SELECTIVE ATTENTION TO FACE CUES IN ADULTS WITH AND WITHOUT AUTISM SPECTRUM DISORDERS

by

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ABSTRACT

Individuals with autism spectrum disorders (ASD) use atypical approaches when processing facial stimuli. The first purpose of this research was to investigate face processing abilities in adults with ASD using several tasks, to compare patterns of interference between static identity and expression processing in adults with ASD and typical adults, and to investigate whether the introduction of dynamic cues caused members of one or both groups to shift from a global to a more local processing strategy. The second purpose was to compare the gaze behaviour of groups of participants as they viewed static and dynamic single- and multiple-character scenes. I tested 16 adults with ASD and 16 sex-, age-, and IQ-matched typical controls. In Study 1, participants completed a task designed to assess processing speed, another to measure visual processing bias, and two tasks involving static and dynamic face stimuli -- an identity-matching task and a Garner selective attention task. Adults with ASD were less sensitive to facial identity, and, unlike typical controls, showed negligible interference between identity and expression processing when judging both static and moving faces. In Study 2, participants viewed scenes while their gaze behaviour was recorded. Overall, participants with ASD showed fewer and shorter fixations on faces compared to their peers. Additionally, whereas the introduction of motion and increased social complexity of the scenes affected the gaze behaviour of typical adults, only the latter manipulation affected adults with ASD. My findings emphasize the importance of using dynamic displays when studying typical and atypical face processing mechanisms.

Keywords: autism spectrum disorders, dynamic, face processing, gaze patterns, selective attention

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Despite the fact that faces are very similar, most people are able to recognize the identity of others and distinguish nuances in facial expressions. Being able to correctly perceive and integrate facial cues is important for engaging competently in social interactions. Individuals with autism spectrum disorders (ASD) often experience difficulties interpreting other peoples' behaviours in social situations, which may be due, in part, to them using atypical approaches when processing facial stimuli (Barton, Hefter, Cherkasova, & Manoach, 2007). Studying face processing abilities in typical adults and in adults with ASD may help us to better understand how these abilities contribute to difficulties in social perception, and assist researchers and clinicians in developing more effective interventions to help improve their social functioning. This thesis explored how people attend to and process facial information typically, and how these abilities differ in adults with ASD. In this section, I provide a brief review of the literature on typical and atypical face processing and an overview of the two studies that comprised this thesis.

Faces are Important Social Stimuli

Faces communicate a wealth of information to perceivers, including clues as to an individual's identity, emotional state, and thought processes. Not surprisingly, most people appear to process faces differently than they process non-face objects (see Tanaka & Farah, 1993; Yin, 1969; Yovel & Kanwisher, 2004). This is evident from a young age; for example, infants have been shown to track face-like stimuli longer than non-face stimuli within an hour after birth (Johnson, Dziurawiec, Ellis, & Morton, 1991) and show evidence of being able to recognize specific faces early in life (Otsuka, 2014). At three to four months of age, infants spend more time looking at the eyes and mouths of moving faces than other aspects of scenes (Wilcox, Stubbs, Wheeler, & Alexander, 2013). By nine months of age, they spend a disproportionate amount of time looking at the eyes, suggesting that they have learned that the eyes convey socially relevant information that can be gleaned easily. Some face processing strategies become adult-like as early as four years of age (de Heering, Houthuys, & Rossion, 2007).

Clearly, faces are to some degree innately salient to humans, and accurate perception of facial cues is important from an evolutionary perspective. Being able to efficiently recognize caretakers and "read" expression cues that might signal social threat are adaptive abilities (Nelson, 2001). However, as noted above, face processing skills do develop with continued experience (see Nelson, 2001 for a review). This *expertise hypothesis* promotes the idea that face processing is an ability that is more developed than other kinds of visual processing due to the vast experience most people have looking at faces, and because most people recognize faces as socially relevant (Grelotti, Gauthier, & Schult, 2002).

Most previous research exploring face processing has presented photographic stimuli to typically developing viewers (see O'Toole, Roark, & Abdi, 2002 for a review) and to those with atypical face processing abilities, including individuals with prosopagnosia (face blindness) or ASD (e.g., Behrmann, Avidan, Marotta, & Kimchi, 2005; Lahaie, Mottron, Arguin, Jemel, & Saumier, 2006; Riby, Doherty-Sneddon, & Bruce, 2009). While important, the external validity of findings from research utilizing static images of faces is questionable, because faces encountered in everyday life are typically in motion. Recent research suggests that processing moving faces involves more extended neural networks in humans than in non-human primates (Polosecki, Moeller, Schweers, Romanski, Tsao, & Freiwald, 2013). In addition, accumulating behavioural evidence suggests that people process moving faces differently than static faces (e.g., Chiller-Glaus, Schwaninger, Hofer, Kleiner, & Knappmeyer, 2011; Hill & Johnston, 2001; Pilz, Thornton, & Bülthoff, 2006; Stoesz & Jakobson, 2013; 2014). Neuroanatomical evidence suggests that there is some degree of bifurcation between the ways in which humans process static compared to dynamic faces. Whereas certain cortical areas, such as the fusiform face area and the occipital face area (Pitcher, Dilks, Saxe, Triantafyllou, & Kanwisher, 2011; Yovel & Kanwisher, 2004) are important for static face processing, other face-selective regions in the superior temporal sulcus are involved in processing facial motion (Foley, Rippon, Thai, Longe, & Senior, 2012; Kessler, Doyen-Waldecker, Hofer, Hoffman, Traue, & Abler, 2011; Pitcher et al., 2011).

Recent functional imaging work suggests that both the fusiform face area and the occipital face area are more strongly activated by moving than by static faces (Schultz, Brockhaus, Bülthoff, & Pilz, 2013). These authors found that this enhancement was due to the richness of information presented, rather than motion itself. Thus, when participants were shown the same number of static frames that were used to generate dynamic clips but separated them in time to disrupt the fluidity of motion, enhanced activation in these cortical areas was still observed. A different result was seen in the superior temporal sulcus. Here, the increased richness of static information could not be fully account for by the enhanced activation in response to dynamic faces could not be fully accounted for by the increased richness of static information, suggesting that the superior temporal sulcus is sensitive to the *fluidity* of facial motion.

In addition to revealing differences in *activation levels* in certain brain areas, research suggests that processing facial motion recruits different *neural regions* than those involved in processing static face cues. In line with this, Pitcher, Duchaine, and Walsh (2014) recently observed evidence of dissociable pathways for processing static and dynamic facial cues. Using thetaburst transcranial magnetic stimulation, they found that disrupting the right occipital face area reduced activation in the right posterior superior temporal sulcus in response to static, but not dynamic, faces. In contrast, disrupting the right posterior superior temporal sulcus itself reduced activation in this region when participants were presented with dynamic, but not static, faces. These findings provide evidence that static and dynamic face cues are, to some degree, processed through independent cortical pathways. Because of these differences in behavioural and neurological results depending on whether faces are presented as frozen images or as moving displays, I used both static and dynamic face stimuli in the studies that comprise the present thesis.

Face Processing in ASD

ASDs are neurodevelopmental conditions on a continuum that present early in childhood; they involve persistent deficits in social interactions and communication, and are characterized by restrictive, repetitive behaviours and interests (American Psychiatric Association [APA], 2013). The prevalence of ASD is estimated to be approximately 1% of the general population (APA, 2013), and it is diagnosed more often in males than females (ratio of 4.5:1, Autism and Developmental Disabilities Monitoring [ADDM] Network, 2012). Based on data from 2010, the ADDM Network (2012) reported that 1 in 68 children are diagnosed with ASD. In Canada, prevalence estimates range between 9.7% and 14.6% depending on the province (Ouellette-Kuntz, Coo, Lam, Breitenbach, Hennessey, et al., 2014).

Individuals with ASD tend to exhibit atypical gaze and face processing abilities (e.g., Senju, 2013) that may negatively impact their ability to develop social relationships (Baron-

Cohen, 1995) by contributing to difficulties with spontaneous social cognition – often evidenced by deficits in theory of mind abilities and trait emotional intelligence (Montgomery, Stoesz, & McCrimmon, 2012). Individuals with ASD also often show deficits in some executive functions, such as inhibition and cognitive flexibility (Montgomery et al., 2012), which can further exacerbate their social difficulties.

Research exploring face processing in individuals with ASD suggests that faces do not capture the attention of adults with ASD in the same way they capture the attention of typical adults (Remington, Campbell, & Swettenham, 2011), especially with regard to information from the eyes (Senju, 2013; Spezio, Adolphs, Hurley, & Piven, 2007). Work by Dalton, Nacewicz, Johnstone, Schaefer, Gernsbacher, et al. (2005) suggests that reduced attention to the eyes may explain, in part, why adults with ASD sometimes show hypoactivation of the fusiform gyrus when completing face perception tasks (Dalton et al., 2005; Hall, Szechtman, & Nahmias, 2003; Pierce, Müller, Ambrose, Allen, & Courchesne, 2001; Schultz, Gauthier, Klin, Fullbright, Anderson, et al., 2000). However, certain layers of this brain region are also known to contain fewer and smaller neurons in those with ASD than in typical controls (van Kooten, Palmen, Cappeln, Steinsbush, Korr, et al., 2008).

Although some researchers have found group differences in activation of certain neural regions during viewing of *static* faces (see Dawson, Webb, & McPartland, 2005 for a review), others have not (e.g., Weisberg, Milleville, Kenworthy, Wallace, Gotts, et al., 2014). For example, Weisberg et al. (2014) found that adolescents with and without ASD showed similar cortical activation when viewing pictures of bodies, neutral faces, and tools, and when they were presented with different videos of tools. However, when presented with dynamic *social* stimuli, individuals with ASD showed atypical connectivity between the fusiform gyrus, the amygdala, and the posterior superior temporal sulcus. Some researchers suggest that those with ASD show generalized motion processing deficits, possibly due to damage in the dorsal visual stream (Greimel, Bartling, Dunkel, Brükl, Remschmidt et al., 2013).

One question that arises is whether problems with face processing in ASD develop because of a perceptual impairment or because of atypical motivation to look at faces (Dawson et al., 2005). Individuals with ASD usually spend less time looking at faces compared to typical individuals (Boraston & Blakemore, 2007; Klin, Jones, Schultz, Volkmar & Cohen, 2002; Riby & Hancock, 2009). Whereas some researchers have theorized that children with ASD are innately less likely to attend to/process facial information, other research has revealed normal face orienting mechanisms in infants at risk for (and who later developed) ASD (Elsabbagh, Gliga, Pickles, Hudry, Charman, et al., 2013). Elsabbagh et al. speculated that deficits in face orienting could be subtle and, therefore, difficult to detect in infancy, but become more pronounced during childhood. In developing an alternative model of face processing, Nelson (2001) reviews the literature on face processing from a developmental standpoint and concludes that humans might show an innate experience-expectant cortical specialization for face processing. That is, certain cortical areas such as the fusiform gyrus have the innate potential to become specialized for processing faces. This specialization is experience-expectant in that the development of these areas is contingent upon being exposed to faces. From this perspective, face processing is both learned and innate. Because infants at risk for developing ASD may show a weak preference for looking at faces due to lack of interest or aversion to faces, critical periods of cortical specialization may be missed; this, in turn, contributes to the significant difficulties with social perception and communication that are archetypal of ASD (Dawson et al., 2005; Campatelli, Federico, Apicella, Sicca, & Murratori, 2013; Elsabbagh et al., 2013; Pierce et al., 2001; Tanaka & Sung, 2013). If this account of face processing as an experience-expectant process is correct, then early detection of ASD is critical for intervening and potentially preventing the profound social deficits seen in affected individuals (Sigman, Dijamco, Gratier, & Rozga, 2004).

Thesis Overview

The over-arching goal of this research was to investigate face processing mechanisms in typical adults and in adults with ASD and, in so doing, provide new insights into typical and atypical face processing. The purpose of Study 1 was to compare how individuals in these two groups performed in different kinds of tasks requiring active judgments of faces. First, I measured processing speed using a simple reaction time (RT) task in which participants responded to the appearance of face and non-face stimuli shown in photographs or undergoing non-rigid motion. I then compared the groups' performance on two face processing tasks that involved more complex judgments. The first required matching two simultaneously presented faces that were moving or were stationary. In the second task, I explored how the introduction of dynamic cues influenced interference between expression and identity processing in each group. I also examined how individual differences in processing strategies might affect performance in both of these tasks. The purpose of Study 2 was to compare the gaze behaviours of viewers with ASD to those of typical controls as they passively viewed a series of pictures and movies of naturalistic scenes depicting one or more characters.

STUDY 1: STATIC AND DYNAMIC FACE PROCESSING IN ADULTS WITH AND WITHOUT AUTISM SPECTRUM DISORDERS

Most research underscores the role of global (configural) strategies for processing static facial stimuli (e.g., Farah, Wilson, Drain, & Tanaka, 1998; Robbins & McKone, 2003; Tanaka & Farah, 1993). Maurer, Le Grand, and Mondloch (2002) have identified three forms of configural face processing: (1) holistic, (2) sensitivity to first order relations, and (3) sensitivity to second order relations. Holistic face processing occurs when faces are processed as an overall gestalt, rather than as a set of individual features. Sensitivity to first order relations refers to faces being recognized as faces because of the way in which facial features are configured (i.e., with eyes placed above a nose which, in turn, is positioned above a mouth). While first order relations are the same for all faces, the ability to extract the spatial distances between facial features, such as the distance between the mouth and the nose, characterizes sensitivity to second order relations.

There is substantial evidence that most viewers use global strategies when processing static faces. This evidence comes from a variety of experimental models, such as scrambled face paradigms, composite face tasks, and face inversion paradigms. Using a scrambled face task, Tanaka and Farah (1993) found that when people were familiarized with intact faces, they were better able to recognize face parts when they were presented in the context of the whole face compared to when they were presented in isolation. In contrast, initially familiarizing viewers with scrambled faces resulted in better recognition of face parts in isolation, rather than in the context of the whole face. This study provides evidence that viewers initially utilize a holistic or global approach when learning a new, intact static face.

Another paradigm commonly used to investigate holistic face processing is the composite face task (e.g., DeGutis, Wilmer, Mercardo, & Cohan, 2013; Farah et al., 1998; Richler, Tanaka, Brown, & Gauthier, 2008; Xiao, Quinn, Ge, & Lee, 2012; Xiao, Quinn, Ge, & Lee, 2013; for detailed descriptions see Xiao, Perrotta, Quinn, Wang, Sun, & Lee, 2014; Young, Hellawell, & Hay, 1987). Composite face tasks involve presenting upper and lower face parts (that belong to different people), either vertically aligned or misaligned. A composite face effect (CFE) occurs if viewers are better able to identify face parts when the half faces are misaligned. This effect is thought to arise because viewers process the aligned face holistically, which makes it difficult for them to ignore the top half of the face when judging the bottom half (Xiao et al., 2014). Holistic strategies are disadvantageous in this task because processing the face as a whole makes it more difficult to selectively attend to its features (Richler & Gauthier, 2014). Using this paradigm, de Heering et al. (2007) observed that holistic face processing is mature as early as four years of age. Richler and Gauthier (2014) posit that holistic processing (as measured by the CFE) is related to experience and may be a perceptual strategy that has become automatized with substantial practice viewing faces; in other words, they suggest that use of this strategy reflects the viewer's expertise in face processing.

Finally, the face inversion effect (FIE; Yin, 1969) refers to the fact that inverting a face disrupts face recognition more than object recognition. That is, it is easier to recognize a face when it is in its canonical (upright) orientation than when it is upside down. The FIE is thought to occur because inversion disrupts global face processing, thereby forcing the viewer to adopt a more local approach. FIEs have usually been demonstrated with static face stimuli (e.g., Farah et al., 1998; Robbins & McKone, 2003; Yovel & Kanwisher, 2004).

While the above-mentioned studies do, in general, support the notion that most people use global strategies to process static faces, these findings are equivocal. Moreover, manipulations such as scrambling a face or misaligning its parts reduce the ecological validity of the stimuli. Ross, Richler, and Gauthier (2013) note that there is low reliability amongst composite face tasks. The lack of consistency in CFEs across studies might reflect disparities in whether researchers employed partial or complete composite face designs (Richler & Gauthier, 2014). With regards to inversion paradigms, some researchers conjecture that face inversion affects featural, as well as holistic, processing efficiency (Richler & Gauthier, 2014; Xu & Tanaka, 2013). Inverting faces might only delay (rather than fully disrupt) holistic processing (Curby, Goldstein, & Blacker, 2013; Richler, Mack, Palmeri, & Gauthier, 2011). Additionally, results from experimental paradigms that measure holistic processing do not necessarily converge (Richler & Gauthier, 2014). Therefore, it is plausible that these different tasks tap into different components of face processing abilities.

It is also possible that faces are processed less globally than what was traditionally thought. Indeed, there appears to be considerable individual variability in the extent to which typical individuals rely on local or global strategies when viewing static faces (Happé, Briskman, & Frith, 2001; Martin & Macrae, 2010; Roalf, Lowery, & Turetsky, 2006). For example, Macrae and Lewis (2002) found that priming viewers with a task where they either identified local or global properties of a hierarchical stimulus (i.e., to induce processing bias) influenced their ability to later recognize faces. In their study, directing attention to global features had a more beneficial effect on subsequent face recognition than attending to local features. However, Perfect, Weston, Dennis, and Snell (2008) found that when priming typical participants by asking them to identify the global or local properties of stimuli in which these properties were the same (consistent stimuli) or different (inconsistent stimuli), identity recognition was not impacted by whether participants were primed to respond more globally or locally. When the stimuli in the priming task were *consistent*, participants were better able to recognize identity, regardless of whether they were primed to respond in a more local or global manner. Women have been found to respond faster to local than global targets, whereas this discrepancy was not seen in men (Roalf et al., 2005). Moreover, Scherf, Behrmann, Kimchi, and Luna (2009) found that children and adolescents exhibited a local processing bias, in contrast to adults who were more likely to exhibit a global processing bias, suggesting that reliance on different processing strategies may change over time. A bias toward local processing, compared to global processing, can result in smaller FIEs (Martin & Macrae, 2010). Additionally, whether individuals rely on local or global strategies might also vary depending on the individual's affective state. Indeed, Curby, Johnson, and Tyson (2012) found that inducing a negative emotional state (i.e., fear) by showing a video clip from a horror movie later decreased the use of holistic processing as measured by a composite face task, whereas inducing positive and neutral affective states (by showing a stand-up comedian and an instructional carpentry video, respectively) did not.

