigate the equivalency of the contracted and expanded distortions and evaluate the utility of this methodology for measuring high-level face adaptation.

Conclusions

This goal of the series of experiments included in this thesis was to provide some clarification about the nature of face processing deficits in ASD. While there is a large existing literature of studies reporting behavioural differences in performance on various face processing tasks, there is still not a clear understanding of what the core deficits are and what may be the underlying causes of these core deficits. Together the results of the four studies included in this thesis suggest that 1) the perceptual mechanisms believed to facilitate typical face perception (i.e., adaptation and norm-based coding) are intact in adults with ASD and therefore atypical encoding of facial information is not likely to explain previously reported deficits on face perception tasks; 2) when processing emotional expressions adults with ASD rely on an alternative and perhaps compensatory rule-based perceptual strategy, and that 3) adults with ASD have a core deficit in processing emotional expression information faces, but not other basic (e.g., gender, identity) or non-emotional but socially complex (e.g., trustworthiness) information. While the results of these studies may be limited by the demographics of the individuals with ASD included in the studies (e.g., adults, high-functioning, average to above average cognitive abilities), they provide interesting direction for future research in the field.

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