PARTS-BASED PROCESSING IN AUTISM

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A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

In partial fulfillment of the requirements of the degree of

MASTER OF ARTS

Department of Psychology

University of Manitoba

Winnipeg

Abstract

Individuals with autism spectrum disorder (ASD) often have difficulty "seeing the big picture" and tend to process objects by their parts. This study used a perceptual grouping task (Experiment 1) involving the Ponzo illusion to determine if individuals with ASD show a local processing bias due to difficulties grouping stimuli preattentively. Individuals with ASD were less likely than TD individuals to report an illusion-based response. The percentage of responses consistent with the illusion indicated at chance performance in the ASD group, suggesting that they experience deficits preattentively when grouping stimuli. This study also used a viewing window paradigm (Experiment 2) to evaluate the parts-based processing strategies used by individuals with ASD when allowed to either actively or passively view blurry objects using a restricted viewing aperture. For both conditions performance was similar across groups, suggesting that individuals with ASD use similar parts-based processing strategies as TD individuals to identify objects.

Acknowledgments

I would like to thank my advisor, Dr. Jonathan Marotta, for his support and guidance over the course of this study. I would also like to thank my committee members, Dr. Jane Lawrence-Dewar and Dr. Cheryl Glazebrook, for their valuable feedback to making this project a success. Special thanks also to Dr. Sarah Shomstein and Dr. Lee Baugh whose assistance was invaluable, to members of the *Neuropsychology of Vision: Perception and Action Lab*, whose moral support have been greatly appreciated, as well as to my family, who provided endless amounts of support and encouragement. Finally, a special thank you to the volunteers who freely and generously gave their time.

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CHAPTER I

GENERAL INTRODUCTION

Preamble

Imagine communicating with friends and being unable to read subtle changes in their body language or form logical sentences from their words and syntax. The ability for an individual to attach meaning to their surroundings requires processing parts of information and integrating it into a coherent whole. Integrating pieces of information into a coherent whole relies on global processing strategies, which allows an individual to understand the gist or "the big picture". This is critical for day-to-day functions such as sensory processing, communication, and social interactions (Navon & Norman, 1983; Happe & Frith, 2006). Local processing, which focuses on perceiving the details of an object or situation, allows an individual to add context to a situation or object but focuses on the finer details. Both global and local processing skills are important when it comes to successfully interacting with the surrounding environment because the behavioral goals at any given moment may depend on either or both of these forms of processing. Although most individuals tend to make sense of their visual world by relying on a processing strategy that allows them to integrate pieces of information into a coherent whole, not all individuals adopt this processing strategy. It has been proposed that individuals with autism spectrum disorders tend to place greater importance on local processing strategies, resulting in a perception of the world based on specific features rather than "the big picture". However, it is unclear which part of the visual processing pathway is responsible for this differential form of visual processing.

Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that is associated with three core deficits: poor language development, poor social behavior, and repetitive or stereotyped behaviors (American Psychiatric Association, 2000). In the Diagnostic and Statistical Manual version IV (DSM-IV), ASD is synonymous with pervasive development disorder (PDD), which is made up of 5 diagnostic subtypes: Autistic disorder, PDD Not Otherwise Specified (PDD-NOS), Asperger syndrome, Rett syndrome, and Childhood Disintegrative Disorders (American Psychiatric Association, 2000). The more recent DSM-V collapses these diagnostic subtypes into a single category called 'Autism Spectrum Disorder'. Under this diagnosis, the social and communication impairment criteria are combined into one domain, thus reducing these three core deficits down to two core domains. Only individuals who present with the full range of symptoms under these two core domains are given an ASD diagnosis, which occurs on a spectrum in accordance with the severity of their symptoms (American Psychiatric Association, 2013). Individuals placed on the higher end of the spectrum are diagnosed with higher functioning forms of ASD (including Asperger's, PDD-NOS and less severe forms of Autistic disorders), and tend to show higher cognitive functioning abilities than those with more severe forms of ASD while still exhibiting deficits in communication, social interaction and repetitive or stereotyped movement (Carpenter, Soorya, & Halpern, 2009). Although a diagnosis may be made at any age, the initial symptoms of ASD can occur as early as the first year of life, and a diagnosis is generally made around 3-4 years old (Zwaigenbaum et al., 2009; Lord, 1995). Early signs include a decrease in looking at faces, failure to turn when name is called, failure to show interests by showing or pointing, and delayed pretend play (Zwaigenbaum, 2001). Early intervention can help decrease the symptoms of ASD, with many individuals showing improvements as they get older (Dawson & Osterling, 1997; Harris & Handleman, 2000; Sheinkopf & Siegel, 1998).

In addition to the main components classifying an ASD diagnosis, individuals with ASD also tend to show atypical perceptual processing, often showing superior performance in tasks requiring processing details of a stimulus compared to stimulus configurations (Liu, Cherkassky, Minshew & Just, 2011). This is often assessed using a block design test, which relies on segmenting a whole object into parts in order to construct an object. In this test, the participant is required to arrange blocks with either all white sides, all red sides, or red and white sides according to a predetermined pattern. When children with both low- and high-functioning forms of ASD are administered the block design subtest of the Wechsler Intelligence Scale for Children (WISC), both groups perform better than would be expected according to their developmental level (Lockyer & Rutter, 1970; Tymchuk, Simmons, & Neafsey, 1977). This suggests that these children may show a perceptual preference towards the local processing rather than global processing of a design since arranging the blocks into the pattern would first require segmenting the pattern into parts in order to determine which blocks are required to form the pattern. A study by Shah and Frith (1993) also showed that individuals with ASD performed better than controls on the block design of the Wechsler test. However, this superiority disappeared when both groups were shown segmentations of the visual stimuli and asked to construct the object, suggesting that segmentation was a cause of difficulty in the block design for controls due to a preference to see the object as a whole (Shah & Frith, 1993). This finding of a superiority in local processing has been further supported by studies showing that individuals with ASD show superior performance at detecting hidden figures compared to typically developing individuals (Jolliffe & Baron-Cohen, 1997) and enhanced detection of a local target in a visual search task (O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted, O'Riordan, & Baron-Cohen, 1998b). The tendency for individuals with ASD to focus on finer stimulus features suggests atypical perceptual processing may be in the form of a superiority in local processing abilities compared to typically developing individuals.

Although individuals with ASD show better local processing abilities when compared to controls, they also tend to recruit global processing strategies less often than controls when presented with tasks requiring global processing. As a result, these individuals also tend to rely less on the structural laws that are typically used to construct a whole from its parts. These structural laws are called Gestalt principles, which are based on relational properties including the law of proximity, similarity, and closure (see Westheimer, 1999 for review). Each law defines a basis upon which individuals tend to perceive and make sense of objects in their environment. The law of proximity states that when an individual perceives an assortment of objects, those objects that are close to each other are perceived as a group. The law of similarity states that elements within an assortment of objects are perceptually grouped together if they are similar to each other. The law of closure states that individuals perceive objects such as shapes, letters and pictures as being whole when they are not complete. Brosnan, Scott, Fox and Pye (2004) examined visual processing atypicalities using Gestalt principle stimuli in children with low functioning ASD and found that these children used Gestalt heuristics following the laws of proximity, similarity, and closure less often than age matched children with learning difficulties. Similarly, Bolte, Holtmann, Poustka, Scheurich and Schmidt (2007) examined Gestalt perception in adults with high-functioning ASD and its relation to tasks that have been previously found to be sensitive to local-global processing in ASD, such as the hierarchical letter task, the block design and embedded figures test, and found that these individuals processed stimuli less in accordance with Gestalt laws, particularly regarding the law of similarity. In the hierarchical letters task, adults who used Gestalt processing strategies also tended to show increased global processing abilities. Adults with ASD, however, showed decreased Gestalt perception. Consistent with previous research, adults with ASD showed superior performance on the embedded figures task and block design compared to typically developing adults, suggesting that decreased Gestalt perception in adults with ASD is associated with a more general local visual processing bias. This tendency for adults with ASD to focus more on fine stimulus features, or local processing strategies, more so than stimulus configurations further suggests that these individuals rely on different processing strategies than those of typically developing individuals. As a result, two models have been developed to interpret these atypicalities in ASD perception: 1) the weak central coherence theory, and 2) the enhanced perceptual functioning theory.