Other work suggests that reliance on local or global strategies may vary depending on the task. For example, Song and Hakoda (2012) obtained evidence that identity information from static faces is processed globally, whereas static facial expressions are processed locally. Additional support for the idea that expression processing may be, at least in part, reliant on local strategies was provided by Lipp, Price, and Tellegen (2009), who observed that judging expression accurately is not necessarily impaired when global processing is disrupted by inversion. That is, when static faces were inverted, participants were not impaired at making judgments regarding facial expression, possibly because they were processing expression information using a more local strategy. Overall, these findings suggest that task requirements, emotional state, and the nature of the stimuli affect the extent to which viewers adopt global strategies when processing static faces.

Less is known about how we process faces in motion, though some evidence suggests that global strategies may be less critical when viewing dynamic faces. For example, while inverting dynamic faces does result in a FIE, this effect is usually found to be attenuated compared to that seen when inverting static faces (Hill & Johnston, 2001; Knappmeyer, Thornton, & Bülthoff, 2003; Lander, Christie, & Bruce, 1999), although the opposite effect has also been reported (Thornton, Mullins, & Banahan, 2011). Chiller-Glaus et al. (2011) found that recognizing happy, sad, and surprised facial expressions using static and dynamic composite face tasks relied more on configural strategies than did recognizing anger, disgust, and fear. Using a composite face paradigm, Xiao et al. (2012; 2013) found that familiarizing viewers with moving as opposed to static faces improved their ability to recognize faces in a part-based manner at testing, resulting in a smaller CFE. Loucks and Baldwin (2009) observed that viewers attended more to local information than global information when viewing dynamic human action sequences. Together, these results suggest that, while global strategies may be most important for processing static faces, dynamic face processing may rely to a greater extent on local strategies.

Dynamic Advantage

Most research exploring dynamic face perception has found advantages for expression and identity processing when faces are presented in motion. For example, facial motion can facilitate expression judgments in terms of improved accuracy (e.g., Bassili, 1978; Kamachi, Bruce, Mukaida, Gyoba, Sakiko, & Amatsu, 2001), and faster RTs (e.g., Chiller-Glaus et al., 2011; Horstmann & Ansorge, 2009). Motion seems to be most useful for identifying emotions that are subtle (Ambadar, Schooler, & Cohn, 2005) or difficult to recognize (e.g., Chiller-Glaus et al., 2011). The beneficial effect is maintained even after controlling for the richness of dynamic information by showing multi-static images (Ambadar et al., 2005; Lander et al., 1999). However, the benefits of having motion cues available appear to vary depending on the particular expression. For example, Ceccarini and Caudek (2013) found evidence of a processing advantage for angry (rather than happy or neutral) dynamic faces. In contrast, there was no expression superiority effect when faces were static. Dynamic advantages might also vary depending on the speed at which the expression unfolds. Thus, Kamachi et al. (2001) have reported that while sad expressions are judged more accurately when motion is slowed down from normal rate, happy and surprised expressions are best detected when motion is sped up from normal rate, and anger is best identified in medium-paced (i.e., normal rate) dynamic sequences.

Motion also confers an advantage when making identity judgments in typical and atypical populations (e.g., Kaufmann & Schweinberger, 2004; Longmore & Tree, 2013; Pilz et al., 2006). O'Toole et al. (2002) propose two hypotheses regarding why facial motion may benefit identity recognition. The *representation enhancement hypothesis* emphasizes that facial motion helps to provide a better structural representation of the face, which can help viewers to judge identity. The *supplemental information hypothesis* suggests that idiosyncratic facial motion signatures (e.g., having a characteristic arched eyebrow) provide helpful clues for recognizing familiar faces. Dynamic advantages usually occur when viewing conditions are not ideal (e.g., Knight & Johnston, 1997; Lander et al., 1999; O'Toole et al., 2002). For example, motion confers an advantage when faces are negated (Knight & Johnston, 1997) or thresholded (Lander et al., 1999). Motion cues can improve the identification of non-degraded faces in adults with developmental prosopagnosia, ostensibly by providing them with supplementary information that is unavailable from static images alone (Bennets, Butcher, Lander, Udale, & Bate, 2015). In addition, dynamic advantages are sometimes observed under optimal viewing conditions even for typical individuals (e.g., Knappmeyer et al., 2003; Pike, Kemp, Towell & Phillips, 1997; Thornton & Kourtzi, 2002). However, some research has found no benefit to presenting faces in motion (e.g., Christie & Bruce, 1998; Fiorentini & Viviani, 2011; Thornton et al., 2011).

Interference between Identity and Expression Processing

Traditional face processing models posit that identity and expression cues are processed independently (e.g., Bruce & Young, 1986). This parallel pathways hypothesis suggests that extracting different kinds of information from faces (e.g., identity, expression, eye gaze) involves functionally independent neural pathways. Research that lends support to this conceptualization includes studies that have examined populations of cells that are specific to expression or identity processing (Hasselmo, Rolls, & Baylis, 1989), studies assessing discrepant abilities in individuals with brain lesions (Humphreys, Donnelly, & Riddoch, 1993), and speeded identity-expression classification tasks (Ectoff, 1984).

Calder and Young (2005) stress that while the parallel pathways hypothesis has dominated the literature on face processing, this theory is not strongly supported. More current research supports the view that while identity and expression *can* be processed independently, there is likely some degree of interdependency between the processing of these two facial dimensions in static faces (e.g., Baudouin, Sansone, & Tiberchien, 2000; Chen, Lander, & Liu, 2011, Ganel & Goshen-Gottstein, 2004; Kaufmann & Schweinberger, 2004; Levy & Bentin, 2008, Stoesz & Jakobson, 2013).

Interference between identity and expression processing is often assessed using Garner's selective attention paradigm (1976). Garner tasks are used to assess the ability to process one dimension of a visual stimulus (e.g., facial expression) while ignoring another dimension (e.g., facial identity). When interference is observed this suggests that the processing of the two dimensions are, at least to some degree, interdependent. Depending on the stimuli used, the ability to judge the identity of a static face is influenced by changes in facial expression, and (to a smaller extent) changes in identity can interfere with judgments of static expressions (e.g., Schweinberger, Burton, & Kelly, 1999; Schweinberger & Soukup, 1998; Stoesz & Jakobson, 2013). Recently, Fitousi and Wenger (2013) explored the independence of static identity and expression processing using several experimental paradigms and found evidence for different *levels* of independence. They argued that viewers can attend selectively to either expression or identity information if separating (as opposed to integrating) these facial cues would be beneficial.

One model of face processing that takes into account changeable aspects of the face, such as facial motion, is Haxby, Hoffman, and Gobbini's (2000) *distributed neural system for face processing* model. This model acknowledges the independent and interdependent nature of facial processing. Haxby et al. (2000) suggest that there are core and extended neural systems for processing facial information. The core system (comprised of the inferior occipital gyri, the superior temporal sulcus, and the lateral fusiform gyrus) is thought to be responsible for processing invariant (e.g., identity – lateral fusiform gyrus) and variant (e.g., expression, eye gaze, lip movement – superior temporal sulcus) facial information, with further processing occurring in the extended system. Haxby et al. (2000) comment, however, that it is unlikely that the two core pathways are mutually exclusive, and there is likely at least some interdependency between expression and identity processing. Lander and Butcher (2015) question whether this neural model fully accounts for the role of motion when processing identity. These authors note that it is important to study the independence versus interdependence of processing facial cues from dynamic faces.

Interestingly, while interference effects are often observed between expression and identity cues with static faces, these effects disappear with dynamic faces (Rigby, Stoesz, & Jakobson, 2013; Stoesz & Jakobson, 2013). One possible explanation for this finding is that viewers use different strategies to process expression and identity information from dynamic faces than they use to process information from static faces. Perhaps viewers are engaging more in local processing strategies when faces are dynamic (see above). Using an approach more heavily weighted toward local processing might make it easier to attend to facial details and ignore task-irrelevant cues, resulting in less interference. While a traditional interpretation of the lack of interference seen with dynamic faces would be that viewers are better at selectively attending to important cues, an alternative possibility is that viewers are better able to integrate cues when faces are in motion. In line with the latter interpretation, Stoesz and Jakobson (2013) observed decreased *interference* with dynamic faces, but participants took *longer* to make judgments about moving, compared to static, faces.

Face Processing in ASD

Deficits in various aspects of facial processing in individuals with ASD are well documented in the literature (e.g., Barton et al., 2007; Dalton et al., 2005; Enticott, Kennedy, Johnston, Rinehart, Tonge, et al., 2013; Pelphrey, Sasson, Reznick, Paul, Goldman, & Piven, 2002; Scherf, Behrmann, Minshew & Luna, 2008; however, see Song, Kawabe, Hakoda, & Du, 2012, Spezio et al., 2007). Results from these studies suggest that, in general, individuals with ASD are worse than typically developed controls at processing facial expression (see Harms, Martin, & Wallace, 2010 for an explanation of some inconsistent findings). Although individuals with ASD are often found to be slower at recognizing facial expressions (e.g., Behrmann, Avidan, Leonard, Kimchi, Luna, et al., 2006; Eack, Mazefsky, & Minshew, 2014), group differences in performance on these tasks might partially depend on the expression displayed. For example, Eack et al. (2014) found that adults with ASD misinterpreted happy faces as neutral, and misinterpreted neutral faces as having a negative valence. Enticott et al. (2013) found that adults with ASD were worse at identifying dynamic, sad expressions compared to typical controls. Additionally, these authors observed that adults with ASD were worse at identifying angry and disgusted faces, regardless of modality. Adults with ASD have been found to show deficits in recognizing fearful expressions compared to control participants, and these deficits were associated with erratic gaze fixation patterns (Pelphrey et al., 2002). However, Song et al. (2012) found that children with ASD were not impaired when making identity or expression judgments of happy faces. It could be that the expression recognition deficits often seen in ASD are limited to negative emotions (see Enticott et al., 2013; Song et al., 2012), or those that predominantly involve the upper half of the face. The latter possibility would be predicted from studies showing that individuals with ASD often avoid looking toward the eye region (Tanaka & Sung, 2013).

Face processing deficits in ASD are sometimes seen in identity processing tasks. Scherf et al. (2008) found that individuals with ASD showed some evidence of facial expertise, however, they were not as skilled as a control group at discriminating between identities. In a review of the literature on identity processing in ASD, Weigelt, Koldweyn, and Kanwisher (2012) noted that there is often a quantitative difference seen in facial identity recognition in ASD, particularly in tasks that place memory demands on participants.

Overall, the literature summarized above supports the theory that people with ASD show atypical face processing abilities, and are more strongly inclined to adopt an extreme local approach when processing static faces (Bölte, Holtmann, Poustka, Scheurich & Schmidt, 2007; Castelli, Frith, Happé & Frith, 2007; Nishimura, Rutherford & Maurer, 2008; Wang, Mottron, Pengy, Berthiaume & Dawson, 2007). However, the local bias often seen in ASD does not necessarily come at the expense of competent configural/global processing abilities (e.g., Nishimura et al., 2008; Wang et al., 2007), and abnormalities in face recognition abilities are not completely explained by deficits in holistic processing (Joseph & Tanaka, 2003). Those with ASD may show a bias to process local information yet still are able to process faces globally if local information is less salient.

Findings from studies using a Garner interference paradigm are inconsistent with regards to whether individuals with ASD experience more or less interference than controls when processing static face cues. For example, some research with children suggests that typical controls experience interference from both identity and gaze when judging facial expressions, but that children with ASD do not (Akechi, Senju, Kikuchi, Tojo, Osanai, & Hasegawa, 2009; Krebs, Biswas, Pascalis, Becker, Remschmidt, & Schwarzer, 2011). Others report that both groups can successfully ignore identity when making expression judgments (Song & Hakoda, 2012). When the task involves making identity judgments, some investigators find that task-irrelevant changes in expressions do not interfere with performance in typical children *or* those with ASD (Krebs et al., 2011), whereas others find that children with ASD experience *more* interference than controls (Song & Hakoda, 2012).

Inconsistencies across studies may be related to the particular emotions depicted. Past research indicates that typical viewers tend to process identity information using a global approach (see Song et al., 2012), but process (at least some) expressions more locally (Lipp et al., 2007; Song et al., 2012). However, this general pattern might not hold for individuals who show a tendency to focus on particular facial features (i.e., local processors). These individuals might exhibit little (if any) interference from identity information when completing static expression tasks, but experience some interference from expression information when completing static identity tasks. There may, however, be a point beyond which local processing hampers performance, especially during identity processing. That is, extreme local processors may become so focused on a facial feature (such as a smiling mouth) that it is harder for them to judge the identity of a static face efficiently. In this case, we would expect to find that they would experience *greater* interference from expression on static identity processing than those with a more global processing bias. If many people with ASD have strong local processing biases, this could explain the pattern of results described by Song and Hakoda (2012), described above. It is important to remember, however, that processing biases may change over the course of development (Scherf et al., 2009). As the existing research exploring Garner interference between expression and identity processing in individuals with ASD has been limited to children, it remains unclear what pattern of results would be seen in an adult population.

While it is important to consider the possible impact of group differences in processing biases on task performance, one should also consider that when adults with ASD fixate on the eye region of happy, fearful, and neutral static faces, they experience greater amygdala activation (Kliemann, Dziobek, Hatri, Baudewig, & Heekeren, 2012) and a heightened emotional response (Dalton et al., 2005) compared to controls. They also take longer than controls to decide whether an expressive face is emotional or neutral – suggesting that they find socially engaging faces more difficult to process (Dalton et al., 2005). This could also have an effect on their performance -- altering the degree to which they attend to, and are influenced by, task-irrelevant changes in facial expressions when making identity judgments.

To my knowledge, there are no existing studies exploring interference between expression and identity processing when adults with ASD view moving faces. If, as argued above, introducing facial movement leads to a shift toward local processing in typical viewers, then one should expect that this manipulation would eliminate any group differences in interference seen in static testing conditions.

The Present Study

The purpose of this mixed quasi-experimental study was to investigate face processing abilities in typical adults and in adults with ASD using three tasks requiring active judgments of faces: a simple RT task, a simultaneous identity-matching task, and a Garner speeded classification task. In a recent study, Kenworthy, Yers, Weinblatt, Abrams, and Wallace (2013) reported that individuals with ASD exhibited normal processing speed when asked to make simple yes/no decisions about non-face objects via a key press. Based on this, I did not expect to find that individuals with ASD would show a generalized impairment in processing speed in the simple RT task. It was important to determine, however, whether the groups responded equally quickly to *both* faces and non-face stimuli, and whether they responded similarly to the introduction of non-rigid motion.

I administered the simultaneous identity face-matching task to investigate static and dynamic identity processing in a task involving minimal memory demands. The Garner task allowed me to investigate how the introduction of dynamic cues and individual differences in processing biases might influence interference between expression and identity processing. For reasons outlined above, I expected to find that group differences in performance on these two more complex face-processing tasks might be more marked when static, as opposed to dynamic, faces served as test stimuli. I also expected to find that with static (but not dynamic) faces the ASD group would show more interference from expression on identity judgments than the reverse, whereas controls would (if anything) show the opposite pattern. Finally, I predicted that both performance on the matching task and interference levels observed in the Garner task might vary as a function of processing style during static (but not dynamic) testing.

METHOD

Participants

My sample consisted of 16 adults with ASD (11 males, 5 females; aged 18-46 years, *M* = 27.8 years, *SD* = 7.8) and 16 typical adults (11 males, 5 females; aged 19-46 years, *M* = 27.3, *SD* = 7.5), all of normal or above-normal intelligence (see below). Whereas the ratio of men to women with ASD in the general population is 4.5:1 (ADDM Network, 2012), the ratio in the present sample was 2.2:1. Thus, women with ASD were over-represented in this study compared to the general population of individuals with ASD.

I recruited some participants in each group by accessing a participant registry provided by Dr. Janine Montgomery (Department of Psychology, University of Manitoba, Winnipeg, Canada). The individuals listed on this registry had previously participated in research in Dr. Montgomery's lab and indicated that they would like to be contacted to participate in future research studies. I also recruited additional participants with ASD through an advertisement placed on Dr. Montgomery's website, and recruited additional typical participants from the introductory psychology participant pool at the University of Manitoba. All participants with ASD had received a formal diagnosis of an ASD or Asperger's disorder from a physician, psychologist, or psychiatrist, and those recruited from the registry had also previously completed several confirmatory diagnostic assessments. The typical participants were sex- and age- (within two years) matched with the ASD group. All participants had normal or corrected-to-normal vision and typical participants had normal developmental histories, as verified by their responses on a general information questionnaire.