Weak Central Coherence Theory

The central coherence theory proposed by Frith (1989) refers to the tendency for typically developing individuals to process incoming information using global processing strategies in order to extract the meaning of the information provided. However, individuals with ASD tend to show 'weak' central coherence. This was originally explained as a deficit in global processing abilities leading to a bias for processing local information and an inability to extract the gist or "see the big picture" in everyday situations (Frith, 1989). Early research using visuospatial tasks have demonstrated this processing bias, with individuals with ASD showing better than expected outcomes on a disembedding task (Shah & Frith, 1983), greater reliance on neighboring elements in extracting patterns (Frith, 1970), and a reduced inversion effect in face processing (Langdell, 1978). This is further supported by more recent research involving visual perception, with individuals with ASD showing superiorities in tasks such as visual search (Plaisted, O'Riordan & Baron-Cohen, 1998a; O'Riordan et al., 2001) and discrimination learning of highly confusable patterns (Plaisted et al., 1998b). This has led to a more recent version of the weak central coherence theory, which places more emphasis on individuals with ASD showing a bias for local processing rather than on deficit in global processing (Happe & Frith, 2006). However, in contrast with a superiority in local processing, individuals with ASD have also been shown to recruit global processing strategies less often than typically developing individuals in tasks requiring global processing such as Gestalt grouping (Brosnan et al., 2004; Bolte et al., 2006). Individuals with ASD have also been found to show reduced susceptibility to visual illusions (Happe, 1996), which are affected by global processing strategies, although this has been debated (Ropar & Mitchell, 1999; 2001). Thus, the most recent versions of this theory reemphasize the idea of reduced global integration of information (Happe & Booth, 2008).

Although it is obvious that to some extent individuals with ASD are capable of integrating some forms of information, such as the elements of daily events into a daily routine or the placement of elements of a visual scene in relation to one another when drawing a picture, it is important to ensure that accounts of global processing are in fact true accounts of global processing. It is possible that local processing strategies may be used to simply “link” events together, or the individual may know that one event follows another. In these cases, global processing is still not required to ensure that the schema of the event or drawing occurs in the proper order. A good example of this misleading account of intact central coherence is in the Wechsler Adult Intelligence Scale Picture Arrangement subtest (WAIS; Wechsler, 1997) in which a coherent story must be made by arranging pictures shown on separate cards. Although it would appear that central coherence is required to formulate a coherent story, many stories can be completed by simply linking each picture to the next without having to take into account more than the adjacent picture. In this case, only local processing is required to complete the task, giving the illusion that global processing was used to formulate the story (Happe & Frith, 2006).

Being aware of these possible misinterpretations of global processing will help to further solidify the extent to which the weak central coherence theory can explain atypicalities in perceptual processing in individuals with ASD. Although one must be cautious about using this theory to explain all perceptual atypicalities in ASD, the framework of weak central coherence has been able to consistently explain strengths on some visuo-spatial tasks such as superior performance on the embedded figures test and block design from the Wechsler Intelligence Scale, both of which require resisting the urge to experience one global visual stimuli in order to see several single elements. However, another theory has also been put forward to account for this bias, called the enhanced perceptual functioning theory.

Enhanced Perceptual Functioning Theory

An alternative explanation to the tendency for individuals with ASD to orient towards the parts rather than the whole of a design is the Enhanced Perceptual Functioning (EPF) theory (Mottron, Dawson, Soulières, Hubert & Burack, 2006). This theory is based on an earlier version of EPF linked to savant syndrome called the hierarchisation deficit hypothesis (Mottron & Belleville, 1993). In this hypothesis the local bias found in individuals with ASD was not explained by a preference for local processing or an integration deficit, but rather non-hierarchical access to information favoring local elements (Mottron et al., 2006). This theory assumes that individuals with ASD are as able as others to process global and local elements, however, while typically developing individuals show a preference for global elements, adding them first to a processing hierarchy, individuals with ASD are thought to process parts and wholes with similar efficiency (Mottron & Belleville, 1993; Mottron, Belleville & Ménard., 1999). Since local features tend to be more numerous than global features in the environment, a non-hierarchical processing strategy would favor local features. Thus, contrary to the weak central coherence theory, the hierarchical deficit hypothesis explains superior processing of local elements in individuals with ASD compared to typically developing individuals on tasks such as the embedded figures task and block design of the Wechsler Intelligence Scale by an absence of the precedence for global elements found in typically developing individuals, rather than an inability to integrate parts into wholes (Mottron & Burack, 2001; Mottron, Burack, Iarocci, Belleville & Enns, 2003).

The basis of the hierarchical deficit hypothesis was formed from a case study involving patient EC, a savant autistic draughtsman with exceptional graphic and perceptual abilities who demonstrated perfect global proportions and local details in drawing (Mottron & Belleville, 1993, 1995). Although a comparison of his graphic construction over several trials showed graphic inconsistency, probably due to the fact that he would start his drawings with local details and progress by contiguity, the accuracy of his drawing in both detail and proportion surpassed that of controls who showed a fixed copying sequence, beginning with a global outline of the drawing and then proceeding to the details. EC also demonstrated atypicalities in short-scale reaction time tasks assessing visuoperceptual processing. First, he failed to show the hierarchical global-to-local interference effect found in typically developing individuals, who show a slowed reaction time in identifying local features of an object due to the interference of global processing mechanisms. Second, EC was unable to detect geometric impossibility, a property that surfaces in typically developing individuals from several local features of briefly exposed “impossible figures”. These various atypicalities formed the basis of the hierarchisation deficit hypothesis, since there seemed to be an absence of hierarchisation in visual perception.

However, an attempt to generalize EC’s particularities to non-savant autistic individuals produced conflicting results. Although clear examples of locally oriented processing in tasks involving graphic construction were found, the atypical hierarchical properties of EC at the perceptual level were not replicated (Mottron et al., 1999). During a copying task, non-savant individuals with ASD were found to draw more local features at the start of copying compared to controls, but did not differ from controls in graphic constancy (Mottron et al., 1999). These individuals were also less affected by figure impossibility than were controls. These results suggest a local bias for visual information processing in non-savant individuals with ASD may exist, but to a lesser extent than that which was found in patient EC (Mottron et al., 1999).

The need to restructure the hierarchisation deficit hypothesis became necessary after the finding of enhanced visual discrimination in non-savant autistic individuals (Plaisted et al., 1998a). This study tested high-functioning adults with ASD and typically developing adults on a perceptual learning task that compared discrimination performance on familiar and novel stimuli. Typically developing adults showed the perceptual learning effect, that is, better discrimination abilities for familiar stimuli compared to novel stimuli. Individuals with ASD did not show the perceptual learning effect, although they were able to discriminate the novel stimuli significantly better than typically developing adults. These results suggest that features held in common between stimuli are processed poorly and features unique to a stimulus are processed well in individuals with ASD compared to individuals without ASD (Plaisted et al., 1998a). Thus, only under certain conditions do individuals with ASD show superior perceptual discrimination – in this case, enhanced discrimination of novel, highly similar stimuli. This notion of superior perceptual discrimination of novel stimuli and diminished processing of common features was critical in pointing to the new enhanced perceptual functioning account, which holds that individuals with ASD are oriented more towards local processing but not impaired at global perception (Mottron et al., 2006). However, the enhanced perceptual functioning account emphasizes that discrimination is probably not the unique explanation for cognitive superiorities in ASD, but rather one among many other perceptual operations (detection, matching, reproduction, memory, categorization and discrimination), highlighting an enhanced perceptual functioning in individuals with ASD (Mottron et al., 2006). In line with this theory, individuals with ASD should perform as well as typically developing individuals on global tasks while performing better on tasks that require local attention or perception (Mottron et al., 2003; Plaisted, Saksida, Alcantara, & Weisblatt, 2003).

Considering both the weak central coherence and the enhanced perceptual functioning accounts together, there are some remarkable similarities and differences. Both theories suggest an atypical relationship between local and global processing in individuals with ASD. Although these two theories differ in the sense that the enhanced perceptual functioning theory suggests that individuals with ASD are not impaired in their ability to use global processing skills, while the weak central coherence theory suggests global processing skills are reduced in individuals with ASD, both of these theories share the notion that individuals with ASD tend to show a preference for local processing than global processing strategies, suggesting a bias towards local processing strategies.

Local Bias

Behavioral Evidence

Although it appears that individuals with ASD show perceptual atypicalities that are best explained by theories suggesting a local bias, it is important to consider the evidence driving these theories in order to ensure that a local bias is actually occurring. Much of this evidence comes from behavioral studies in which a task is administered that requires a local focus, but that also contains global information that is generally processed automatically. This allows researchers to observe whether or not individuals with ASD showing a bias towards local processing are hindered by interference from the processing of task-irrelevant global information. Research has shown that these individuals are less hindered than typically developing individuals by task-irrelevant global information, supported by studies showing that individuals with ASD are superior at copying impossible figures compared to controls (Mottron et al., 1999), are able to complete the block design tasks faster and with fewer mistakes than controls when presented with unsegmented geometric designs (Shah & Frith, 1993), and are less influenced by the number of distractors in visual search tasks (O'Riordan et al., 2001). However, in the same way that typically developing individuals are affected by task-irrelevant global information when completing tasks that require a local focus, individuals with ASD are affected by task-irrelevant local information when completing tasks that require a global focus (Behrmann, Thomas & Humphreys, 2006; Rinehard, Bradshaw, Moss, Brereton & Tonge, 2000). This atypical local interference pattern provides support to the notion that individuals with ASD may have difficulties processing whole elements in their environment. Understanding the underlying mechanism driving this differential processing strategy may become more clear by looking at the connection between neurological and behavioral characteristics. While much of the support for a local bias comes from behavioral studies, neuroimaging studies have also shown that individuals with ASD tend to focus more on local processing strategies.

Neuroimaging Evidence

Most neuroimaging studies exploring a local bias in individuals with ASD have involved the embedded figure task (EFT), which has participants mentally break down complex figures into local parts in order to determine whether one of the parts matches the target figure. Neuroimaging studies have shown that individuals with ASD who are administered this task tend to show less activation in brain regions associated with higher levels of cognitive function and more activation in regions associated with lower levels of cognitive function when compared to controls (Just, Cherkassky, Keller & Minshew, 2004; Ring et al., 1999). More specifically, Ring et al. (1999) showed that performance on the embedded figures task resulted in greater activation of ventral occipitotemporal regions in individuals with ASD and greater prefrontal activity in controls, suggesting that the two groups may use different cognitive strategies. The activation of the ventral occipitotemporal region suggests that individuals with ASD depend on visual systems for object feature analysis (Ring et al., 1999). This finding suggests that individuals with ASD tend to prefer visually based processing strategies, which have been shown to activate posterior brain regions, while they are not generally as efficient in using higher level functions such as memory and language, which tend to activate areas in the anterior cortical regions (Koshino et al., 2005).

A study by Manjaly et al. (2007) contrasted brain activation in response to the EFT with a closely matched visuospatial control task in adolescent population. Task-specific activation was found to be left-lateralized in parietal and premotor areas for controls, but was found in right primary visual cortex and bilateral extrastriate areas in ASD. This suggested that enhanced local processing, rather than impaired processing of global context, is characteristic of performance in the EFT by individuals with ASD. Similarly, Damarla et al. (2010) found greater activation of visuospatial areas in ASD and greater activation of left dorsolateral prefrontal and inferior parietal areas in controls in an EFT. Reduced frontal-posterior functional connectivity in ASD was also observed, suggesting that the integration of higher-order executive/working memory brain regions with visuospatial regions might be impaired in individuals with ASD in EFT.

Liu et al. (2011) provided the first direct neural evidence of reduced global-to-local interference in ASD perception. Individuals were presented with possible and impossible 3-D objects, where several contours were colored. Participants were asked to simply count the colored lines, a form of local visual processing. It was expected that while counting the lines participants would automatically process the 3-D structure as well, thus introducing a task-irrelevant form of global processing. In a contrasting 3-D task, participants were asked to judge whether the same 3-D stimulus object depicted a possible or impossible 3-D object, which was intended to focus attention on the 3-D structure, a form of global processing. Results showed that in the line counting task, the ASD group did not show increased medial frontal activity (relative to the possibility task), or increased functional connectivity between the medial frontal region and posterior visual-spatial regions, as was found in the control group. The control group also showed a positive correlation between a measure of spatial ability (Vandenberg scores) and activation in the medial frontal region, suggesting that more spatially able control participants suppressed the irrelevant 3-D background information more in order to focus on the line counting task. This indicates that the global 3-D object had a smaller effect, if any, on local processing in the group with ASD compared to the control group, demonstrating a reduction in global-to-local interference in individuals with ASD. Taken together, this research shows how cognitive approaches such as weak central coherence and enhanced perceptual functioning have substantially increased the understanding of mechanisms possibly underlying perceptual processing in ASD. However, it is still unclear where in the visual processing pathway that coherence is lacking.

Visual Pathways

The human visual system allows an individual to perceive and interact with many elements of their surroundings, forming a unitary representation of the visual world. However, within this visual system lies a complex network of cortical and subcortical regions, each of which is specialized to carry out various vision related functions. First, visual input from the environment is carried by ganglion cells to the visual cortex via the retino-geniculo-cortical pathway (Merigan & Maunsell, 1993). Information sent through this pathway is transported from the retina to the lateral geniculate nucleus (LGN), a structure within the thalamus. This information is then projected to the primary visual cortex (area V1) via three streams: magnocellular, parvocellular and koniocellular, each of which segregates in the LGN and remains segregated while information is sent to lower visual regions between the retina and primary visual cortex (Merigan & Maunsell, 1993; Livingstone & Hubel, 1988). Neurons in the magnocellular system are color insensitive and relatively fast, with low spatial resolution and high contrast sensitivity (Lee, 2004; Swanson & Cohen, 2003). Neurons in the parvocellular system are color selective for red and green dimensions of color vision, and are relatively slow with low contrast sensitivity and high spatial resolution, while those neurons in the koniocellular system are sensitive to the blue and yellow dimensions of color vision, and are relatively slow with low contrast sensitivity and low spatial resolution (Lee, 2004; Swanson & Cohen, 2003). The extrastriate cortex (area V2) receives information from the primary visual cortex, and these two lower level visual processing structures together process all basic visual attributes, such as color, form, depth and motion perception before this information is sent to higher visual regions (DeYoe & Van Essen, 1985; Shipp & Zeki, 1985; Sincich & Horton, 2005). At this point the visual association cortex divides into two pathways: a ventral stream, which projects from area V1 to the inferior temporal lobe consisting of mainly magnocellular input (Livingstone and Hubel, 1988), and a dorsal stream, which projects from V1 to the posterior parietal lobe, consisting of mainly parvocellular input (Merigan & Maunsell, 1993).

Information sent to the ventral stream moves through the extrastriate cortex into area V4, which is highly sensitive to properties such as orientation, spatial frequency, simple geometric shapes, and color, and then projects to a variety of subareas of the inferior temporal cortex (Braddick et al., 2001). As information is propagated along the ventral pathway the neurons become more highly specified, and as a result the specificity required for activation of the cells to occur increases (Culham et al., 2003). Receptive fields for cells within the temporal lobe also appear to become larger compared to those in earlier visual regions. This higher specificity and the larger receptive fields of these cells allow for activation to be generalized across the entire visual field, and as a result the features of an object can be encoded in the visual field regardless of its location (Milner & Goodale, 1995). Thus, the ventral pathway is generally activated during perceptual based tasks involving recognition of size, shape, color or texture and during object recognition (Grill-Spector, 2003).

The other processing stream, the dorsal stream, is most commonly associated with interpreting motion, representing the location of objects, and allowing for skilled control of movements. Dorsal stream information is sent from area V2 to area V3, where information related to global motion is processed. The final destination of all dorsal stream information is the posterior parietal cortex (PPC), which is also thought to be the converging point for receiving information from both ventral and dorsal streams. Thus, the dorsal stream plays a large role in integrating motion, and as a result the dorsal pathways is generally activated during tasks involving reaching and grasping (ie: Grafton, Fagg, Woods & Arbib, 1996; James, Culham, Humphrey, Milner & Goodale, 2003).

Visual Processing in ASD

Although theories such as weak central coherence and enhanced perceptual functioning are strongly supported by research showing that individuals with ASD use atypical visual processing strategies compared to typically developing controls, there are mixed findings about the area of the visual processing stream that may be responsible for this atypicality. Plaisted, Swettenham & Rees (1999) suggested that enhanced processing in individuals with ASD may be linked to the pathway responsible for carrying high spatial frequency information (the parvocellular or ventral pathway) related to identification of object features. However, Badcock, Whitworth, Badcock and Lovegrove (1990) showed that a local precedence effect does not occur when low spatial frequency information (ie: color) was removed from hierarchical stimuli. This suggests that it is unlikely that the local advantage on the Navon task in children with ASD is due to superior processing in the ventral pathway. Milne et al. (2002) predicted that it is actually the dorsal pathway that is impaired in individuals with ASD, and tested the notion that a local processing bias exists in individuals with ASD as a result of impairments in the dorsal pathway (responsible for both low special frequency and motion processing). Children with high-functioning ASD were examined in their ability to perceive global motion by having them determine the overall direction of coherently moving dots amidst a background of randomly moving dots. Compared to typically developing children, the ASD group required more dots to be moving coherently in order to perceive global motion, suggesting that individuals with ASD may show a deficit in the dorsal visual pathway (Milne et al., 2002). Since faster processing of the global level of a stimulus indicates that lower spatial frequency information is being transmitted quicker (Badcock et al., 1990), it was further suggested that a deficit in dorsal stream processing may also explain weak central coherence.