Procedures

The Psychology/Sociology Research Ethics Board at the University of Manitoba approved my testing protocol. I tested participants individually in a quiet room. I provided each participant with a brief overview of the testing procedure. Participants then began by completing the general information questionnaire, the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) (where applicable), the Peabody Picture Vocabulary Test-Fourth Edition (PPVT-4; Dunn & Dunn, 2007), the Autism Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001), and the Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2004). Following this, participants completed five experimental tasks: (1) the simple RT task, (2) the simultaneous identity-matching task, (3) the Garner selective attention task, (4) the Local-global task, and (5) a gaze pattern task (described in Study 2). The order in which these experimental tasks were administered was reversed for half of the participants in each group in order to control for effects of testing, with the exception that the identity-matching task always directly preceded the Garner task. During the computerized tasks, participants were seated approximately 57 cm from the screen. Each experimental task was explained verbally to each participant before they began and participants could ask questions during this time. The entire testing protocol took approximately two hours for each participant to complete. Participants form the introductory psychology participant pool received course credit for their participation. All other participants received a $40 honorarium.

Materials

General information questionnaire. The general information questionnaire (see Appendix A) was designed to gather information regarding variables such as parental education, language abilities, and developmental history that could potentially influence participants' performance on the experimental tasks.

Wechsler Abbreviated Scale of Intelligence. The WASI is a test designed to estimate Verbal IQ (VIQ), Performance IQ (PIQ), and Full Scale IQ (FSIQ) in individuals between the ages of 6 and 89 years. It is individually administered and is nationally standardized. The WASI consists of four subtests (Vocabulary, Block Design, Similarities, and Matrix Reasoning) and provides an estimate of an individual's general cognitive functioning. Subtest *T* scores are summed to obtain a Full Scale *T* score, which can be converted to a standard score ($M = 100$, $SD = 15$). The WASI shows excellent internal consistency ($\alpha = .98$ for average adult FSIQ), and excellent test-retest reliability ($r = .92$ for FSIQ with adults). The WASI FSIQ correlates strongly with the WAIS-III FSIQ ($r = .92$; Wechsler, 1999). While there does exist a recently revised version of this test (Wechsler Abbreviated Scale of Intelligence – second edition; WASI-II; Wechsler, 2011), I administered the original WASI because many participants in the ASD group who had been recruited from the participant registry had already been tested using the first edition. If this assessment had occurred within the last two years I accessed their previous results. I administered the WASI in order to ensure that the ASD group was matched with the typical adult group in terms of VIQ, and to ensure that all participants had FSIQ scores above a standard score of 70 (i.e., not more than two *SD* below the mean).

Peabody Picture Vocabulary Test – Fourth Edition. Participants completed the PPVT-4, which is a receptive vocabulary test that is used to estimate VIQ in children and adults.

It is a nationally standardized instrument. I administered this test as a supplementary measure of VIQ to ensure that ASD and typical groups were equally matched in terms of intelligence. This test is individually administered. On each trial of this task, the examiner presents a card that shows four full-coloured drawings, and asks the participant to say the number of the drawing that best represents the meaning of the word spoken by the examiner. The word items represent 20 content areas (e.g., musical instruments, fruits and vegetables, body parts) and parts of speech (e.g., nouns, verbs, adjectives). The cards are grouped in sets of 12 that increase in difficulty. The examiner continues to administer the PPVT-4 until they find 'basal' and 'ceiling' sets for the participant. The basal set is the card set in which the participant makes one or no errors; the ceiling set refers to the card set in which the participant makes eight or more errors. Test scores can be converted to a standard score (M = 100, SD = 15). The PPVT-4 has high split-half reliability and internal consistency ($\alpha \geq .94$), and has excellent test-retest reliability (r = .93).

Autism Spectrum Quotient. The AQ is a 50-item self-report questionnaire. While this screening tool cannot be utilized to diagnose ASD, it provides a measure of behavioural traits that are typical of individuals on the autism spectrum. There are 10 items devoted to each of five core domains: (1) social skills, (2) communication skills, (3) imagination, (4) attention to detail, and (5) attention switching/tolerance of change. During this test, adults of average intelligence are asked to read and then respond to each item independently using a 4-point Likert scale ranging from *"definitely agree"* to *"definitely disagree."* Each item on the AQ scores one point if the individual reports autistic behaviour mildly or strongly. Therefore, participants can receive a maximum score of 50 and a minimum score of zero. Scores of 32 and above signify that the individual presents with clinically significant levels of autistic traits. The selection of this cut-score was based on the results of two studies showing that 80% of those formally diagnosed with

ASD score above this cut-score, versus 2% of controls (Baron-Cohen et al., 2001; Baron-Cohen, Wheelwright, Robinson, and Woodbury-Smith, 2005).

The AQ has good internal consistency in all five domains (Baron-Cohen et al., 2001). Scores on the AQ correlate with the Social Responsiveness Scale -- another tool commonly used to assess the severity of ASD symptoms (Armstrong & Iarocci, 2013). Woodbury-Smith, Robinson, Wheelwright, and Baron-Cohen (2005) found that the AQ has good discriminate and predictive validity as indicated by concordance with clinician diagnoses. In an instrument review of assessment tools designed to diagnose Asperger's Disorder in adults, Stoesz, Montgomery, Smart, and Hellsten (2011) reported that the AQ has good test-retest reliability and is diagnostically valid.

Empathy Quotient. Participants completed the EQ to assess their degree of empathy. I administered this task because individuals with ASD often exhibit less empathy than is typical (Baron-Cohen, Leslie, & Frith, 1985). The EQ is a 60-item instrument to be completed by adults of average or superior intelligence. Forty items were designed to measure empathy and the other twenty are filler items. Participants are asked to read each item very carefully and respond to it using a 4-point Likert scale, which ranges from "*definitely agree*" to "*definitely disagree.*" Each item scored one point if the participant indicated that they exhibited empathic behaviour either definitely or slightly. A minimum EQ score of zero indicates that the participant experiences significant difficulties with empathy, whereas a maximum EQ score of 80 signifies a high degree of empathy.

Baron-Cohen and Wheelwright (2004) found that 81% of adults with ASD in their sample scored at or below 30 on this measure, in comparison to only 12% of their control sample. In a later study, Baron-Cohen, Wheelwright, Robinson, and Woodbury-Smith (2005) confirmed that adults with ASD generally score below 30 on the EQ. In their instrument review, Stoesz et al. (2011) reported that the EQ has high internal consistency and test-retest reliability. Finally, Allison, Baron-Cohen, Wheelwright, Stone, and Muncer (2011) reported that the EQ is a good, unidimensional measure of empathy.

Simple RT task. The simple RT task consisted of 20 trials designed to assess processing speed. For each trial participants viewed a fixation cross for a variable period that ranged from 100-500 ms which was followed by the presentation of a face (i.e., a woman with a surprised expression) or an object (i.e., a flag). Half of the trials consisted of static photographs, whereas the other half of the trials consisted of movies of the face or flag undergoing non-rigid motion. Participants were instructed to press a key on the keyboard as soon as the stimulus appeared on the screen.

Local-global task. All participants completed a Local-global task that I designed to assess individual visual processing biases. This task was based on that used in Navon's (1977) seminal study, and I created stimuli for my task using E-Prime in accordance with procedures used in past research (see Behrmann et al., 2005; Insch, Bull, Phillips, Allen, & Slessor, 2012). The goal of this task was to correctly identify either the global or local properties of a hierarchical stimulus on a computer screen as quickly as possible. The stimuli for this task were pictures of large (global) shapes that were made up of smaller (local) shapes. These shapes were presented in red or blue; if the image was blue participants were asked to identify the global shape of the stimulus, while if the image was red they were asked to identify the local shapes comprising the stimulus. The shapes presented were circles, squares, triangles, and diamonds. Stimuli subtended a visual angle of 15° in height and 10.5° in width.

The hierarchical shapes could be congruent or incongruent (see Figure 3). For congruent stimuli the global and local properties of the shape matched (e.g., a large circle made up of smaller circles). Incongruent stimuli had disparate global and local properties (e.g., a large circle made up of smaller triangles). There were four experimental conditions for this task: global congruent, global incongruent, local congruent, local incongruent. Participants made their local-global judgments by pressing one of four marked keys: “F” for triangles, “G” for circles, “H” for diamonds, and “J” for squares.

There were 32 different hierarchical stimuli in this experiment, each of which was presented three times (i.e., 96 trials). Trials were ordered randomly for each participant. Each trial began with the presentation of a black fixation cross on a white background for 500 ms, following which a stimulus shape was presented. Each stimulus remained on the screen until the participant made an appropriate response (by pressing one of the four marked keys) and the next trial followed an inter-stimulus interval of 500 ms. Participants completed 20 practice trials before beginning the experiment and were instructed to respond as quickly and accurately as possible. I collected data on accuracy and RT for each trial.

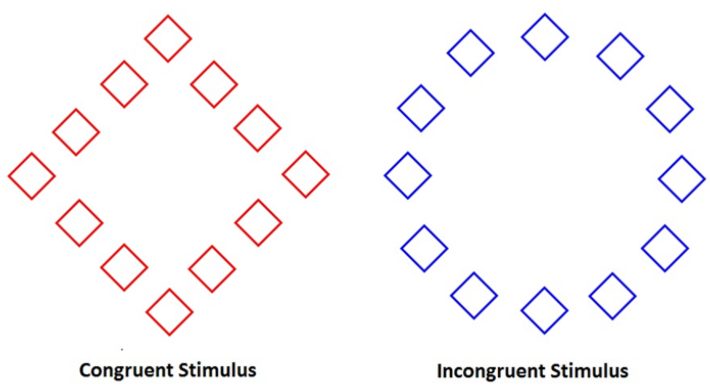

***Figure 1*. Example stimuli from the Local-global task.** Participants viewed hierarchical stimuli on the screen that were congruent or incongruent. Depending on the colour (red = local, blue = global) of the hierarchical stimulus, participants identified either the local or global properties of the shape. Stimuli remained on the screen until an appropriate response was made.

Face stimuli. Stimuli for the identity-matching and Garner tasks (described below) were obtained from Dr. Karen Pilz (McMaster University). These stimuli were created at the Max Planck Institute of Biological Cybernetics in Germany, and are described in detail elsewhere (see Pilz et al., 2006). The actors were photographed wearing a black cap and a scarf covering their hair and clothes. This was done so that only the faces, ears, and necks of the actors were visible. Each actor was photographed expressing emotions of anger, surprise, joy, and disgust at a frame rate of 25 frames per second. Dynamic movies of each actor were created from the 26 static frames captured as each expression unfolded. Only the surprised and angry facial expressions for each actor were used in the tasks described below. The actors were of adult, white women.

Simultaneous identity-matching task. This task allowed me to familiarize participants with the faces and expressions that were later presented in the Garner task, and also provided information regarding participants' ability to match facial identity – a frequently used paradigm in face processing research. In this task (created using MATLAB; The MathWorks, Inc., MA), participants were shown two faces on a computer screen concurrently, and made a judgment as quickly and accurately as possible as to whether the two faces belonged to the same person, or to two different people (see Figure 2 for an example of the task).

Across trials, four individuals displayed two facial expressions (surprised and angry) in two presentation modes (static and dynamic). Static trials consisted of presenting the participant with two static faces, whereas dynamic trials consisted of presenting two dynamic faces. When both faces presented on a given trial shared the same identity, they always displayed different expressions. Each trial began with the presentation of a fixation cross in the middle of the screen for 500 ms, following which two faces appeared on the screen for 1,040 ms, displayed right and left of center. Half of the participants made a two-alternative, forced-choice response by pressing the "z" key if the faces belonged to the same person (marked "same"), and the "m" key if they belonged to different people (marked "different"). Key assignment was reversed for remaining participants. There were 64 experimental trials (half of which were dynamic) and there were an equal number of "same" and "different" trials. Trial order was randomized for each participant and participants completed 20 static and 20 dynamic practice trials before moving on to the experimental trials. I recorded accuracy and response time (RT) data for each trial.

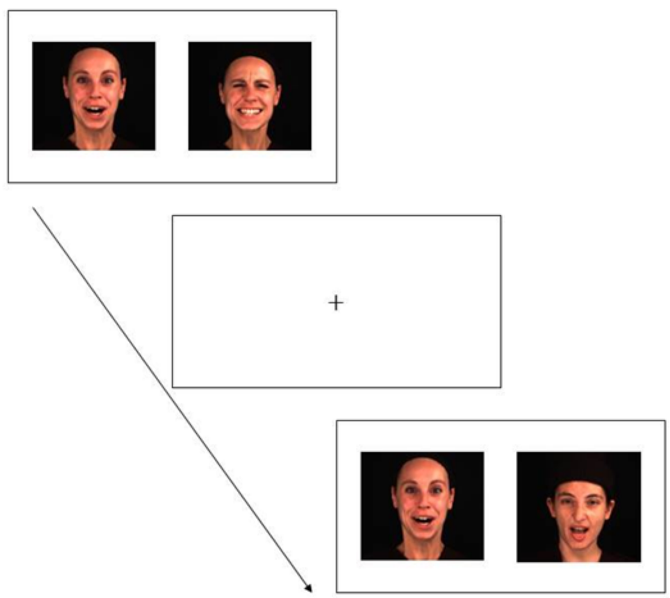

Figure 2. **Example stimuli from the Simultaneous identity-matching task.** Participants judged whether two faces belonged to the same person. Each trial began with a fixation cross that remained on the screen for 500 ms followed by the presentation of two concurrent static or dynamic faces. Each stimulus was presented for 1,040 ms. Participants made "same" or "different" judgments by pressing a corresponding key on the keyboard. Face stimuli used in this task were obtained from Dr. Karen Pilz (Pilz et al., 2006).

Garner's selective attention task. Participants completed a version of Garner's selective attention task (after Garner, 1976). In this task, participants were asked to make expression or identity judgments as quickly and accurately as possible for faces that were presented in static or dynamic conditions. Two actors from the identity-matching task ("Anne" and “Jane”) were shown expressing anger or surprise. Identity and expression tasks were presented in a counterbalanced order across participants. Half of participants began each task with static trials, while the other half started with dynamic trials.

Each task (expression and identity) consisted of a baseline block followed by an orthogonal block. In the baseline block, the task-relevant dimension of the face (e.g., identity for the identity task: Anne or Jane) varied while the task-irrelevant dimension (e.g., expression for the identity task: surprised or angry) was held constant. In the orthogonal block, relevant and irrelevant dimensions varied randomly; as such there were four possible combinations of the two dimensions in the orthogonal block (i.e., Anne/surprised, Anne/angry, Jane/surprised, Jane/angry, see Figure 3 for an example of the different blocks). For each task, there were 20 trials for the baseline block and 40 trials for the orthogonal block. In both blocks, viewers were asked to make judgments regarding the relevant facial dimension while ignoring the irrelevant dimension. Each trial began with the presentation of a fixation cross for 500 ms, which was followed by the presentation of a stimulus face for 1,040 ms. Participants were asked to make a two-alternative, forced-choice response by pressing one of two marked keys. The next trial began immediately after a response was entered. Key assignments were reversed for half of participants. Before starting the experimental trials participants completed five static and five dynamic practice trials for each block. I recorded accuracy and RT data for each trial.

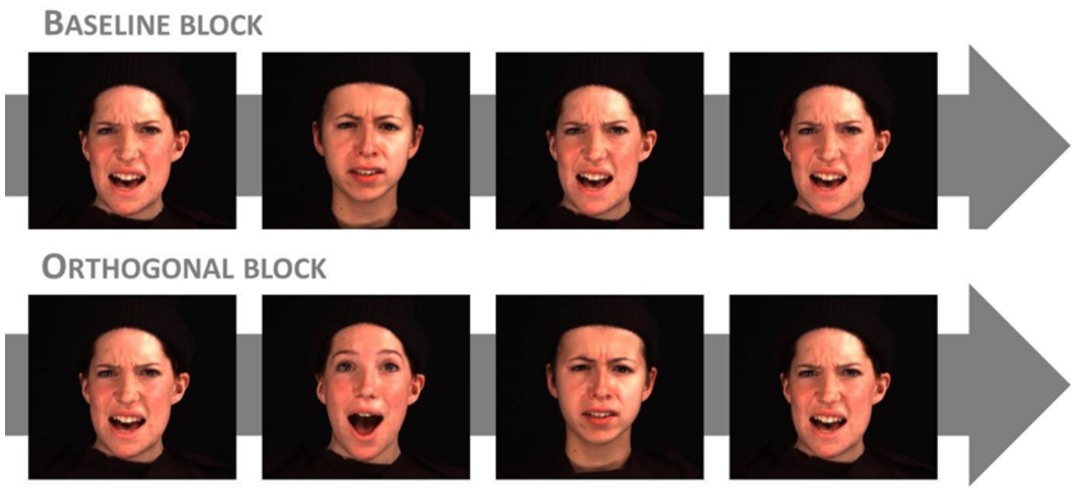

***Figure 3*. Example stimuli from the Garner identity task.** Participants judged the identity of faces on the screen (Anne or Jane) for both static and dynamic trials by pressing a corresponding key on the keyboard. Each stimulus face was presented for 1,040 ms. In the baseline block, the irrelevant dimension (expression) remained constant while the relevant dimension (identity) varied from trial to trial. In the orthogonal condition the relevant and irrelevant dimensions varied randomly. Participants completed the baseline block followed by the orthogonal block for identity and expression tasks in both static and dynamic conditions. Face stimuli used in this task were obtained from Dr. Karen Pilz (Pilz et al., 2006).

RESULTS

I used SPSS 22 (SPSS Inc., Chicago, IL, USA) for all analyses described below, adopting an alpha level of .05 for all tests of significance. Table 1 presents the descriptive statistics for the demographic and screening measures gathered from participants. Participants in the ASD and the typical groups were comparable in terms of age (independent samples *t*-test) and had identical sex distributions. The groups performed equally well on all IQ measures from the WASI and on the PPVT-4 (independent samples *t*-tests); no participant in either group scored more than two *SD* below the mean (M = 100, SD = 15) on any component of these tests. One participant in the ASD group had a FSIQ score of 83, with the next lowest score in this group being 94. The lowest FSIQ score in the typical group was 98. Therefore, overall my samples consisted of individuals who were functioning in the normal range.