Coherence at lower and higher level processing along the dorsal pathway has most commonly been examined in children with ASD by testing their sensitivity to motion stimuli. A study by Bertone, Mottron, Jelenic, and Faubert (2003) tested the perceptual processing abilities of children with ASD by administering two tasks, one of which required ‘simple’ perceptual processing (luminance-defined) and one requiring more ‘complex’ perceptual processing (texture-defined). Children with ASD showed poor performance on the task requiring complex perceptual processing when compared to typically developing children, suggesting a lack of coherence at higher levels of perceptual processing due to a deficit in integrating ‘complex’ information at the global level. Bertone et al. (2003) further suggested that this deficit may extend beyond the processing of moving stimuli and also include static stimuli. However, Spencer et al. (2000) found that although children with ASD showed elevated thresholds on a global motion task compared to typically developing children, they nonetheless showed similar global form thresholds, discounting Bertone et al.’s (2003) notion that a lack of coherence at higher levels of perceptual processing due to an inability to integrate ‘complex’ information might also negatively affect form perception in addition to motion perception. As a result, Spencer et al. (2000) suggested that their findings of poor global motion perception but intact global form perception in ASD may be a result of a more general dorsal stream processing impairment.

Pellicano, Gibson, Maybery, Durkin and Badcok (2005) sought to disentangle these competing explanations by assessing the integrity of the dorsal pathway at both lower and higher levels. Low-level visual processing was assessed in children with and without ASD using a Flicker Contrast Sensitivity (FCS) task, which required children to view two intervals, one of which contained a flickering target stimulus, and to indicate which interval contained the stimulus. Visual processing in higher cortical areas was assessed in these children by means of a Global Dot Motion (GDM) task, which required children to indicate the direction of motion of a coherently moving dot pattern. Relative to typically developing children, the children with ASD showed higher GDM threshold but equivalent FCS thresholds, suggesting that elevated global motion thresholds in ASD are the result of high-level impairments in dorsal cortical regions. Furthermore, Pellicano et al. (2005) also examined the notion that atypicalities in dorsal stream functioning may be responsible for weak central coherence in ASD (Bertone et al., 2003; Milne et al., 2002) by administering a common measure of central coherence – the Embedded Figures task (EFT). Children with ASD showed faster response times on the EFT compared to typically developing children, and this along with higher GDM thresholds suggests that weak central coherence in children with ASD may be a result of a lack of coherence at higher levels of visual processing, more specifically in the dorsal pathway (Pellicano et al., 2005).

Biological motion, which involves using global, complex motion processing strategies to determine body movement, is another form of visual processing occurring in the dorsal pathway. Intact processing of biological motion offers more insight into the complexity of the dorsal processing stream, as tasks examining both coherent motion and biological motion have shown differing and dissociable performance levels in typically developing individuals (Grossman & Blake, 1999), in individuals with brain-damage (Vaina, Lemay, Bienfang, Choi, & Nakayama, 1990) and in individuals with Williams syndrome (Jordan, Reiss, Hoffman & Landau, 2002). Point-light animations (Johanson, 1973) have been used to assess integrity of biological motion processing in individuals with ASD, although evidence for impaired detection of biological motion is not clear. One study has shown impairments in the ability to accurately determine biological from nonbiological motion (Blake, Turner, Smoski, Pozdol & Stone, 2003), while another study has shown no effect on accuracy (Freitag et al., 2008). Moreover, whether or not individuals with ASD are impaired in their ability to detect biological motion appears to be partially dependent on whether or not emotional actions are presented. The ability for individuals with ASD to make simple, accurate judgments about whether a point-light sequence is a human or inanimate object appears to be comparable to typically developing individuals (Moore, Hobson & Lee, 1997). However, when adults with ASD and typically developing adults were asked to classify basic emotions from point-light displays of body movements, adults with ASD were reliably less accurate in classifying emotions compared to typically developing adults (Atkinson, 2009). As a result, detecting the area of the visual processing stream responsible for atypicalities in visual processing in individuals with ASD is a complicated task. Various components, such as featural information, biological versus non-biological information, and even whether or not an emotional component is evident can affect whether or not differences in visual processing occur in individuals with and without ASD.

Summary

Although much of this research focuses on children and adolescents, it has been shown that in typically developing individuals, form and motion coherence thresholds develop largely in parallel, with form performance reaching adult levels between 6-7 years old, and motion performance reaching adult levels around 10-11 years old (Gunn et al., 2002). However, it is not known whether or not this same developmental process occurs in individuals with ASD. In this regard, research involving visual processing abilities in children can serve as a basis for developing similar studies for adults, but generalizations across groups should be made with caution.

It is clear that this research shows that perceptual processing differs in individuals with ASD compared to typically developing individuals. In many cases, individuals with ASD often show superiorities in analyzing local elements in a visual scene compared to typically developing individuals, an atypicality most commonly explained according to the weak central coherence or enhanced perceptual functioning theories. Both of these theories argue that a local bias keeps individuals with ASD from experiencing interference from global information, allowing for greater attention to be given to local details of a stimulus. However, each of these theories are driven by differing explanations for accounting for these atypicalities in local and global processing. Whether these atypicalities are a result of a reduction in global processing abilities (Weak Central Coherence), or simply a preference for local processing strategies (Enhanced Perceptual Functioning), as well as the underlying brain mechanisms responsible for these atypicalities, remains unclear.

CHAPTER II

GENERAL METHODOLOGY

The purpose of the current study was to examine parts-based processing strategies in adults with high-functioning ASD. To achieve this goal, the study was conducted over two sessions of 1-hour each. The Perceptual Grouping Task in Experiment 1 evaluated visual processing at a low, preattentive level of coherence by assessing susceptibility to a visual illusion called the Ponzo illusion. The Viewing Window Paradigm in Experiment 2 compared the visual scanpaths of individuals with ASD and typically developing individuals when forced to use parts based processing strategies to identify common, everyday objects. Each of these experiments sought to examine a unique aspect of visual processing and to provide a better understanding of the mechanisms underlying visual processing in ASD.

Participants

Fifteen (10 males; age range 18 – 70 years; mean age = 35 years) adults with high-functioning ASD (defined as those individuals with an Asperger's, PDD-NOS, or high-functioning Autism diagnosis) and 15 age/gender/handedness matched typically developing (TD) controls were recruited using social media advertisements, newspaper advertisements, and by word of mouth. All but two participants were right-handed, and all participants had normal or corrected-to-normal vision as reported in pre-test screening (Appendix D). All participants were tested on the Perceptual Grouping Task, however only 13 ASD participants and 13 TD participants were tested on the Viewing Window Paradigm due to participants dropping out of the study. Participants were tested either in the *Neuropsychology of Vision Perception and Action Lab* at the University of Manitoba or in their homes. This research was approved by the Psychology/Sociology Human Research Ethics Board (PSREB) at the University of Manitoba.

General Procedure

Prior to testing, all participants were required to provide written informed consent (Appendices A-C) and to complete a short demographics questionnaire inquiring about the participant's age, gender, handedness, vision, current medications and if they had a history of head injury or seizure disorders (Appendix D). Information regarding medical history was only collected to determine if medications, other conditions, or injury may be affecting the participants' visual skills. During the first session individuals with ASD completed two standardized tests: the Peabody Picture Vocabulary Test version 4 and the Raven's Standard Progressive Matrices Test. Both groups of participants also completed the Perceptual Grouping Task in the first session. During the second session, all participants completed the Viewing Window paradigm. Once testing was completed, participants were debriefed and given an opportunity to ask questions about the reasoning behind the study (Appendix E).

Standardized Testing

The standardized tests administered during session 1 measured both verbal and nonverbal levels of IQ. Verbal IQ was assessed using a test of receptive language called the Peabody Picture Vocabulary Test (PPVT-4, Dunn & Dunn, 1997), which ensured that all participants in the ASD group were fully capable of comprehending the required instructions for this study, and that deficits in receptive vocabulary were not hindering a participants ability to identify and name objects. Nonverbal IQ was assessed using the Ravens Standard Progressive Matrices Test (RSPM, Raven, Court & Raven, 2000), which focused on the ability of the individual to perceive and identify patterns. This test ensured that all participants in the ASD group were functioning at cognitive levels similar to those of typically developing individuals. Individuals with ASD had RSPM (mean score = 44.87, SD = 7.47) and PPVT (mean standard score = 109.4, SD =

11.36) scores that were consistent with previous research involving both adults with high-functioning ASD and typically developing adults (Kretschmer, Altgassen, Rendell & Bolte, 2014; Lartseva, Dijkstra, Kan & Buitelaar, 2014; Mayer, Hannent, & Heaton, 2014; Mayer & Heaton, 2014), indicating that both verbal and non-verbal cognitive abilities were similar to those of typically developing individuals.