Table 1

Demographic Information and Scores on Screening Measures of the ASD and Typical Groups

	Adults with ASD (*n* = 16)	Typical Adults (*n* = 16)
Age (years: months)	27:10	27:4
Sex distribution	11 men: 5 women	11 men: 5 women
WASI VIQ	*M* = 107.8 (*SD* = 13.9) Range (78 – 128)	*M* = 110.7 (*SD* = 9.5) Range (95 – 137)
WASI PIQ	*M* = 103.9 (*SD* = 15.7) Range (71 – 129)	*M* = 113.3 (*SD* = 11.4) Range (94 – 127)
WASI FSIQ	*M* = 106.3 (*SD* = 10.8) Range (83 – 121)	*M* = 113.4 (*SD* = 8.7) Range (98 – 133)
PPVT-4 (standard score)	*M* = 106.2 (*SD* = 12.8) Range (89 – 137)	*M* = 108.4 (*SD* = 10.0) Range (94 – 125)

Autism Screening Measures

As expected, the ASD group reported significantly more autistic-like traits than the typical group based on AQ Total scores, and on scores on each of the AQ's five subscales, $t(32) \geq 2.78$, $p \leq .009$ for all contrasts. However, as can be seen in Figures 4 and 5, their AQ Total scores and their scores on both the Social and the Imagination subscales were significantly lower than those obtained by a sample of high functioning individuals with ASD described by Baron-Cohen et al. (2001), $t(72) \geq 3.53$, $p < .001$ in each case. In contrast, participants in the typical group exhibited scores similar to those of the normative sample described by Baron-Cohen and colleagues on all measures. Five participants in the present ASD sample scored above the cutoff endorsed by Baron-Cohen et al. for identifying individuals with clinically significant autistic traits (i.e., AQ Total score ≥ 32), compared to one participant in the typical group.[1]

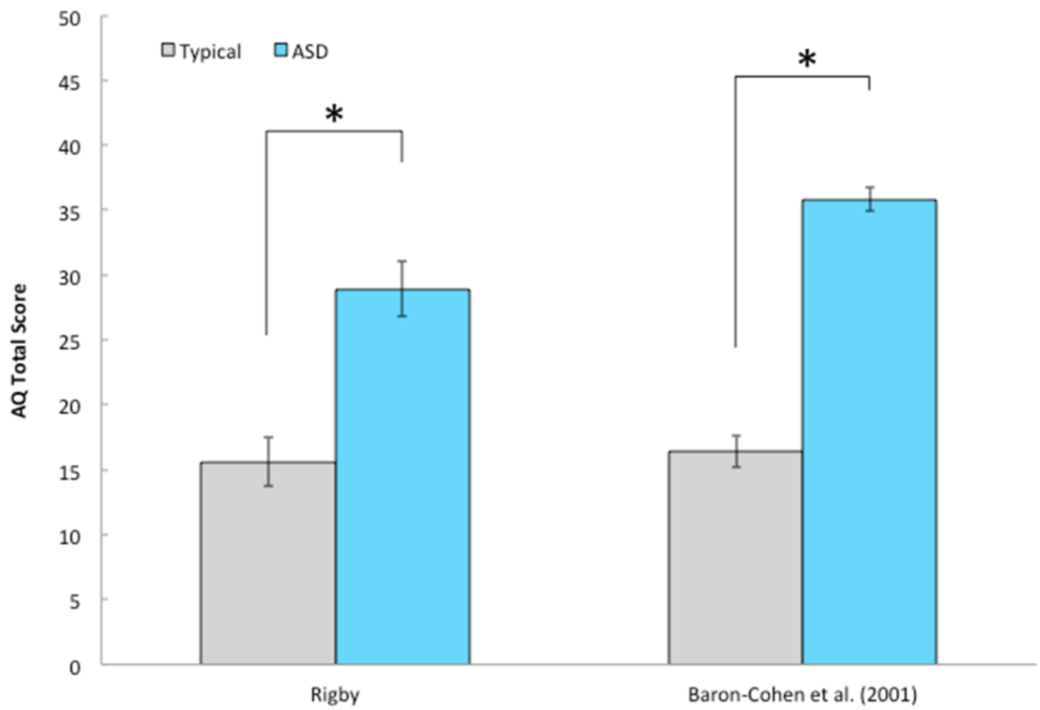

Figure 4. **AQ Total score comparisons between the typical and ASD samples in the current study to the norms provided by Baron-Cohen et al. (2001).** Participants with ASD in both studies exhibited higher levels of autistic traits than typical participants on this measure. Asterisks indicate significance at $p < .05$. Standard errors are indicated.

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[1] In screening a clinical sample of 100 adults with suspected Asperger's Syndrome, Woodbury-Smith et al. (2005) found that a lower cut-score of 26 resulted in correct classification of the largest number of individuals (83% correctly classified; 0.95 sensitivity, 0.52 specificity). In the present study, 1 typical and 9 ASD participants scored above this cut-score.

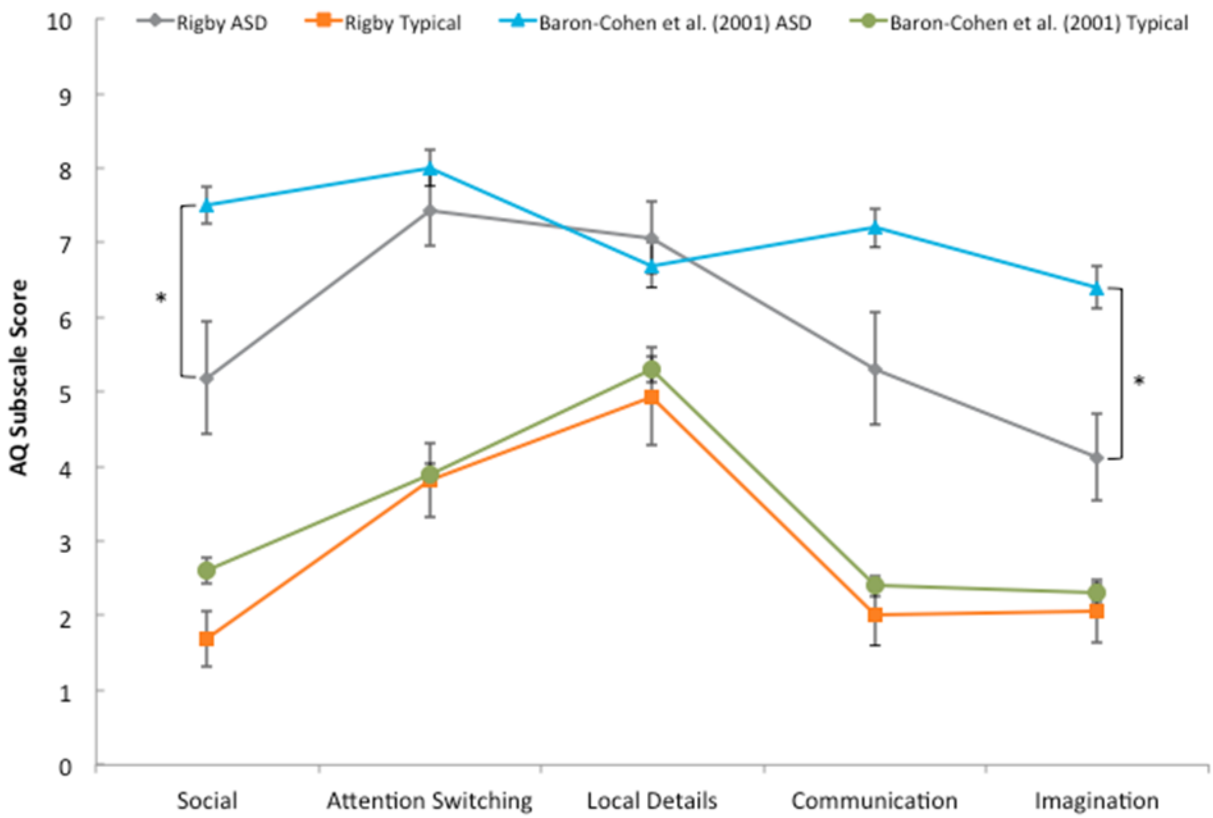

***Figure 5*. Comparison of subscale scores on the AQ between the typical and ASD samples in the current study to the norms provided by Baron-Cohen et al. (2001).** Participants with ASD in the current study showed fewer autistic traits on the Social and Imagination subscales compared to participants with ASD in Baron-Cohen et al. Asterisks indicate differences between the clinical samples in the present study and the Baron-Cohen study at $p < .05$. Standard errors are indicated.

Past research indicates that those with ASD generally endorse fewer empathic traits on the EQ than is typical (Baron-Cohen & Wheelwright, 2004). Figure 6 shows the mean EQ scores from the typical and ASD groups in the current study, along with those obtained by samples tested by Baron-Cohen and Wheelwright (2004). As expected, the typical group in the present study reported more empathic traits than the ASD group, $t(32) = -4.8$, $p < .001$. Only one participant in the typical group scored below the cutoff score of 30 endorsed by Baron-Cohen and Wheelwright (2004), compared to 11 in the ASD group. Participants with ASD in the present study exhibited more empathic traits than those in the comparison study, $t(104) = 3.8$, $p < .001$, whereas the two typical groups scored similarly.

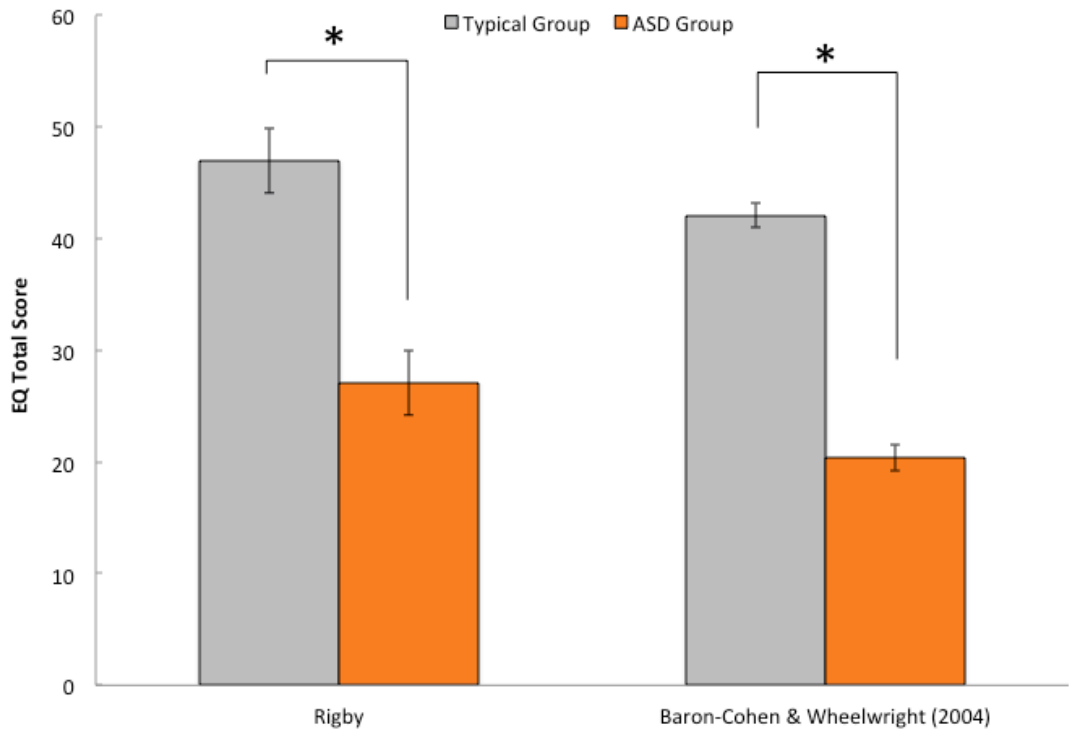

***Figure 6*. Comparison of AQ Total scores between the typical and ASD samples in the current study to the norms provided by Baron-Cohen et al. (2001).** Participants with ASD in both studies exhibited less empathy than typical participants on this measure. Asterisks indicate significance at $p < .05$. Standard errors are indicated.

Simple RT Task

Processing speed was measured by examining median RTs for all four conditions of the simple RT task: static/flag, static/face, dynamic/flag, and dynamic/face. To correct for problems with normality, I transformed the RT data using a reciprocal transformation. I then submitted the transformed scores to a 2 (Group: typical, ASD) x 2 (Type: Face, Flag) x 2 (Mode: Static, Dynamic) analysis of variance (ANOVA) with repeated measures on the last two factors. Overall, participants responded faster to faces ($M = 530$ ms, $SD = 120$) than to flags ($M = 590$ ms, $SD = 130$), $F(1, 30) = 12.09$, $p = .002$, $\eta_p^2 = .29$; this result may reflect the evolutionary importance of perceiving facial cues. Participants also responded more slowly to dynamic (*M* = 730 ms, *SD* = 150) than to static stimuli (*M* = 380 ms, *SD* = 100), $F(1, 30) = 283.96$, $p < .001$, $\eta_p^2 = .90$, which may indicate that some processing of motion is obligatory, even when there are no difficult decisions to make. Importantly, there were no significant group differences in performance on this task, and no significant interactions involving the grouping variable. This indicates that, as expected, participants with ASD did not show deficits in processing speed (as measured by this task) that might complicate interpretation of their performance on the more cognitively complex Local-global and face processing tasks.

Local-global Task

Because mean accuracy scores on the Local-global task were quite high (> 93% in the typical group; > 87% in the ASD group), I examined participants' median RTs for correctly answered trials to provide an indication of how easily the global or local features of each stimulus were processed. To compute each participant's bias score, I used a formula obtained from Wang, Li, Fang, Tian, and Liu (2012):

$$Bias = \frac{[Consistent\ (Global - Local) - \ Inconsistent\ (Global - Local)]}{[Consistent\ (Global + Local) - Inconsistent\ (Global + Local)]}$$

This formula provided an index of the extent to which participants were distracted (i.e., slowed) by the presence of inconsistent local information when asked to judge global information, or by the presence of inconsistent global information when asked to judge local information. A positive bias score reflects relatively greater interference from global than local cues (global processing bias), whereas a negative score indicates more interference from local than global cues (local processing bias). Given past research (e.g., Bölte et al., 2007; Castelli et a., 2007; Happé et al., 2001; Martin & Macrae, 2010; Roalf et al., 2006), I expected that most participants in the ASD group would be classified as local processors, whereas members of the typical group would show more variability in their bias scores. In fact, the proportions of global and local processors in the two groups were similar, and both groups had comparable mean bias scores that one-sample *t*-tests confirmed were not significantly different from zero ($M_{Typical}$ = .006, *SD* = .04; M_{ASD} = .016, *SD* = .10). This suggests that neither group exhibited a processing bias that was significantly "local" or "global" when instructed to respond in either direction. Bias scores were not correlated with AQ Total or EQ scores. Finally, sex did not impact performance on this task; thus, men and women did not differ with regard to their mean bias scores (M_{men} = .011, *SD* = .08; M_{women} = .011, *SD* = .071).

Simultaneous Identity-matching Task

I eliminated individual trials in which the RTs for each participant fell outside the window of 200-5,000 ms after stimulus onset. Responses faster than 200 ms were eliminated because this would indicate that participants were responding before they saw the stimulus presented, and responses longer than 5,000 ms were eliminated because this would suggest that participants were not paying adequate attention to the task. In total, eliminating these trials accounted for a total of 0.88% of static trials and 1.6% of dynamic trials. Separate 2 (Group: typical, ASD) x 2 (Mode: Static, Dynamic) mixed ANOVAs were carried out on accuracy and sensitivity scores; here, sensitivity was defined as $d' = Z(\text{Hit Rate}) - Z(\text{False Positive Rate})$. Both analyses produced a significant main effect of Group, $F(1, 30) \geq 4.84$, $p \leq .036$, $\eta_p^2 \geq .14$, with participants in the typical group being more accurate ($M_{Typical}$ = 87% correct, *SD* = .09; M_{ASD} = 75% correct, *SD* = .16) and showing greater sensitivity to facial identity ($M_{Typical}$ = 2.63, *SD* = .97; M_{ASD} = 1.75, *SD* = 1.29) than those in the ASD group. Although neither accuracy nor sensitivity was affected by the mode of presentation, an analysis of correct median RTs revealed that, on average, responses on static trials were faster (M = 1,330 ms, SD = 66) than those made on dynamic trials (M = 1,776 ms, SD = 73), $F(1, 30) = 146.17$, $p < .001$, $\eta_p^2 = .83$.

I ran regression analyses to assess both linear and quadratic relations between the three performance measures and bias scores from the Local-global task. In both presentation modes, median correct RT showed a significant curvilinear relationship with processing bias, accounting for 25 and 39% of the variance (static $R^2 = .39$, $p = .001$; dynamic $R^2 = .25$, $p = .017$), such that individuals who showed no bias responded more quickly than those who were either strong local or strong global processors (see Figure 7).