CHAPTER III

PERCEPTUAL GROUPING TASK

Although cognitive approaches such as the weak central coherence theory and enhanced perceptual functioning theory have substantially increased the understanding of mechanisms possibly underlying ASD, it is still unclear where in the visual processing stream coherence is lacking. Studies showing that individuals with ASD are better than controls at spotting embedded figures (Shah & Frith, 1983), and better able to reproduce unsegmented block designs (Happé, 1994c; Shah & Frith, 1993) suggest problems in coherence at a relatively early perceptual or attentional stage. However, findings showing failure to process information in context during sentence reading (Frith & Snowling, 1983; Happé, 1997) and problems detecting global motion (Pellicano et al., 2005; Spencer et al., 2000) suggest that deficits in coherence may actually be at higher levels of the visual processing stream. Visual illusions, which are not processed purely according to their physical properties but rather as a result of visual elements being automatically integrated via Gestalt principles to generate an inaccurate judgment, have been used as an argument for a lack of coherence in lower levels of the visual processing stream (Bolte et al., 2007; Frith, 1989; Happé and Frith, 2006; but see Ropar & Mitchell, 1999, 2000). Neuroimaging studies have confirmed that visual illusions of size (ie: Ponzo illusion) affect neural activation in early visual areas, including V1, in typically developing individuals, making them a good assessment of coherence at lower levels of visual processing (Fang, Boyaci, Kersten, & Murray, 2008; Murray, Boyaci, & Kersten, 2006).

Previous research using visual illusions have shown that the brain is not solely reliant on sensory information in order for perception to occur (Gregory, 1963). In fact, visual illusions show how our perception of the world sometimes makes us ‘see’ what we expect or want to see.

Thus, visual illusions are ideal for looking at whether or not weak central coherence theory can explain perceptual processing in ASD (Frith, 1989; Happé and Frith, 2006). According to the weak central coherence theory, problems with global processing in individuals with ASD frees them to see the local elements in a visual scene for what they really are, making them less susceptible to visual illusions. However, studies using visual illusions to examine weak central coherence in individuals with ASD have shown mixed results. Happé (1996) found that individuals with ASD were less likely to succumb to visual illusions and showed reduced benefit from 3D segmentation. Similarly, a study examining Gestalt perception and its relation to tasks suggestive of local visual processing found that individuals with ASD processed Gestalt stimuli less in accordance with Gestalt laws, and succumbed to visual illusions less than typically developing controls, suggesting that decreased Gestalt perception in individuals with ASD is associated with a more general local visual processing bias (Bolte et al., 2007). However, subsequent research on the processing of visual illusions has shown that compared to controls, individuals with ASD are just as susceptible to visual illusions (Ropar & Mitchell, 1999, 2001).

One explanation for these inconsistencies may have to do with procedural differences related to the amount of attention focused directly at the visual illusion. Studies have shown that individuals with ASD will process stimuli in a global nature when their attention is directed to it during selective attention tasks (Hayward et al., 2012; Koldewyn, Jiang, Weigelt, & Kanwisher, 2013; Plaisted et al., 1999), but tend to show a reduced preference for global processing when given a choice in divided attention tasks (Koldewyn et al., 2013; Plaisted et al., 1999). Thus, the amount of attention directed towards the visual illusion may determine whether or not individuals with ASD show susceptibility to the illusion. If individuals with ASD are instructed to direct their attention to a visual illusion during the task, then it is likely they will have recruited some forms of global processing strategies when performing the task (ie: recruiting Gestalt properties), which may make them more susceptible to the visual illusion. However, if individuals are unaware of the illusion, they may process the illusion using local processing strategies, decreasing their susceptibility to the illusion. This would suggest that coherence is lacking at very low, preattentive levels of processing, but that coherence becomes more intact once attention is given to the stimuli.

The point at which Gestalt grouping occurs in the visual processing stream will also affect an individual's susceptibility to the visual illusion. In typically developing individuals it has been found that Gestalt grouping does occur without attention, thus rendering these individuals susceptible to illusions even at preattentive levels (Moore & Egeth, 1997; Shomstein, Kimchi, Hammer & Behrmann, 2010). However, it is unknown whether individuals with ASD use the same processing strategies as typically developing individuals. Thus, it is possible that individuals with ASD may not recruit Gestalt grouping strategies until they recruit attentional processes. If this is the case, then individuals with ASD should not be susceptible to visual illusions at low, preattentive levels of processing, indicating a lack of coherence in low levels of the visual processing stream.

Experiment 1 consisted of a Perceptual Grouping task, which evaluated coherence at a lower-level of processing using the Ponzo illusion (also known as the railroad-track illusion) – an illusion in which a line segment located near the narrow end of two converging lines appears longer than a line segment located closer to the diverging end, when in fact both lines are the same length. Participants were shown two parallel lines superimposed on a background of either randomly distributed or patterned dots, the latter of which was used to induce the Ponzo illusion, and asked to indicate which of the two lines was longer. It was hypothesized that if individuals with ASD fail to integrate all elements of the illusions, then they would be less likely to be fooled by the misleading effect of the stimuli.

Experiment 1

Stimuli. Figure 1 shows the random dot background and each of the two pattern trials used to display the Ponzo illusion. For half of the illusion trials the two lines were displayed on a background of random black and white dots (Figure 1A), and on these random matrix trials one line segment was presented as slightly longer than the other. For the other half of the illusion trials the black dots were displayed so that they formed two converging black lines, as in the Ponzo illusion (Figure 1B). Half of these trials showed the illusion with the two lines converging at the bottom while the other half will showed the illusion with the two lines converging at the top. On these pattern matrix trials the line segments were presented as the same length. The two equal lines used for discrimination were centered within this pattern of converging lines, which was centered within the dotted matrix.

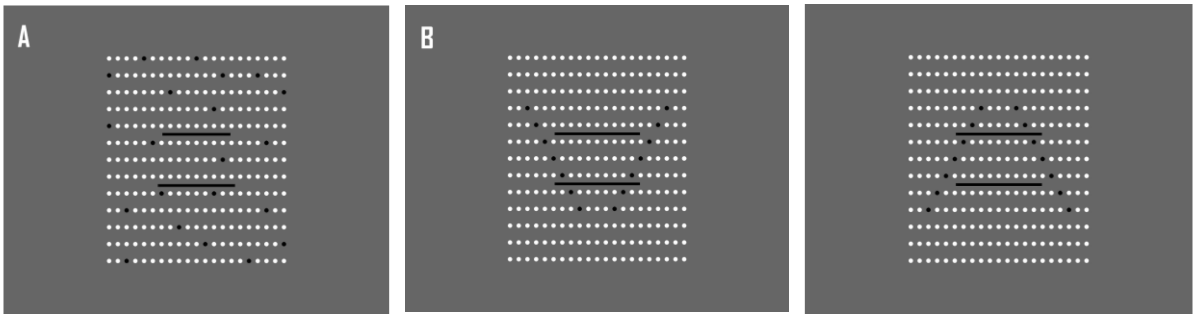


Figure 1. Perceptual Grouping Task. These figures show the backgrounds used for the various trails. For half of the illusion trials the two lines were displayed on a background of random black and white dots (Figure 1A). For the remaining trials, the black dots were displayed so that they formed two converging black lines, as in the Ponzo illusion (Figure 1B).

Procedure. Participants were tested on a 17" Apple MacBook Pro-laptop, and all stimuli were presented in a program using Eprime. Figure 2 displays the experimental structure. At the beginning of the task, participants were told that each trial would begin with a fixation point, followed by a brief presentation of a matrix of black and white dots with two line segments superimposed on it. Participants were told to indicate which of the two black parallel lines presented was longer, indicating their response by pressing '1' for the top line and '2' for the bottom line. Following these instructions, participants were presented with the first set of trials of the experiment, consisting of 10 practice random matrix trials. This allowed participants to adjust to the quick presentation of the stimuli. After the practice trials participants completed a second set of trials consisting of 32 trials, some of which showed the lines presented on a randomly generated black and white dotted background and others of which showed the black dots arranged so that they formed a V or inverted V pattern. This pattern arrangement produces the Ponzo illusion in healthy controls, and these individuals report that the two equal lines actually differ in length. After this set of 32 trials participants then completed a final set of 8 trials assessing their susceptibility to the illusion under various conditions of attention. Of these 8 trials, the first three trials as well as the fifth and sixth trials appeared as random matrix trials, and participants simply reported which line segment was longer. The fourth, seventh, and eighth trials appeared as pattern matrix trials, which looked at inattention, divided-attention and full-attention, respectively. The fourth and seventh trials required participants to indicate which line was longer, while the eighth trial did not require a response. During the eighth trial participants were asked to ignore the line segment and look for the pattern in the matrix.