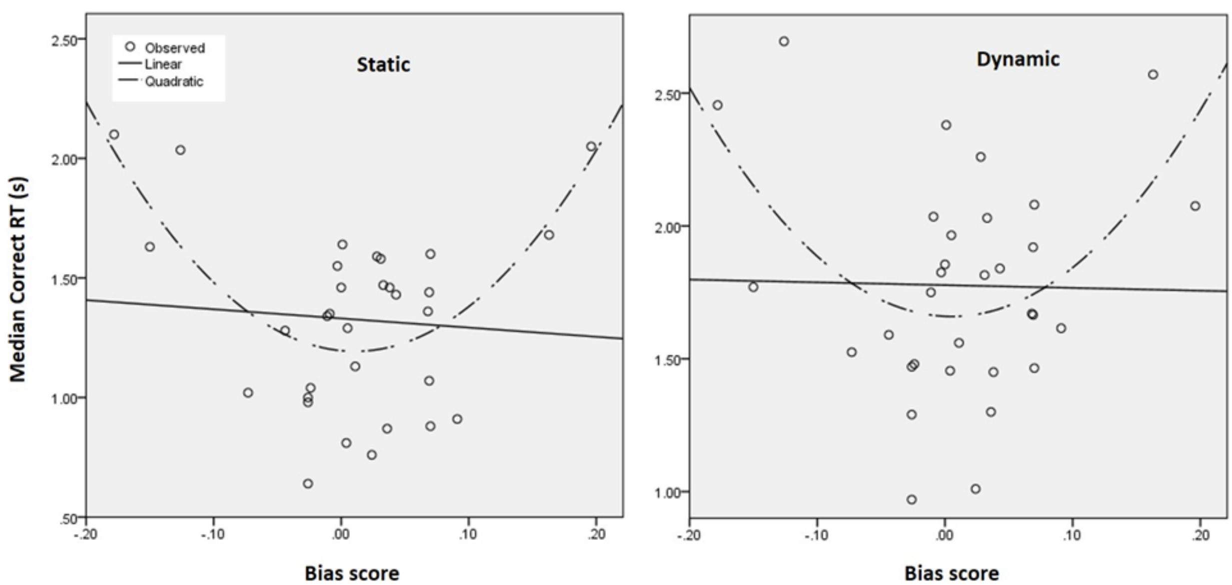

***Figure 7*. Curvilinear relationship between bias scores and RTs on the simultaneous identity-matching task.** Participants who showed no bias were faster on this task compared to participants who were more strongly biased toward local or global processing.

Garner's Selective Attention Tasks

Accuracy scores in the baseline and orthogonal blocks of all four conditions of the Garner task were high, and did not differ between groups ($M_{Typical}$ > 92% correct; M_{ASD} > 96% correct) or across conditions ($M \geq$ 94% correct in all cases). For this reason, I examined performance based on median RTs for correctly answered trials. Individual trials in which a participant's RT fell outside the window of 200-5,000 ms after stimulus onset were eliminated before determining the median correct RT in each condition; a total of 0.16% of static trials and 0.44% of dynamic trials were removed from further analyses based on this criterion. RT data were analyzed using nonparametric tests because the data in some of the conditions were not normally distributed. Of note, completing the analyses described below using mean rather than median RTs did not change the pattern of results.

Baseline conditions. I first examined performance in baseline conditions of the Garner task. The ASD group responded more slowly than the typical group in the baseline conditions of both the static and dynamic expression tasks, Mann-Whitney $U \geq 66$, $p \leq .021$ (see Table 2). That is, compared to their peers, those with ASD required more time to judge the expression of a face, even when identity was held constant from trial to trial.[2] Although a similar pattern was evident in the identity task, the group comparisons were not significant in this case. Within-group comparisons of static and dynamic baseline performance revealed that, whether judging expression or identity, both groups were significantly slowed by the introduction of facial motion, Wilcoxon $Z \geq -3.3$, $p \leq .001$ for all contrasts.

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[2] Group differences in the static and dynamic Expression tasks were still evident after correcting for individual differences in Simple RT, Mann-Whitney $U \geq 68$, $p \leq .023$. Group differences were also evident whether one considered judgments of only surprised or of only angry faces (Mann-Whitney $U \geq 58$, $p \leq .039$), although the former judgments were made more quickly than the latter in both groups when faces were moving (Wilcoxon $Z \leq -2.41$, $p \leq .016$).

Table 2

Baseline RT data (ms) from the Garner Interference Tasks

Group	**Task**	**Mode**	**Median RT**	**Range** (Min – Max)
Typical	Expression	Static	628	465 - 960
		Dynamic	933	740 - 1375
	Identity	Static	528	450 - 680
		Dynamic	810	700 - 1585
ASD	Expression	Static	725	420 - 1100
		Dynamic	1063	850 - 1550
	Identity	Static	600	440 - 1360
		Dynamic	918	695 - 1810

Garner interference. Given the observed group differences in baseline performance, I calculated *corrected Garner interference scores* using the following formula:

$$\text{Corrected Garner Interference} = \frac{\text{Median Correct RT (orthogonal) - Median Correct RT (baseline)}}{\text{Median Correct RT (baseline)}} \times 100.$$

These scores indicate the percent change from baseline RT seen in the orthogonal condition. Note that completing the interference analyses described below using uncorrected scores did not change the pattern of results. Wilcoxon signed ranks tests indicated that the typical group showed interference in both the static expression ($Z = -2.33$, $p = .02$) and static identity ($Z = -1.93$, $p = .05$) tasks; thus, their corrected interference scores were significantly greater than zero in both tasks, indicating that response times were longer in the orthogonal block than during baseline testing. The levels of interference were comparable in the two static tasks ($Z = -1.29$, $p = 20$). In contrast, when the test faces were moving typical participants showed negligible interference when making expression judgments, and were actually quicker at judging identity compared to their performance at baseline (i.e., their interference scores were negative; $Z = -2.27$, $p = .023$). The drop in interference seen when motion cues were introduced was significant in both tasks (Expression Task: $Z = -2.28$, $p = .023$; Identity Task: $Z = -2.33$, $p = .02$). Unlike typical participants, individuals with ASD showed negligible interference in all testing conditions, and their interference scores did not change appreciably with the introduction of dynamic cues ($p > .05$ for all comparisons; see Figure 8).

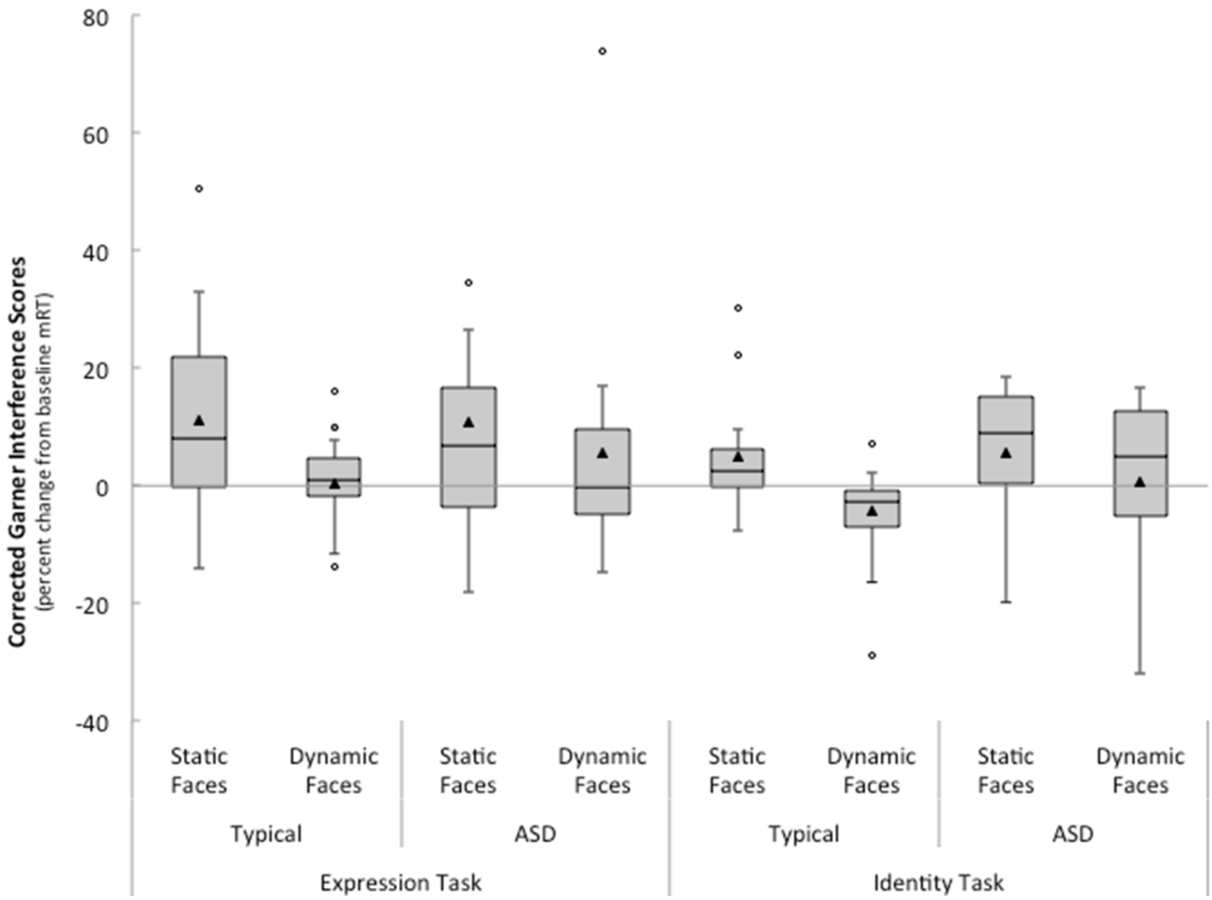

***Figure 8.* Comparison of Corrected Garner Interference scores in the typical and ASD samples.** Horizontal lines within boxes represent medians, whereas triangles represent means. Circles represent outliers. The top of the fence represents maximum values, whereas the bottom of the fence represents minimum values. Typical participants experienced significant interference in the static tasks, and showed a significant drop in interference when motion was introduced. The participants with ASD did not show significant interference in any task condition.

DISCUSSION

In Study 1, I documented differences in performance on a simultaneous identity-matching task, and in interference between expression and identity processing in adults with and without an ASD diagnosis. Importantly, results from the simple RT task confirmed that these group differences could not be accounted for by differences in processing speed. Thus, although viewers were quicker to respond to faces than to flags, and quicker to respond to static than to dynamic displays, no group differences were evident in the simple RT task. The present results confirm earlier reports of atypical face processing in individuals with ASD with regards to judging facial expressions, and between identity and expression processing interference when faces are static.

I expected to find group differences in performance on both the matching and Garner tasks would be more marked when static, as opposed to dynamic, faces served as test stimuli. The findings did not support this hypothesis in the case of the matching task, or during baseline conditions of the Garner task. In both instances, deficits in performance were evident in the ASD group regardless of testing modality. The results do, however, replicate and extend previous findings suggesting that individuals with ASD show atypical face processing (e.g., Barton et al., 2007; Dalton et al., 2005; Enticott et al., 2013; Pelphrey et al., 2002; Scherf et al., 2008).

I further hypothesized that (a) with static faces the ASD group would show more interference from expression on identity judgments than the reverse, whereas controls would show the opposite pattern; and (b) group differences in interference would be eliminated in dynamic testing conditions. Although interference levels in the static conditions did not vary as a function of task in either group, typical participants showed a significant drop in interference when motion cues were introduced, whereas participants with ASD showed negligible levels of interference in all testing conditions, suggesting that motion cues might have enhanced independent processing of identity and expression cues for typical participants, but not those with ASD.

Finally, I predicted that both matching performance and interference levels observed in the Garner task might vary as a function of processing style during static (but not dynamic) testing. Unexpectedly, neither group showed a significant bias towards local or global processing, overall. However, although processing bias was unrelated to interference in any condition of the Garner task, in both conditions of the matching task, individuals who showed no bias responded more quickly than those who were either strong local or strong global processors. I discuss each of these findings in detail below.

Simple RT Task

I administered the Simple RT task to explore whether there were any group differences in processing speed abilities. This task employed static and dynamic versions of faces and flags to see if processing speed varied depending on stimulus type in either group. If there were observed differences between groups with regard to overall processing speed (particularly with face stimuli), then this would need to be taken into account when interpreting performance on more complex face processing tasks. Importantly, there were no group differences in performance on this task, and no interactions involving the grouping variable. This suggests that participants with ASD did not show overall deficits in processing speed as measured by this task. Although some research has observed processing speed deficits in those with ASD (e.g., Hedvall, Fernell, Holm, Johnels, Gillberg, & Billstedt, 2013; Oliveras-Rentas, Kenworthy, Robertson, Martin, & Wallace, 2012; Spek, Scholte, & van Berckelaer-Onnes, 2008) other studies have found that these abilities are intact when motor demands are low (Kenworthy et al., 2013), and when participants have average IQ scores (Wallace, Mike, & Happé et al., 2009), as was the case in the present study.

Participants in both groups responded faster to faces than to flags. From an evolutionary perspective, efficient processing of face cues might be more important than other types of visual information, however this would certainly depend on context. Nelson (2001) proposed that the human brain is innately prepared to process facial information, and increased experience with faces helps to promote cortical specialization for face processing. The fact that all participants responded faster to faces than flags reflects this face-specific advantage. Notably, even participants with ASD in the current study showed a face advantage on this task. This may suggest that although participants with ASD generally look at faces less than is typical (see results from Study 2; Klin et al., 2002; Nomi & Uddin, 2015 for a review; Riby & Hancock, 2009; Rice, Moriuchi, Jones, & Klin, 2012) and are less competent at processing certain facial cues (see below), they still show the typical face advantage in terms of processing speed.

Overall, participants took longer to respond to dynamic than static stimuli regardless of group membership. This effect of motion was observed when participants viewed a face displaying an unfolding expression and when they viewed an undulating flag. This finding reveals that some processing of facial and non-facial motion is obligatory and occurs automatically, even in the absence of task decisions. Increased RT following the introduction of facial motion is consistent with the findings from other researchers (Fiorenti & Viviani, 2011; Stoesz & Jakobson, 2013). One reason for this increase in processing time could be explained by the fact that moving stimuli provide the viewer with more information than non-moving stimuli. Additionally, processing facial motion recruits more extensive cortical networks (Foley et al., 2012; Kessler et al., 2011; Polosecki et al., 2013). Extended cortical processing is also seen for non-facial (object) motion in typical individuals (Beauchamp, Lee, Haxby, & Martin, 2002) and in people with ASD (Weisberg et al., 2014). Therefore, the integration of these cortical networks in response to motion cues may result in increased processing time, as reflected in this task.

Local-global Task

In the Local-global task, neither group was biased toward using local or global processing strategies when making judgments about hierarchical stimuli. This finding was unexpected given the plethoric evidence of a local processing bias in individuals with ASD (e.g., Bölte et al., 2007; Castelli, Frith, Happé & Frith, 2007; Nishimura et al., 2008; Wang et al., 2007). However, in a recent meta-analysis of the literature on visual processing strategies in ASD, Van der Hallen, Evers, Brewaeys, Van den Noorgate, and Wagemans (2014) reviewed the research from over 1,000 affected individuals and found that there is little evidence of enhanced local processing or global deficits in ASD, overall. Although individuals with ASD may be slightly slower at processing global information when there is incongruent local information (Van der Hallen et al., 2014), when judgments about global information are required they do not seem to be impaired or disadvantaged by this (Behrmann et al., 2006; Lahaie et al., 2006; Nishimura et al., 2008; Tanaka & Sung, 2013).

It is possible that processing biases vary as a function of the *severity* of symptoms of ASD. In other words, it is conceivable that group differences might be easier to detect when the clinical sample under study includes many individuals showing a large number of autistic characteristics. In the present study, only nine participants in the ASD group scored above the clinical cut-off score of 32 on the AQ. Although this was not necessarily unexpected given that the AQ is simply a *screening* measure, it does suggest that the ASD group in the current study was (on average) rather mildly affected, compared to other ASD samples that have been assessed with this instrument (Baron-Cohen et al., 2001; Woodbury-Smith et al., 2005). However, despite the wide range in bias scores observed in the present sample, there was no relationship between AQ Total scores and bias scores on the Local-global task.

Although some work involving typical viewers suggests that having a global processing bias promotes better face recognition abilities (Martin & Lewis, 2002), this is not always the case (e.g., Perfect et al., 2008). It is notable that, in the present study, quadratic relationships were observed between bias scores and performance in both conditions of the matching task. The data indicated that (irrespective of group) optimal performance on a task requiring *identity* processing was observed in those who showed a balanced processing style.

With the two expressions used here (surprised and angry), no relationship was found between performance on the Garner task and processing bias. Some research suggests that angry expressions are processed using a more featural approach, whereas surprised expressions are processed more globally (see Bassili, 1978; Nusseck, Cunningham, Wallraven, & Bulthoff, 2008). One might expect that processing bias would be related to interference between expression and identity processing if both expressions displayed are processed more locally (such as anger and fear), or more globally (such as surprise and sadness). More work is needed to explore differences in processing strategies across different expressions.

One limitation of this study is that I did not collect pilot data for this task using a large sample, nor did I have reliability or validity estimates of the task itself. Another potential limitation is that I computed bias scores using a subtraction formula (see Wang et al., 2012). DeGutis and colleagues (2013) criticized measures of holistic processing that employ difference scores because they do not take into account individual differences. Alternatively, these authors recommend using regression approaches. Another limitation of this study might be the design of the Local-global task itself. Different tasks designed to assess processing biases are not necessarily related, and test-retest reliability on these tasks is quite low (Dale & Arnell, 2013). Further, I used a non-face task to determine bias predispositions. Understandably, processing bias scores as measured by this task may not provide a valid indication of how people process *faces*, particularly those that are moving. This might mean that scores on the local-global task did not tap into face processing biases. Future research should examine face processing biases using face-specific tasks. One such measure could involve computing face-specific bias scores from performance on composite face tasks or part-whole tasks (which are thought to assess holistic processing; as in DeGutis et al., 2013), preferably with dynamic stimuli (e.g., Xiao et al., 2012; 2013).

Simultaneous Identity-matching Task

Identity-matching tasks are commonly used paradigms to investigate face processing abilities in typical development (e.g., Chen et al., 2011; O'Toole, Phillips, Weimer, Roard, Ayyad, et al., 2011; Thornton & Kourtzi, 2002) and in ASD (e.g., Joseph & Tanaka, 2003; Riby et al., 2009; Scherf et al., 2008). Although the predominant goal of administering this task was to familiarize participants with the faces that they would see in the Garner interference tasks that followed, it is still relevant to examine performance on this task. In line with previous research that generally finds some deficits in identity processing in individuals with ASD (e.g., Scherf et al., 2008; see Weigelt et al., 2012 for a review), typical participants in the current study were more accurate and more sensitive to facial identity than participants with ASD. It should be noted, however, that no group differences were apparent in baseline performance in the Garner identity task (either in terms of accuracy or RT). In their review of the literature, Weigelt et al.

(2012) speculate that inconsistent findings on identity recognition in ASD might be due to changes in task demands. Interestingly, however, they suggest that the largest group differences are observed when tasks involve delays – the opposite of what was seen here. One factor that might have made my matching task more difficult for individuals with ASD was that they were required to compare two faces simultaneously. In addition, on "same" trials (i.e., when the two faces presented belonged to the same person), the two faces always displayed different expressions. These factors may have disproportionately increased the cognitive and affective load for individuals on the spectrum (e.g., Doherty-Sneddon, Riby, & Whittle, 2012; Riby & Hancock, 2009).

In both groups, participants compensated for the increased challenge of processing dynamic cues by taking longer to respond. This is consistent with the idea that viewers use non-rigid motion to help them to discriminate between facial identities. The fact that this extra processing time did not lead to a dynamic advantage in terms of accuracy might reflect the fact that dynamic advantages are most often seen under non-optimal viewing conditions (Knight & Johnston, 1997; Lander et al., 1999; O'Toole et al., 2002). While it could be argued that viewing conditions were non-optimal in the current experiment due to the brief presentation time, participants in both groups were still able to make quick judgments about the faces with a high degree of accuracy.

Garner Task Accuracy

There were no group differences in accuracy in baseline and orthogonal blocks for all four conditions of the Garner task. In other words, participants with ASD were able to judge facial expression and identity quite accurately. While ostensibly this result may seem inconsistent with results from the identity-matching task, differences in task demands might account for this performance discrepancy. Although the two faces in the Garner tasks were shown previously in the identity-matching task, there were four faces to discriminate between in the latter. In addition, all participants completed the face-matching task immediately before they were administered the Garner task. Therefore, whereas faces were *unfamiliar* to participants when they were initially presented in the matching task, they were to some degree familiar in the Garner task. Facial familiarity increases the perceptual integrality of different face cues (Ganel & Goshen-Gottstein, 2004) and can facilitate expression judgments. Additionally, Pierce and Redcay (2008) observed atypical activation of the fusiform gyrus in response to unfamiliar (but not familiar) faces in individuals with ASD. Increasing the familiarity of face stimuli may have facilitated identity judgments in the Garner tasks and might help explain why accuracy in the ASD group was comparable to the typical group in this experiment.

Garner Task Baseline Conditions

All participants were slowed significantly by the presence of motion cues in the baseline blocks of the Garner task. One intuitive explanation for this is that they were waiting for the face's expression to unfold before making their judgments. In static versions of these tasks, the apex of the expression is immediately available to viewers (see Fiorenti & Viviani, 2011; Lander et al., 1999; Stoesz & Jakobson, 2013). Interestingly, Stoesz and Jakobson (2013), as well as Fiorenti and Viviani (2011), observed that typical participants in their

studies initiated their responses to dynamic stimuli *prior* to the face reaching its expression apex. In other words, participants responded to dynamic faces when expressions were still quite subtle. The same result was seen in the current study, as evidenced by the fact that responses in the baseline condition were generally *completed* within 200 ms of the apex of each unfolding expression, which occurred at 840 ms (see Table 2). This may represent a dynamic advantage of sorts. In other work, Ambadar et al. (2005) observed a dynamic advantage with non-degraded faces when expressions were subtle.

Although both groups took longer to respond to moving than static faces during baseline testing, participants with ASD required more time, overall, to make accurate expression judgments (regardless of modality). This speed-accuracy trade-off suggests that participants with ASD were disadvantaged when making relatively simple judgments of facial expression (i.e., when identity was held constant). Supplementary analyses confirmed that group differences in the expression tasks were still apparent after controlling for individual differences in processing speed (as measured in the Simple RT task).

Enticott et al. (2013) found that individuals with ASD were disadvantaged compared to controls when processing negative (i.e., sad, angry, and disgusted) but not positive expressions, possibly because the former expressions are perceived as more threatening in adults (Enticott et al., 2013) and children and adolescents (Swartz, Wiggins, Carrasco, Lord, & Monk, 2013) with ASD. Therefore, one might have expected that group differences would be more apparent on "angry" than "surprised" trials in the current study, given that surprised expressions have been characterized by some as being positively valenced (e.g., Pilz et al., 2006; Stoesz & Jakobson, 2013). Despite this, exploratory analyses confirmed that there were no differences in performance related to the particular expression that was shown. It is possible that participants in the present study found the "surprised" expressions somewhat ambiguous or, in the case of individuals with ASD, somewhat threatening (see Eack et al., 2014; Swartz et al., 2013; Tottenham, Hertzig, Gillespie-Lynch, Gilhooly, Millner, et al., 2013). Future research should explore a wider range of facial expressions with varying positive and negative valence.

Garner Task Interference

As expected, typical participants showed significant levels of interference in the static expression and identity tasks. This replicates previous findings (e.g., Chen et al., 2011; Ganel & Goshen-Gottstein, 2004; Levy & Bentin, 2008; Schweinberger et al., 1999; Schweinberger & Soukup, 1998; Stoesz & Jakobson, 2013) and supports the interpretation that there is some interdependency between the processing of expression and identity cues in typical populations (Haxby et al., 2002). That is, changes in expression can interfere with one's ability to judge a face's identity, and changes in identity interfere with expression judgments even when faces are somewhat familiar.

In line with my hypotheses, typical participants showed a significant reduction in interference when motion cues were introduced (as in Rigby et al., 2013; Stoesz & Jakobson, 2013). Traditionally, a lack of Garner interference suggests that the facial cues are processed using independent and functionally distinct neural pathways (Garner, 1976). If this is correct, then adding dynamic cues forces greater functional independence between identity and expression processing. One might suggest that the introduction of motion cues causes a shift toward greater local processing, which allows viewers to attend more selectively to relevant facial cues (Loucks & Baldwin, 2009; Stoesz & Jakobson, 2013; Xiao et al., 2012; 2013). However, this interpretation was not supported by the current study. Thus, processing bias did not affect levels of *interference* seen in the Garner task, although (as noted earlier) bias scores were related to performance in the identity-matching task. An alternative explanation for the drop in interference seen with the introduction of motion cues is that viewers are better able to *integrate* identity and expression cues when processing moving, as opposed to static, faces (see Stoesz & Jakobson, 2013). Support for this idea comes from the fact that motion cues cause a shift in the ways that various parts of face processing networks interact. Thus, in addition to recruiting cortical areas thought to be involved in static face processing (Pitcher et al., 2011; Yovel & Kanwisher, 2004), dynamic faces recruit areas in the core and extended face processing networks, including the superior temporal sulcus (Haxby et al., 2002; Kessler et al., 2011; Miki, Takeshima, Watanabe, Honda, & Kakigi, 2011) – a region known to be involved in sensory integration (e.g., lipreading; Olson, Gatenby, & Gore, 2002).

Interestingly, participants with ASD showed negligible levels of interference in all task conditions. The lack of interference in the static conditions replicates findings from children with ASD described by Krebs et al. (2011), but contrasts with findings of Song and Hakoda (2011) who found elevated interference from expression on identity processing in children with ASD compared to typically developing children. Importantly, neither of these earlier studies investigated levels of interference using dynamic stimuli, or in adults with ASD. The differences between how the groups responded to the introduction of motion cues supports the general view that ASD is associated with atypical face processing, and underscores the importance of carrying out research using naturalistic (dynamic) stimuli.

Face Processing and Empathy

As a final note, exploratory analyses revealed that median RTs in the static condition of the matching task were negatively correlated with EQ scores in the full sample ($r = -.46$, $p = .009$). Although this was not seen with the dynamic condition of the matching task, I did observe that EQ scores were negatively correlated with baseline RTs in both static ($r = -.42$, $p = .017$) and dynamic ($r = -.37$, $p = .039$) conditions of the Garner expression task. Generally speaking, then, participants with fewer empathic traits took longer to match the identities, and judge the expressions, of faces displaying different emotions. Intuitively, it makes sense that this would be the case. Balconi and Canavesio (2014) observed that trait empathy and various indicators of performance on facial emotion recognition tasks were correlated, and suggest that being more empathic facilitates one's understanding of facial emotion. In a task designed to make participants empathize with faces expressing different emotions, Schulte-Rüther, Markowitsch, Fink, and Piefke (2007) found that asking participants to empathize with the face that was shown activated theory of mind and mirror neuron circuits in the brain. Therefore, being a more empathic individual, and actively empathizing, might improve face processing abilities, especially when making emotion judgments.

Summary

In conclusion, Study 1 provided insights into face processing abilities in typical adults and in those with ASD. Overall, adults with ASD performed differently than typical controls when making judgments about identity and expression cues within faces. In Study 2, I investigated attention to faces when people with and without ASD passively viewed naturalistic scenes. This study provided information on how adults with ASD directed their attention to faces in real life encounters when there were no active judgments to make.

STUDY 2: GAZE PATTERNS DURING SCENE PROCESSING IN TYPICAL DEVELOPMENT AND IN AUSTISM SPECTRUM DISORDERS

Research findings from studies in which faces are presented in isolation generally show that individuals with ASD fixate less on the eyes than typical individuals (e.g., Dalton et al., 2005; Kliemann et al., 2012; Klin et al., 2002; Pelphrey et al., 2002; Riby et al., 2009; Rice et al., 2012; Senju et al., 2013, Speer, Cook, McMahon, & Clark, 2007; Spezio et al., 2007; van der Geest, Kemner, Verbaten, & Engeland, 2002; Yi, Feng, Quinn, Ding, Liu, & Lee, 2014; however, see McPartland, Webb, Keehn, & Dawson, 2011; Song et al., 2012; Wagner, Hirsch, Vogel-Farley, Redcay, & Nelson, 2013). Individuals with ASD may avoid looking at another person's eyes in order to reduce social contact, but they may also perceive the eye region as threatening or aversive (Kliemann et al., 2012; Tanaka & Sung, 2013). In this case, glancing away from the eye region may reflect an effort to compensate for increased physiological arousal (i.e., affective load).

Support for this idea comes from studies investigating amygdala activation in those with and without ASD (e.g., Dalton et al., 2005; Kliemann et al., 2012; Swartz et al., 2013, however, see Pelphrey, Morris, McCarthy, & LaBar, 2007 for evidence of amygdala hypoactivation in adults with ASD). The amygdala is a brain structure that is thought to be involved in processing facial expressions (Campatelli et al., 2013); it may promote the development of face expertise through its role in signaling the social importance of faces (Grelotti et al., 2002). Even when viewing static faces, individuals with ASD experience greater amygdala activation (Kliemann et al., 2012) and a heightened emotional response (Dalton et al., 2005) than controls when fixating on the eye region.

Swartz et al. (2013) examined amygdala habituation in children with ASD as they made gender judgments of static faces displaying different expressions. Unlike typically developing children, those with ASD did not habituate to sad and neutral faces over time. Further, decreased amygdala habituation in the neutral condition was associated with greater ASD symptom severity. This study suggests that faces seem to heighten arousal in those with ASD to a greater extent than typical individuals. In an experimental paradigm where they manipulated participants' gaze toward the eye region of a static stimulus face, Tottenham et al. (2013) found that adults with ASD were less likely to direct their gaze toward the eyes of faces displaying neutral expressions; this was particularly evident in those who rated the neutral faces as threatening. These findings were complimented with group comparisons of amygdala responses following gaze manipulation. Tottenham et al. found that forcing gaze toward the eyes of neutral faces resulted in increased amygdala activation in participants with ASD. Moreover, those with ASD who were least likely to look toward the eyes spontaneously showed the largest amygdala potentiation when forced to look in that region. Dalton and colleagues (2005) found that, when viewing emotional faces, individuals with ASD took longer than controls to decide whether a face was emotional or neutral – suggesting that they find socially engaging faces more challenging to process. The fact that most of the studies described above found group differences in eye gaze and amygdala responses for negative or neutral expressions provides some evidence that individuals with ASD may perceive these expressions as more aversive than controls, and that they may be more likely to attribute negative valence to expressions that are ambiguous (Swartz et al., 2013; Tottenham et al., 2013).

Research suggests that, rather than looking at the eye region, many individuals with ASD focus on the mouth when looking at faces (e.g., Joseph & Tanaka, 2003; Klin et al., 2002; Riby et al., 2009; Spezio et al., 2007; van der Geest et al., 2002; however see Dalton et al., 2005; Riby & Hancock, 2009). Wagner et al. (2013) found a positive relationship between time spent looking at the mouth and pupil diameter (one physiological indicator of heightened arousal) in adolescents with ASD, but not in controls, during viewing of static faces. The authors suggested that this aberrant face scanning represented a response to increased arousal associated with viewing faces.

Focusing on the mouth can provide the viewer with a substantial amount of socially relevant information, such as the person's emotional state, and assist in analyzing speech patterns (Wilcox et al., 2013). It is interesting, then, that Spezio and colleagues (2007) found that, compared to controls, adults with ASD relied more on information from the mouth than the eyes when making expression judgments of static faces. Because there were no group differences in accuracy or response time (RT), they concluded that individuals with ASD used the information from mouths in a productive manner. In other words, although they used a different strategy to process face stimuli, this did not result in lower performance compared to controls. Interestingly, Klin et al. (2002) found that, although the best predictor of ASD in their eye tracking study was reduced fixation time on the eyes, longer fixations on mouths predicted less social impairment and better social competency. They attributed this counterintuitive finding to the possibility that, for participants with ASD, focusing on the mouth region might allow them to attend better to a person's speech, which in turn might promote a better understanding of social situations. In other words, focusing on the mouth may represent a compensatory strategy that allows those with ASD to garner important social information while minimizing discomfort associated with focusing on the eyes (Tanaka & Sung, 2013).

Scene Perception in Typical Development and in ASD

Numerous investigators have used eye-tracking technology to study scene perception in typically developing individuals. This work generally finds that typical individuals are biased toward attending to *faces* as opposed to other aspects of static social displays (e.g., Remington et al., 2011; Shields, Engelhardt, & Ietswaart, 2012; Stoesz & Jakobson, 2014). However, adding motion may cause viewers to shift their gaze away from salient facial cues (e.g., O'Toole et al., 2011). Stoesz and Jakobson (2014) compared differences in gaze behaviours of typically developing children, adolescents, and adults. They found that adding motion cues led viewers to make fewer, but longer, fixations on faces. This effect was largest in children suggesting that they find dynamic face processing more cognitively demanding than static face processing. When more characters were added to a scene all participants shifted their attention away from faces, but this effect was also strongest in children, suggesting that increasing social complexity increases the affective and/or cognitive load for young viewers, in particular (Stoesz & Jakobson, 2014). This interpretation is consistent with the idea that looking away, or "gaze aversion," is a behavioural response that reflects increased processing demands (Doherty-Sneddon, Bruce, Bonner, Longbotham, & Doyle, 2002; Doherty-Sneddon, Riby, & Whittle, 2012). Observing a similar pattern of results across development in those with ASD would imply that, as with typical viewers, the ability to attend to naturalistic faces improves with age, perhaps as a result of increased exposure.

In a recent developmental study, Rice and colleagues (2012) found that, compared to typical controls, children with ASD spent more time looking at bodies and inanimate objects and made fewer fixations on faces when viewing dynamic social scenes passively. In related work, Riby and Hancock (2009) found that children with ASD spent more time than typical controls looking at backgrounds than at faces when viewing dynamic human action sequences, but not when viewing cartoon pictures. Riby and Hancock concluded that group differences in gaze behaviours are most apparent in realistic viewing conditions, and that the increased complexity of dynamic information functioned to either distract or overload attention in individuals with ASD. Consistent with this, in a naturalistic study exploring gaze behaviours occurring as children responded to questions about arithmetic, those with ASD looked away from the face of the interviewer more than did typically developing controls when listening to questions, although not when thinking about how to answer (Doherty-Sneddon et al., 2012).

Hanley, McPhillips, Mulhern, and Riby (2012) examined gaze behaviours of typically developing adolescents and adolescents with ASD as they viewed three types of static face stimuli: pictures of faces with posed expressions (obtained from a face database), faces of actors displaying exaggerated expressions (obtained from a television show), and faces displaying natural expressions (photographed during naturally occurring interactions). These authors first explored how participants viewed each type of face in a single-character condition. They then explored gaze behaviours when participants viewed acted and naturalistic social interactions involving two characters. While no group differences were observed in fixations on faces in any single-character condition, individuals with ASD looked less at the eyes during the acted social interaction scene, and spent less time looking at the eyes and faces overall in the naturalistic social interaction condition, compared to controls. The authors suggested two probable explanations for these findings. First, adolescents with ASD may have shown a decrease in eye fixations because other features of the socially complex scenes captured their attention (a social perceptual explanation). Second, unlike typically developing adolescents who may have been fixating on the eyes to understand socially complex scenes better; those with ASD might have been less motivated to try to understand these interactions (a social cognitive explanation). Based on their findings, Hanley and colleagues stressed the importance of using ecologically valid stimuli when studying social information processing in ASD. Although their work highlighted differences in responses to spontaneous and posed expressions, their reliance on static stimuli was unfortunate.