Following these three pattern matrix trials, participants were also asked three questions regarding the pattern in the background. First, participants were asked whether or not they noticed a pattern in the background of the dots on the preceding trial, pressing ‘y’ for *yes* and ‘n’ for *no*. Next, participants were shown the two patterns and asked to indicate the pattern they observed, pressing ‘1’ for the first image, ‘2’ for the second image, and ‘5’ if they did not see a pattern. Finally, participants were asked to provide a confidence rating of how confident they were in their response to the pattern they noticed, pressing ‘1’, *not at all*, ‘2’, *somewhat* and ‘3’, *very confident*. Since individuals were not told they would be asked questions about the background pattern before they were presented in Trial 4, this trial served as an inattention trial. Trial 7 was a divided-attention trial since participants may have been prepared for another set of questions to be asked, and as such may have been distributing their attention to both the background task display and the horizontal line segments. Trial 8 was a full-attention trial because participants were directed to only pay attention to the background pattern. Completion of the attention trials marked the end of the experiment.

The order of the trial events is presented in figure 3. The fixation point at the beginning of each trial was shown for 1000ms. The trial display was then shown for 250ms, after which a mask display appeared. This mask remained on the screen until the participant entered a response. An intertrial interval of 3000ms then appeared as a grey background, after which the next trial was presented.

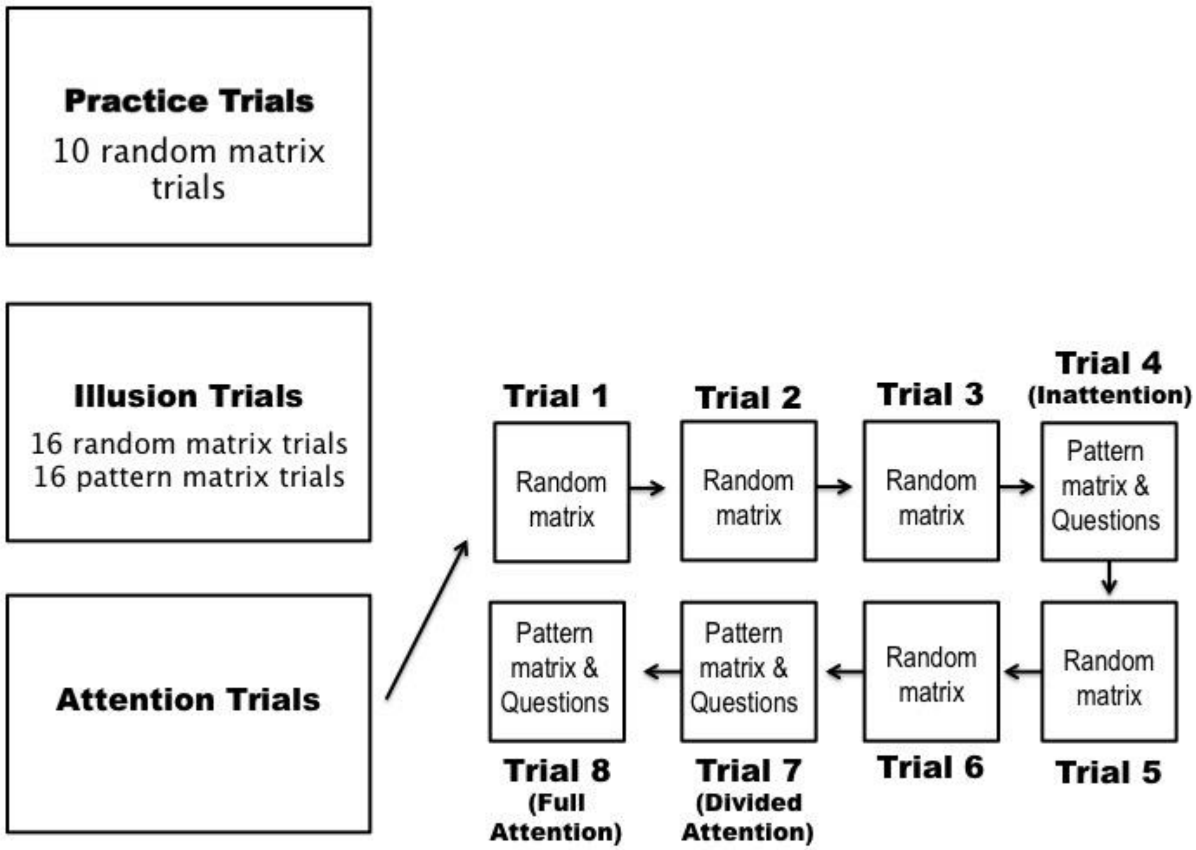


Figure 2. *Experimental structure.*

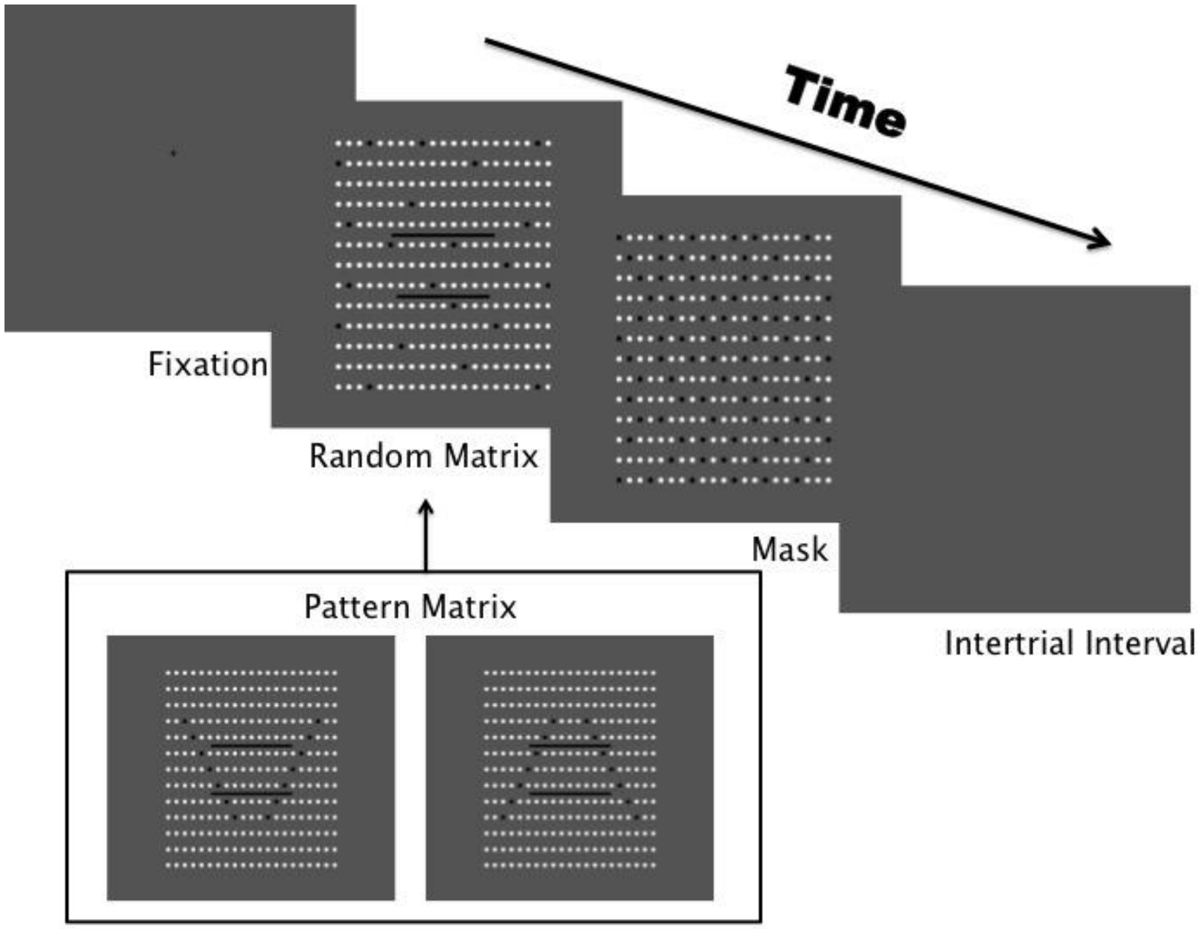


Figure 3. *Trial events.*

Hypothesis. In this task, the dots on the pattern trials were colored in such a way that if the participant groups them together, they form two converging lines, as in the Ponzo illusion. Since the line segments on the pattern trials were the same length, we expected that if participants were unbiased in their responses, they would indicate that the top and bottom lines were longer equally as often. This resistance to the illusion would suggest that their fragmented perception was due to low level perceptual processing impairments. If the participant grouped the dots together, however, then we expected that they would be susceptible to the illusion and respond that the line segment closest to the converging end of the pattern was longer than the other segment. If this occurred, this would suggest that perception at lower levels of processing were not impaired, and that grouping by similarity occurred. Thus it was expected that if individuals with ASD were able to perceptually group the black dots together into a perceived whole at an early stage of visual processing, they should be susceptible to the illusion as well.