Speer et al. (2007) compared gaze behaviours of children with ASD and typical controls as they passively viewed four kinds of stimuli: (a) single-character static scenes, (b) single-character dynamic scenes, (c) multiple-character static scenes, and (d) multiple-character dynamic scenes. Group differences were not evident when scenes were static and involved only one character, but children with ASD spent less time fixating on the eye region and more time fixating on bodies than controls when viewing scenes involving multiple characters that were moving. This finding suggests that it is more difficult for children with ASD to focus on salient facial cues when they are embedded in naturalistic and socially complex scenes. Whether this difficulty persists into adulthood is not known but, based on previous studies, it is reasonable to expect that adults with ASD may find dynamic face cues difficult to process continuously, and may avert their gaze from faces more often than typical controls, especially when viewing socially complex scenes.

The Present Study

The purpose of Study 2 was to compare gaze patterns of adults with ASD to those of typical controls as they passively viewed a series of pictures and movies of single- and multiple-character scenes. I expected that introducing motion to scenes and increasing their social complexity would impact gaze behaviours in both groups, but that viewers with ASD might show an "immature" or atypical pattern of responses. Specifically, I hypothesized that (1) viewers would make fewer but longer fixations on faces in the dynamic compared to the static conditions (reflecting greater processing demands; see Henderson, 2003; Smith & Mital, 2013); (2) viewers would shift their attention away from faces when more characters were present, particularly when dynamic stimuli were used; and (3) these effects would be most evident in individuals with ASD, who would also make fewer fixations on faces than typical individuals, overall. These results would suggest that increasing the affective and/or cognitive load would be particularly challenging for viewers with ASD.

METHOD

Participants

My sample for Study 2 consisted of the same 16 adults with ASD and 16 typical adults who participated in Study 1.

Procedures

The Psychology/Sociology Research Ethics Board at the University of Manitoba approved my testing protocol. Participants began by completing screening measures described in Study 1, following which they completed the experimental tasks for Study 1 as well as the gaze pattern task in a counterbalanced order. During the gaze pattern task, participants were seated approximately 57 cm from the screen. Instructions for this task were explained verbally to each participant before they began the experiment.

Materials

Gaze pattern task. In addition to completing the tasks described in Study 1, participants completed a brief task in which they passively viewed a series of pictures and movies on a computer screen while their eye-gaze was tracked. Stimuli for this task included 12 four-second movie clips and 12 still-frame images from the Andy Griffith Show (see Figure 9 for example stimuli). Half of the scenes depicted a single character and half showed multiple characters. Therefore, there were four conditions for this task: single-character/static, single-character/dynamic, multiple-character/static, and multiple-character/dynamic. Each clip depicted the face and body of one or more characters, as well as several other objects, which allowed me to examine which aspects of the scenes were most salient to viewers. Each stimulus remained on the screen for four seconds. Trials were separated by a fixation cross that remained on the screen for two seconds. The soundtrack was muted for this task.

Stimuli for this task were presented on a Tobii 1750, which houses a non-invasive, binocular corneal-reflection eye-tracker (Tobii User Manual, 2003) and runs Tobii Studio Enterprise experimental software. This allowed me to record participants' gaze as they viewed each stimulus. Participants were instructed to sit as still as they could while looking at the screen. Before beginning the task participants completed a nine-point calibration trial where they were instructed to follow with their eyes a white dot on a black background as it moved to different locations on the screen. Once calibration was complete the Tobii software immediately provided the examiner with feedback regarding the calibration quality. If the calibration was successful (i.e., the eye-tracker could detect the person's eye movements) the participants proceeded to the experimental trials. If not, the participant attempted the calibration again.

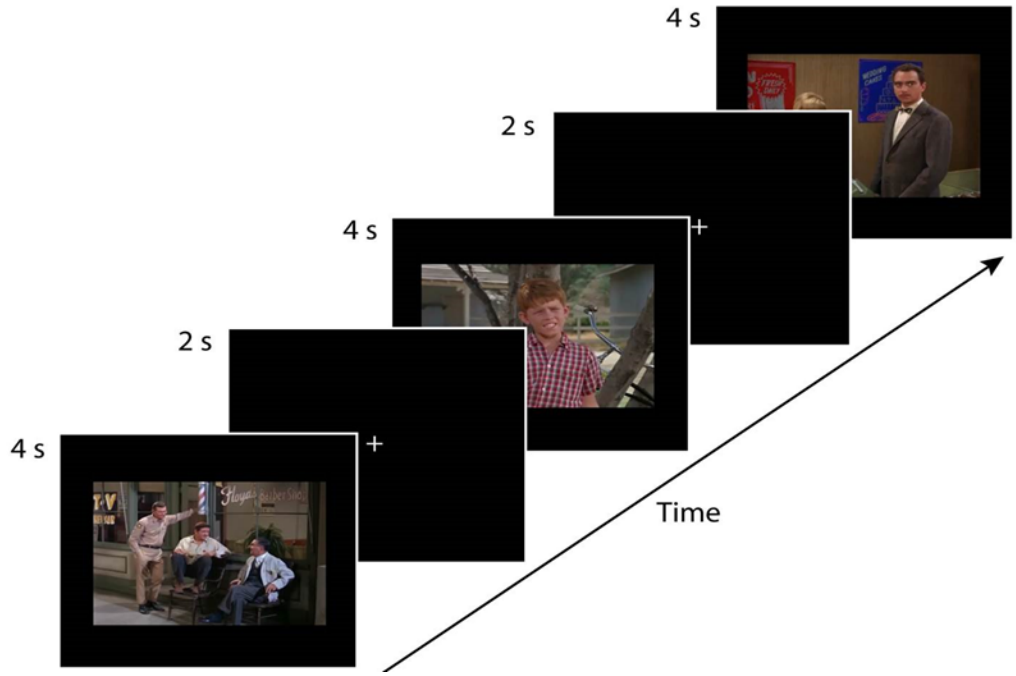

***Figure 9*. Example stimuli from the gaze pattern task.** Participants passively viewed pictures and movies on a screen that displayed a single character or multiple characters interacting while their gaze patterns were tracked. There were six trials for each of the four conditions, resulting in 24 total test trials. Each trial began with a white fixation point on a black background, followed by the presentation of a stimulus for four seconds. This figure depicts three static trials (multiple-character, single-character, multiple-character) and was obtained with permission from Stoesz and Jakobson (2014).

RESULTS

I examined participants' gaze behaviours within face areas of interest (AOIs) for all scenes. As the characters remained in the same location during each dynamic scene, the locations of the AOIs also remained relatively constant, making a complete frame-by-frame analysis unnecessary. Because of differences in camera viewing angles for single-character and multiple-character scenes, individual face AOIs were smaller in the latter condition. However, the combined area of face AOIs in multiple-character scenes was comparable to the area of the face AOI in single character scenes, across both modalities ($p > .05$ in all conditions).

I extracted information for two types of participant gaze behaviour for each trial. The first variable I extracted was the *number of face fixations* that participants made in each trial. Fixations were defined as any period where the participant's gaze remained within a 30-pixel (0.9 degree visual angle) diameter area for at least 200 ms. I also extracted the *duration of face fixations* made in each trial. I then computed the average for each of these variables across the six scenes in a given condition. These data were generally normally distributed. As such, I submitted the data for each variable to a 2 (Group: Typical, ASD) x 2 (Scene: Single-character or Multiple-character) x 2 (Mode: Static, Dynamic) ANOVA, with repeated measures on the last two factors.

Number of Face Fixations

In general, participants made fewer face fixations when viewing dynamic compared to static scenes, $M_{static} = 2.8$, $SD = .93$, $M_{dynamic} = 2.6$, $SD = .89$, $F(1, 30) = 4.86$, $p = .035$, $\eta_p^2 = .14$. As expected, the ASD group made fewer face fixations than typical controls, $M_{Typical} = 3.0$, $SD = .68$, $M_{ASD} = 2.4$, $SD = .94$, $F(1, 30) = 4.19$, $p = .049$, $\eta_p^2 = .12$. No significant interactions were observed in this analysis.

Duration of Face Fixations

Overall, face fixations were longer in dynamic than in static scenes, $F(1, 30) = 23.81$, $p < .001$, $\eta_p^2 = .44$; and longer in single- than in multiple-character scenes, $F(1, 30) = 47.06$, $p < .001$, $\eta_p^2 = .61$. In addition, I observed a significant Mode x Group interaction, $F(1, 30) = 4.88$, $p = .035$, $\eta_p^2 = .14$, which reflected the fact that, overall, typical viewers showed a larger increase in face fixation durations than those with ASD in response to the addition of facial motion ($M_{typical} = 232$ ms increase vs. $M_{ASD} = 88$ ms increase). The Mode x Scene interaction was also significant, $F(1, 30) = 4.18$, $p = .051$, $\eta_p^2 = .12$], but both of the two way interactions had to be interpreted in light of a significant three-way interaction between Mode, Scene, and Group, $F(1, 30) = 6.8$, $p = .014$, $\eta_p^2 = .19$.

To follow-up on the three-way interaction, I conducted a 2 (Mode) x 2 (Scene) ANOVA on the data from each group. In typical participants, I observed significant main effects of Scene, $F(1, 15) = 34.09$, $p < .001$, $\eta_p^2 = .69$, and Mode, $F(1, 15) = 26.08$, $\eta_p^2 = .64$, and an interaction between Mode and Scene, $F(1, 15) = 11.28$, $p = .004$, $\eta_p^2 = .43$ (see Figure 10).

Typical participants made shorter face fixations in the multiple- compared to the single-character condition, but this was most evident when the faces were moving (see Figure 10. The ASD group also made shorter face fixations in multiple- compared to single-character scenes, $F(1, 15) = 17.91$, $p < .001$, $\eta_p^2 = .54$, but the size of this effect did not change with the introduction of motion cues ($p > .05$).

As an aside, scores on the AQ and EQ (described in study 1) were related to the number and duration of face fixations in the overall sample. For example, scores on the AQ negatively correlated with the number of face fixations in static multiple- ($r = -.48$, $p = .006$), and dynamic multiple- ($r = -.53$, $p = .002$) character scenes, and also with the duration of face fixations in static single- ($r = -.60$, $p < .001$) and multiple- ($r = -.56$, $p = .001$) character scenes. EQ scores were positively correlated with the number of face fixations in dynamic multiple-character scenes ($r = -.45$, $p = .009$), and with fixation duration in static multiple- ($r = -.46$, $p = .008$), dynamic multiple (r = -.41, $p = .021$), and dynamic single- ($r = .44$, $p = .011$) character scenes. In other words, in the overall sample, presenting with more autistic characteristics (higher AQ scores) or being less empathic (lower EQ scores) was associated with participants making fewer, and shorter, face fixations.

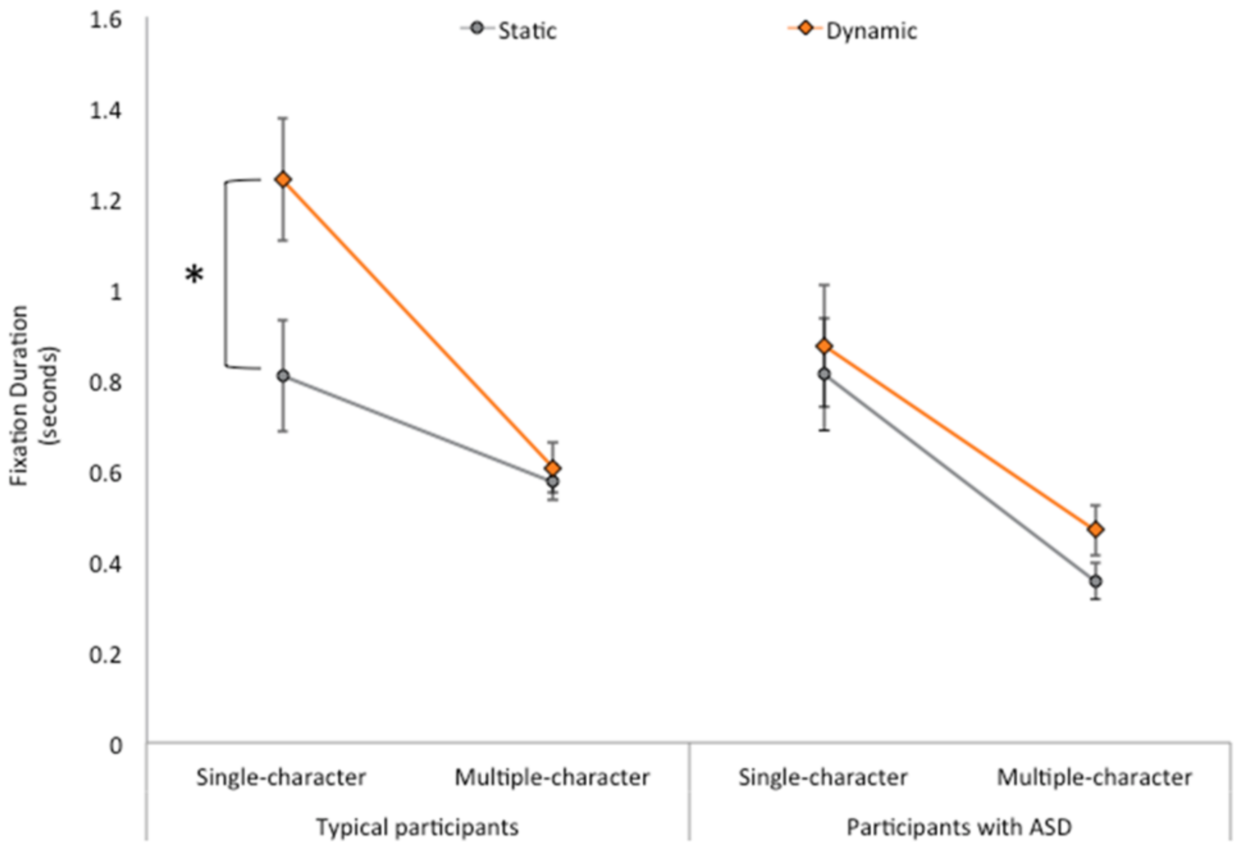

Figure 10. **Duration of face fixations in typical participants and participants with ASD.** Both groups made shorter face fixations in multiple compared to single-character scenes. Typical participants showed longer face fixations in dynamic, compared to static, single-character scenes. The asterisk denotes significance at $p < .05$. Standard errors are indicated.

DISCUSSION

The purpose of Study 2 was to extend research on attention to faces in typical adults and in adults with ASD by comparing their gaze behaviours as they passively viewed various types of 'naturalistic' scenes. I expected that introducing motion and increasing the social complexity of the scenes by adding characters would decrease the number of face fixations and increase face fixation lengths in both groups, due to increasing processing demands (see Henderson, 2003; Smith & Mital, 2013). I also expected these effects to be exaggerated in the clinical group, if they were finding faces particularly difficult to process. Finally, I expected that, compared to typical participants, participants with ASD would show fewer fixations on faces overall. In general, my hypotheses were supported, as discussed below.

Most of the research that has investigated the ways in which people with ASD attend to static or dynamic faces during scene perception has been completed in children (e.g., Doherty-Sneddon et al., 2002; Doherty-Sneddon et al., 2012; Speer et al., 2007). To my knowledge, this is the first study to investigate attention to faces in adults with ASD across static *and* dynamic scenes that vary in social complexity. In the current study, adults with ASD showed fewer face fixations compared to typical participants, overall. This finding is consistent with past research showing that individuals with ASD look less at faces (Boraston & Blakemore, 2007; Campatelli et al., 2013; Klin et al., 2002; Riby & Hancock, 2009), and less at the eyes in particular (Senju, 2013; Spezio et al., 2007), than do typically developing individuals. This may be because they perceive faces to be less socially interesting or compelling (Campatelli et al., 2013) or, indeed, more aversive than typical peers do (Dalton et al., 2005).

As expected, all participants in the current study made fewer but longer face fixations when viewing dynamic as opposed to static scenes. These results are consistent with Stoesz and Jakobson (2014), who conducted a cross-sectional study in which they investigated gaze behaviours of typical participants as they viewed static and dynamic scenes. In their study, all age groups (up to age 27 years) found dynamic faces more challenging to attend to, compared to static faces, particularly when scenes involved multiple characters. By adjusting their fixation behaviours, viewers may have reduced their cognitive or affective load. I observed, however, that adding facial motion led to a *larger* increase in face fixation durations in typical viewers than in those with ASD. This may suggest that typical viewers were better equipped (or making a greater effort) to process the dynamic displays, or that participants with ASD did not find these faces aversive. If these interpretations are correct, they seem to apply mostly to situations in which a single-character was present. Thus, adding motion to multiple-character scenes did not affect the duration of face fixations in either group. One could speculate that typical participants showed longer fixations on faces in single-character scenes because there was less information available to help them to understand those scenes. In the dynamic multiple-character scenes, characters were shown interacting with one another (e.g., talking, smiling). In contrast, in the dynamic single-character scenes, the faces of characters were still moving, but it may have been more challenging to grasp the storyline. Therefore, typical participants might have looked longer at faces in order to help them understand the context of the scene.

I expected that participants in the ASD group would be more likely than typical peers to direct their attention away from faces when they were moving, and when more characters entered the scene (as was seen in typical children tested in Stoesz & Jakobson, 2014). In fact, unlike typical participants, adults with ASD did not make longer face fixations after the introduction of motion cues. One explanation for this could be that they were less interested in understanding the moving displays. Evidence for this idea comes from a recent study conducted by Grynszpan and Nadel (2014). In this study, participants viewed videos of complex social scenes and were then asked to describe the social interactions. In the condition where participants' gaze was manipulated by asking them to focus on the characters' facial expressions, those with ASD who fixated on faces longer showed a better understanding of the social interactions. In contrast, typical controls were able to interpret these social scenes accurately regardless of whether their gaze was manipulated. The authors suggested that participants with ASD were less motivated than typical controls to fixate on faces when viewing social interactions when there were no explicit task demands to do so. In the current study, there were no task demands or behavioural judgments required; participants were simply instructed to passively view the stimuli. As a result, it is not clear what kind of information they were able to glean from the interactions depicted.

As expected, participants with ASD showed shorter fixations on faces compared to their peers in the dynamic single-character condition. Adding characters to scenes affected participants' gaze behaviours in both groups by reducing face fixation durations. These findings contrast with those reported by Hanley et al. (2012). These authors examined spontaneous attention to faces in individuals with Asperger's Syndrome in conditions where faces were presented in isolation, or as part of static social scenes. They found no group differences in gaze patterns in the isolated condition; however, participants with Asperger's Syndrome looked less at the eyes during the social interaction scenes. Hanley et al. conjectured that participants with ASD did not prioritize information from the eyes when viewing social scenes. In contrast, when the social complexity of scenes increased, typical participants were able to prioritize important facial information, possibly because they were motivated to understand these interactions.

A limitation of the current study is that I was unable to examine gaze behaviours to smaller regions within the face (such as the eyes, nose, and mouth) and other aspects of scenes, such as bodies and backgrounds. Closer examination of specific regions of the face may provide further insights. In other research, Klin et al. (2002) presented videos depicting social scenes to males with autism and found that the best predictor of ASD was reduced time looking at the eyes. Increased focus on the mouth in children with ASD was associated with better social adjustment, while spending more time looking at objects was associated with worse social adjustment. One might predict that participants with ASD in the present study would look less at the eyes and more at the mouth when viewing the dynamic compared to the static scenes. This theory should be tested in future studies.

Although videos of faces are more ecologically valid than static photographs in that they provide researchers with a better indication of how faces are attended to in real life encounters, movies of faces still do not “look back” at the viewer (Boraston & Blaekmore, 2007). Some preliminary work has explored where typically developing individuals and those with ASD look when engaging in face-to-face encounters. In a seminal study by Field (1976), infants looked away from their mother’s face more than they looked away from a doll’s face. Greater animation in the infant’s mother face was associated with increased infant heart rate and more time looking away, suggesting that the processing demands were higher in this situation. Field posited that looking away from an engaging moving face helped to modulate arousal. Other work has also suggested that, across typical and atypical development, children look away from examiners’ faces during question and answer sessions as question difficulty increases (Doherty-Sneddon et al., 2012). They also show a decrement in performance when required to maintain eye contact with the examiner (Riby et al., 2012). Interestingly, while the performance of typical children improves when the examiner directs his gaze toward them when posing questions, children with ASD perform best when the examiner looks down (Falck-Ytter, Calstrom, & Johansson, 2015). Children with ASD also have more difficulty than controls at looking at an examiner’s face during dyadic interactions (Noris, Nadel, Barer, Hadjikhani, & Billard, 2012; Riby et al., 2012). Together these results support the conclusion that attending to faces interferes with cognitive performance more in children with ASD than in their peers when viewing faces in real life.

In a related study, Birmingham, Bischof, and Kingstone (2008) found that adding characters to static scenes increased fixations to the eye regions in typical adults. This result was taken as evidence that when there are multiple characters in scenes typical people prioritize information from the eyes, perhaps as a way to better understand these social encounters. One reason that I observed shorter face fixations in multiple- compared to single-character scenes in both groups might be because the social scenes depicted in the current study were not difficult to understand. In future studies, researchers should administer a passive viewing task depicting dynamic scenes involving isolated characters, multiple characters engaging in simplistic interactions, and multiple characters engaging in complex interactions that require greater social reasoning to interpret (similar to stimuli used in Grynszpan and Nadel, 2014). This type of study may provide insight into whether the complexity of a social encounter affects typical (and atypical) motivation to attend to facial cues. Again, as the studies reviewed (Birmingham et al., 2008; Hanley et al., 2012) examined fixations within different regions of faces and at different parts of scenes (e.g., bodies and backgrounds) it is possible that my results would have paralleled theirs if more precise AOI analyses were possible in the current study.

Summary and Future Directions

In conclusion, participants in Study 2 showed differences in gaze behaviour depending on whether scenes were presented in motion and on whether scenes involved a single character or multiple characters. Overall, adults with ASD attended less to faces than did typical participants. When motion was introduced, typical participants exhibited longer face fixations in single-character scenes, which resulted in a significant group difference in this condition. The fact that typical attention to faces varied depending on modality emphasizes the importance for research to shift to using more ecologically valid, dynamic displays when studying scene perception. As adults with ASD showed atypical duration of face fixations in scenes depending on the number of characters displayed, this highlights the need for research to vary the social complexity of scenes to better understand how these factors might influence gaze behaviours in this clinical group. It would also be important to consider ASD sample factors, such as whether individuals had undergone any social skills training that might have reduced group differences in terms of attention to faces in social scenes.

Future research should investigate differences in task demands during scene perception, especially in those with ASD. People with ASD may show differences in attention to faces in tasks in which a judgment is required compared to when there are no task instructions, due to them having less of a motivational drive to understand social scenes (Nomi & Uddin, 2015). Research should also explore differing gradations of social complexity. Additionally, although the AOI approach is commonly used in the literature, there are some limitations to this method of eye-tracking research. For example, Yi et al. (2014) criticize using the AOI approach because it does not provide enough information about gaze behaviours *within* particular AOIs. Another limitation of common eye-tracking studies is that setting a fixation duration threshold disregards potentially important data. More research should examine different kinds of gaze behaviours, such as saccade paths, or adopt a data driven approach in which researchers examine all fixations regardless of AOIs and lengths of fixations (Yi et al., 2014). Finally, while studying gaze behaviours for faces presented in isolation has provided important information about how we attend to faces, it is also important to examine perception of scenes showing bodies (as in this study), as this is the context in which faces are presented in real life encounters. Further, because body language can confer advantages for judging a person's emotions (e.g., Shields et al., 2012) and identity recognition (O'Toole et al., 2011), future research should explore attention to bodies in addition to faces.

GENERAL DISCUSSION

In the two studies that comprise this thesis, I investigated face processing abilities in adults with and without ASD. The findings from Study 1 are consistent with previous research indicating that individuals with ASD are less sensitive to facial identity and slower at judging facial expressions than typical peers. I also found that the way in which identity and expression processing interact is atypical in those with ASD. In Study 2, adults with ASD made fewer face fixations than their peers when viewing naturalistic scenes passively, and were less affected by the introduction of motion cues. Finally, increasing the social complexity of scenes led to reductions in the duration of face fixations in both groups, but only in typical participants was this effect moderated by whether or not the characters were moving.

Limitations and Future Directions

ASD is often accompanied with intellectual or language impairment and other comorbid conditions (APA, 2013) that could potentially influence performance on face processing tasks. For example, attention deficit hyperactivity disorder (ADHD) often co-occurs with ASD, and persons with a dual diagnosis often show greater deficits in attention (Sinzig, Bruning, Morsch, & Lehmkuhl, 2008) and higher rates of ASD/ADHD symptomology than those without a dual diagnosis (Jang, Matson, Williams, Tureck, Goldin, & Cervantes, 2013). Individuals with ASD also frequently show deficits in executive functions, affecting inhibition and cognitive flexibility (Montgomery et al., 2012) and attention switching (Pasculavaca, Fantie, Papageorgiou, & Mirsky, 1998). Although it is possible that problems with attention could have affected performance on the tasks used in the current studies, I did not exclude participants with ADHD in either group because comorbidity between ASD and ADHD is common. Moreover, even if participants in the ASD group experienced greater difficulties with attention or executive functioning overall compared to the typical participants, group differences in terms of accuracy were not found on most tasks or in terms of RT on the simple processing speed task.

Alexithymia, a condition characterized by significant difficulties with understanding, identifying, and expressing feelings and emotions (Way, Yelsma, Van Meter, & Black-Pond, 2007), is present in up to 50% of people with ASD (Lombardo, Barnes, Wheelwright, & Baron-Cohen, 2007). Cook, Brewer, Shah, and Bird (2013) found comorbid alexithymia and ASD, rather than ASD alone, predicted difficulties on a face expression recognition task. Alexithymic traits could have contributed to the group differences observed in the baseline RT of the Garner expression tasks, and in the simultaneous identity-matching task (which required matching of faces showing different expressions). It is important to note, however, that accuracy was still quite high in the ASD group on the Garner expression tasks. That is, participants with ASD were able to label surprised and angry facial expressions correctly. In future, it would be interesting to determine if comorbid alexithymia influences performance to a greater extent on face processing tasks that involve more subtle or ambiguous facial expressions. Some other conditions, such as synesthesia (Neufeld, Roy, Zapf, Sinke, Emrich, et al., 2013) and prosopagnosia (Pietz, Ebinger, & Rating, 2003), which are more common in those with ASD than in the general population, could also potentially impact performance on face processing tasks. For example, one study found that adults with ASD were almost three times more likely than those in the general population (up to 18.9% in those with ASD) to experience synesthesia (Baron-Cohen, Asher, Wheelwright, Fisher, Gregersen, & Allison, 2013). Similarly, there is considerable overlap between prosopagnosic and autistic symptoms (Cook, Shah, Gaule, Brewer, & Bird, 2015). However, even in ASD the occurrence of these conditions still seems to be quite rare, and it is unclear how these conditions might impact performance on the tasks utilized in these studies.

Some limitations of the current studies could be addressed in future research on face processing in ASD. First, my results do not generalize to those with ASD who are lower functioning (i.e., low IQ) or to children with ASD. Future research should explore face processing abilities using methodologies employed in the current studies with different sample characteristics. I expect that the atypical face processing abilities observed in the current research would be exacerbated in individuals who are low functioning. More research should compare performance on face processing tasks in low functioning ASD to comparison groups comprised of individuals matched for FSIQ (i.e., individuals with an intellectual disability without ASD), or of individuals who are chronologically younger than the ASD sample but matched for mental age.

Even though the dynamic displays utilized in this study are more ecologically valid than static images, typical and atypical face processing investigations would benefit from using "live" experiments to better gauge how people process faces in real life (Boraston & Blakemore, 2007). New technologies (such as Tobii Glasses 2; Tobii Technology AB) allow researchers to track gaze behaviours as a person looks around their physical environment. While some eye-tracking work on children with ASD has been completed using live question-and-answer sessions while their gaze was video recorded (Doherty-Sneddon et al., 2012; Riby et al., 2012), future work should explore the gaze behaviours of individuals with ASD using more precise eye-tracking technology as they engage in conversations with typical peers or with other individuals with ASD. Those with ASD might show different gaze patterns depending on the person with whom they are interacting. Another direction that future eye-tracking research might take is to explore the gaze patterns of individuals with ASD as they passively view social interactions in real life.

In the current eye-tracking study, there was no soundtrack presented. Thus, participants may have spent more time looking at the faces in the dynamic scenes as a way to improve their understanding of these scenes. Attempting to read lips would help viewers to garner more information about what the individual is saying. Comparing gaze behaviours when viewing dynamic social interactions with and without sound would be an interesting follow-up study to this research.

Research should continue to explore other areas of social cognition in ASD, such as theory of mind abilities and spontaneous mimicry (Senju, 2013), using dynamic face paradigms. Although there have been some studies completed exploring brain activation in those with ASD when they are exposed to faces, there are some inconsistencies in the literature -- with some studies finding hyperactivation of specific structures (e.g., Dalton et al., 2005; Kliemann et al., 2012) and others reporting hypoactivation (e.g., Pelphrey et al., 2007). These disparate findings might reflect differences in study methodologies or diversity in the samples studied. Future studies in this area should continue to investigate the ways in which task demands and gaze patterns influence neural responding to dynamic scenes and faces (Nomi & Uddin, 2015).

It would also be useful to supplement behavioural, eye-tracking, and fMRI research with integrative qualitative research designs. While it is important to obtain quantitative data to understand face processing deficits in ASD, introducing self-reports or qualitative measures (e.g., asking participants about their experience when holding eye contact with another) would help researchers to develop interventions that are specifically tailored to meet the needs of people with ASD. Finally, although my sample size was similar to those used in other studies, research involving larger samples would help improve the generalizability of ASD research findings.

Significance

The research reported in this thesis makes an original and important contribution to the literature on ASD by documenting deficits the processing of facial motion, demonstrating atypical independence between the processing of particular facial cues, and providing novel insights into ways in which adults with ASD attend to faces when passively viewing social scenes varying in complexity. The findings from this research could help inform the development of better diagnostic and intervention tools that could be used with those with, or at risk for, ASD. This research also highlights the need for further research into dynamic, rather than static, face processing abilities in typical development and in ASD. Early detection and intervention may help prevent the development of certain maladaptive behaviours, such as social isolation, that might compromise the development of the social brain in this clinical group (Sigman et al., 2004). Therefore, developing better ways to detect early, subclinical symptoms of ASD in infants (see Esibbagh et al., 2013) is critical. At a broader level, developing a better understanding of how face perception *typically* develops will help guide clinical work and research with other populations of individuals who have trouble with facial processing, such as those with prosopagnosia and Williams syndrome.

It is unclear whether abnormal face processing skills in ASD contribute to problems with social interactions, or reduced interest in interacting with others hampers the development of face processing skills (Harms et al., 2010). In either case, it is imperative to create naturalistic intervention tools for use with children and adolescents with ASD in order to promote the development of face processing skills. The majority of intervention methodologies described in the literature are designed to improve the ability to recognize emotional expressions depicted in photographs. Unsurprisingly, face processing abilities that are learned and strengthened by training with these computer-based programs do not necessarily generalize to everyday situations (e.g., Bölte et al., 2002; Hadwin, Baron-Cohen, Howlin, & Hill, 1996; Silver & Oakes, 2001). Developing intervention programs using dynamic faces (e.g., Baron-Cohen, Golan, Wheelwright, & Hill, 2004) may improve the generalizability of these treatments.

Understanding the strategies that individuals with ASD use to process faces will help researchers to capitalize on existing processing strengths when developing specific treatments designed to help improve social functioning. There have been exciting recent developments in using virtual reality to improve social cognition (e.g., Kandalaft, Didehbani, Krawczyk, Allen, & Chapman, 2013), and these approaches may help those with ASD to generalize skills they learn in treatment. New research by Domes, Heinrichs, Kumbier, Grossmann, Hauenstein, and Herpertz (2013) has also suggested that administering oxytocin to children with ASD can normalize their brain activation in response to faces. It is unclear whether this research will inform interventions to improve social functioning in ASD, but this would be an interesting avenue of research to explore (Nomi & Uddin, 2015). Finally, if there are differences in intrinsic reward systems for those with ASD, interventions might focus on ways to make social interactions more rewarding for children with ASD, perhaps through using behavioural strategies (Dawson et al., 2005). For example, these authors suggest using conditioned reinforcement to encourage looking at faces by pairing an examiner's face with a reinforcer.

Overall, the findings from the current research emphasize the importance of studying face processing using naturalistic displays, and highlight the need to examine the face processing strategies employed by individuals with ASD using a myriad of tasks.

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APPENDIX A

Participant ID #: ____________

GENERAL INFORMATION QUESTIONNAIRE

NOTE: This information will be kept strictly confidential and will be used for research purposes only. If you wish to decline to answer any of the following questions, please feel free to do so.

Participant's MOTHER

Please indicate the highest level of education completed:

_____ Less than seventh grade
_____ Seventh through ninth grade
_____ Tenth through eleventh grade
_____ Completed high school
_____ At least one year of college/university or other, specialized training
_____ Completed a college or university degree
_____ Completed a graduate degree

Please indicate which diploma(s), degree(s), or certificate(s) earned:

_____ None
_____ High School diploma/GED
_____ Associate degree
_____ BA or BSc
_____ MA or MSC
_____ MD, DDS, JD, LLB, or LLD
_____ PhD or EdD
_____ Certificate (specify): ______________

Mother's present occupation: ____

Participant's FATHER

Please indicate the highest level of education completed:

_____ Less than seventh grade
_____ Seventh through ninth grade
_____ Tenth through eleventh grade
_____ Completed high school
_____ At least one year of college/university or other, specialized training
_____ Completed a college or university degree
_____ Completed a graduate degree

Please indicate which diploma(s), degree(s), or certificate(s) earned:

_____ None
_____ MA or MSc

_____	High school diploma/GED	_____	MD, DDS, JD, LLB, or LLD
_____	Associate degree	_____	PhD or EdD
_____	BA or BSc	_____	Certificate (specify): _____________

Father's present occupation: ____

How many individuals lived in your household growing up? ___________________________

What language(s) are spoken in the home? ______________________________________

What language(s) does the parent/legal guardian speak with the participant?

____

Have either parent ever had any academic problems? If yes, whom and what type?

____

____

The Participant

Date of birth:	__________	Age:		Gender: € Male € Female	
Birth weight:	__________	Current Height:	__________	Current Weight:	__________
Ethnic/Cultural Background:		____			

What language(s) does the participant speak or understand?____________________________

Were there any problems during pregnancy or delivery (including perinatal complications in the mother, such as diabetes, pregnancy–induced hypertension or preeclampsia)? If yes, please describe:

____

____

Has the participant ever sustained a head injury? If yes, please describe:

____

____

If yes, how long was he/she unconscious for? ______________________________________

Has the participant had any other major health problems that required medical attention? If yes, please describe: ____

____

____

Please check the following service(s) that the participant has used and briefly describe the reason(s) for the service(s):

- € Occupational Therapist: ______________________________
- € Physical Therapist: ______________________________
- € Speech Therapist: ______________________________
- € Dietician: ______________________________
- € Psychiatrist: ______________________________
- € Social Worker: ______________________________
- € Infant Development Worker/Infant Stimulation Worker: ______________________________
____
- € Other Special Services (please specify): ______________________________
____

Has the participant been identified with a hearing problem? ______________________________

Have any of the participant's siblings been identified as having academic problems? If yes, whom and what type? ______________________________
____

Have of the participant's siblings been identified as having behavioural difficulties? If yes, whom and what type? ______________________________
____