Results

All analyses were carried out using alpha = .05. Where indicated in the following results, independent sample t-tests were used to determine if there were significant differences between group means and one-sample t-tests were used to compare means to a chance finding (50%). An analysis of variance (ANOVA) was used to analyze the three questions (direct query, forced-choice and confidence rating) following the three pattern matrix trials. Finally, to ensure that the illusion was observed at pre-attentive levels of processing, a point-biserial correlation was calculated between the accuracy of the forced-choice response following the inattention trial and the percentage of pattern matrix trials in the set of illusion trials on which the line at the converging end of the illusion was reported.

Illusion Trials. It was expected that if individuals were able to perceptually group the black dots together into a perceived whole, then they would indicate that the line segment closest to the converging end of the pattern is longer than the other line segment. The results from the pattern matrix trials indicated that individuals in the typically developing (TD) group were influenced by the pattern in the background while individuals in the ASD group were not influenced by the pattern in the background (Figure 4). Since the line segments in these trials were the same length, individuals who guessed without a bias should have reported the line toward the converging end of the patterned lines on approximately 50% of the trials. Individuals in the TD group reported the line toward the converging end of the patterned lines on 67.92% (± 4.09%) of the trials, which was found to differ significantly from a 50% chance result (Values of the form x ± y refer to the mean, x, and the corresponding standard error of the mean, y.). This indicated that the individuals in the TD group reported the line segment at the converging end of the pattern reliably more often than would be expected if they had guessed without bias. Individuals in the ASD group reported the line segment toward the converging end of the pattern on 51.67% (± 4.94%) of the trials. This result did not differ significantly from 50%, indicating that the individuals were guessing without a bias.

To assess whether there were differences between susceptibility to the illusion when the lines converged at the top of the screen compared to the bottom, the pattern matrix trials were separated according to whether the illusion showed the converging end at the top or at the bottom of the screen for each group. When the converging end was at the *top*, 55.0% (± 5.82%) of TD individuals fell susceptible to the illusion, that is, reported the top line as longer. This result did not differ significantly from 50%, indicating that participants were guessing without a bias. When the lines converged towards the bottom of the screen, 80.83% (± 5.01%) of TD individuals fell susceptible to the illusion, reporting the bottom line as longer. This result differed significantly from 50%, indicating that participants reported the bottom line reliably more often than would be expected if they had guessed without a bias. Taken together, these values differed significantly from each other, indicating that individuals in the TD group were more susceptible to the illusion when the lines converged towards the bottom of the screen, $t(28) = -3.362$, $p = .002$.

For individuals in the ASD group it was found that when the converging end was at the top, 57.50% (± 5.43%) of participants fell susceptible to the illusion, that is, reported the top line as longer, while 45.83% (± 8.60%) of participants fell susceptible to the illusion, reporting the bottom line as longer when the lines converged towards the bottom of the screen. Neither of these results differed significantly from 50%, indicating that participants were guessing without a bias. These values did not differ significantly from each other, indicating that individuals in the ASD group were not susceptible to illusion regardless of its direction, $t(28) = 1.147$, $p = .261$. A comparison across groups showed that individuals in the TD group were significantly more likely to report the line towards the converging end of the pattern as longer compared to participants in the ASD group, indicating that participants in the TD group are more susceptible to the illusion that those in the ASD group, $t(28) = -2.536$, $p = .017$.

To ensure that individuals were not impaired in their ability to make a line discrimination, individuals were required to discriminate between two lines, one of which was always longer, superimposed on a background of randomly placed dots. The mean percent correct for reporting which line segment was longer on the random matrix trials was 90.42% (± 1.20%) for the TD group and 88.33% (± 2.92%) for the ASD group (Figure 4). To assess whether participants showed a response bias, the random matrix trials were separated according to whether the correct response was *top* or *bottom*. For the TD group, the mean percent correct for reporting *top* was 95.83% (± 2.33%) and the mean percent correct for reporting *bottom* was 85.0% (± 1.34%). These values differed significantly from each other, indicating that participants in the TD group were biased to report *top* more often than *bottom*, $t(28) = 4.026$, $p < .001$. For the ASD group, the mean percent correct for reporting *top* was 95.83% (± 2.64%) and the mean percent correct for reporting *bottom* was 80.83% (± 3.63%). Similar to the TD group, these values differed significantly from each other, indicating that participants in the ASD group were also biased to report *top* more often than *bottom*, $t(28) = 3.343$, $p = .002$. When the mean percent correct for reporting which line segment was longer on the random matrix trials was compared across groups, no significant differences were found, indicating that both groups showed similar performance in making the line discrimination in random matrix trials, $t(28) = -.661$, $p = .514$.

Attention Trials. It was expected that as participants were directed to increase their attention to the background pattern, the ability to detect and correctly identify the pattern would also increase. The first three trials as well as the fifth and sixth trials were random matrix trials, in which one line segment was longer than the other and participants were expected to be relatively accurate in their line judgments. The fourth, seventh and eighth trials were pattern matrix trials in which the two line segments were the same length. In these trials participants were guided to increase their attention to the background pattern. As such, these pattern matrix trials were the inattention, divided-attention, and full-attention trials, respectively. The mean percent correct in the line-segment task on Trials 1-3 was 100% for the ASD group and 97.78% (± 2.22%) for the TD group. For trials 5-6 it was 83.33% (± 7.97%) for the ASD group and 93.33% (± 4.54%) for the TD group. On the inattention trial (Trial 4) the percentage of participants who reported that the line segment closer to the converging end of the pattern was longer than that closer to the diverging end was 46.67% for the TD group and 53.33% for the ASD group, both of which were not reliably greater than the 50% expected by chance (ASD: $t(14) = .250$, $p = .806$; TD: $t(14) = -.250$, $p = .806$). On the divided attention trial (Trial 7), the percentage of participants who reported that the line segment closer to the converging end of the pattern was longer was 66.67% for the ASD group, which was not reliably greater than the 50% expected due to chance, $t(14) = 1.323$, $p = .207$ and 80% for the TD group, which was reliably greater than the 50% expected by chance, $t(14) = 2.806$, $p = .014$. No response followed the full-attention trial (Trial 8).

Following each of the pattern matrix trials were three questions (the direct query, the forced choice, and the confidence rating). No significant differences were observed between groups on each trial of each question. Results from both groups showed that the dot patterns were perceived extremely poorly on the inattention trial, slightly better on the divided-attention trial, and fairly well on the full-attention trial, as indicated by the direct query (Figure 5) and forced choice (Figure 6) measures. Mean confidence ratings (Figure 7) remained relatively consistent throughout all these trials.

Correlation between forced choice and experience of the illusion. To ensure that the illusion was observed at pre-attentive levels of processing, a point-biserial correlation was calculated between the accuracy of the forced-choice response following the inattention trial and the percentage of pattern matrix trials in the set of illusion trials on which the line at the converging end of the illusion was reported (Figure 8). A significant, positive correlation would suggest that reports indicating that the line at the converging end is longer in the illusion block may have been the result of participants noticing the patterns on the pattern matrix trials. However, no relationship was found between accuracy of the forced-choice response following the inattention trial and the percentage of pattern matrix trials in the illusion block on which the line at the converging end of the illusion was reported for individuals in the TD group, $r(15) = -.380$, $p = .163$, or for individuals in the ASD group, $r(15) = .293$, $p = .289$. Thus, it is likely that those individuals who fell susceptible to the illusion did so at a preattentive level.

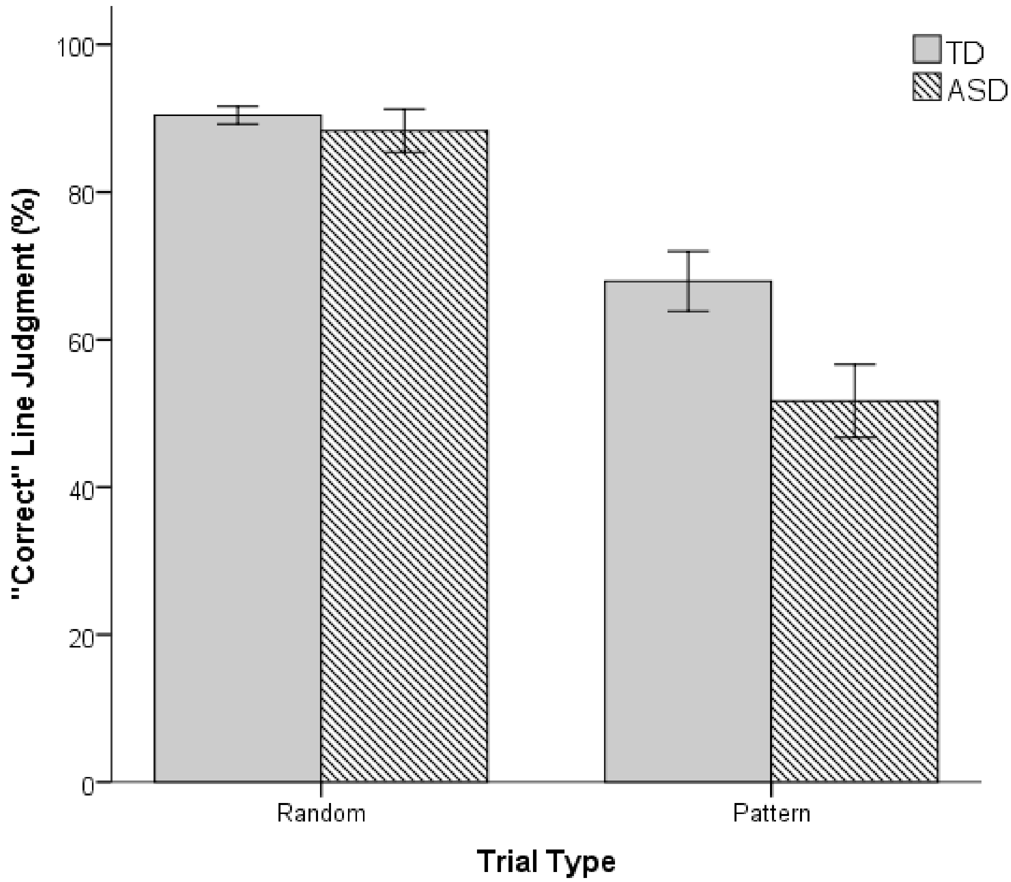


Figure 4. Illusion Trials. Error bars represent Standard Error of the Mean (SEM).

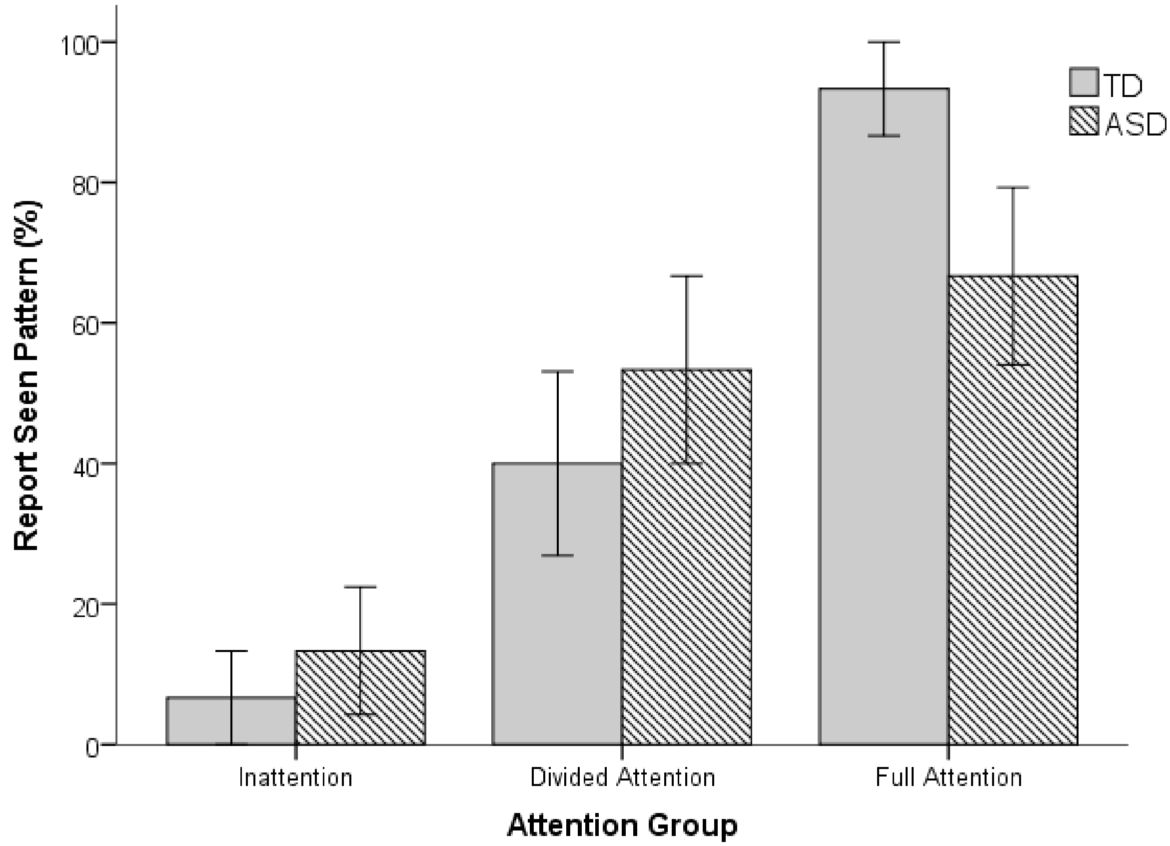


Figure 5. Attention Trials: Direct Query. Error bars represent SEM.

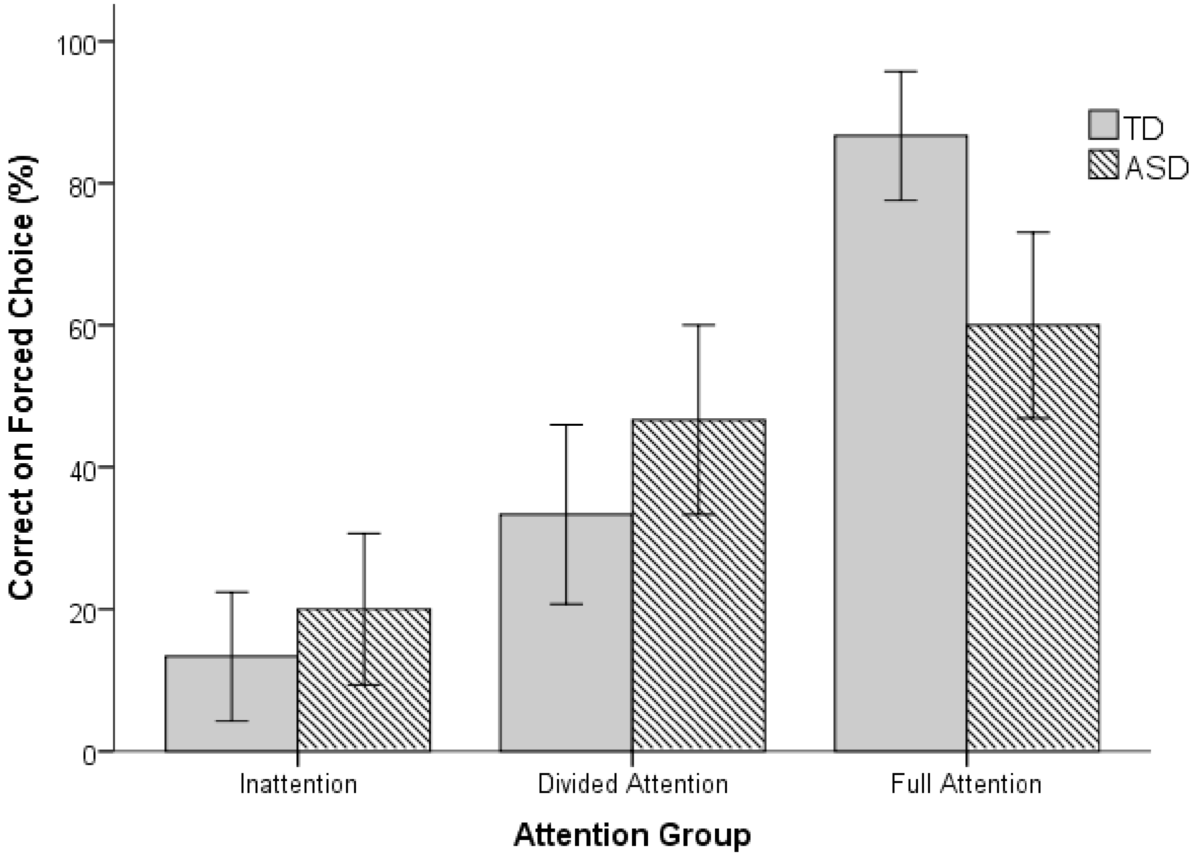


Figure 6. Attention Trials: Forced-Choice. Error bars represent SEM.

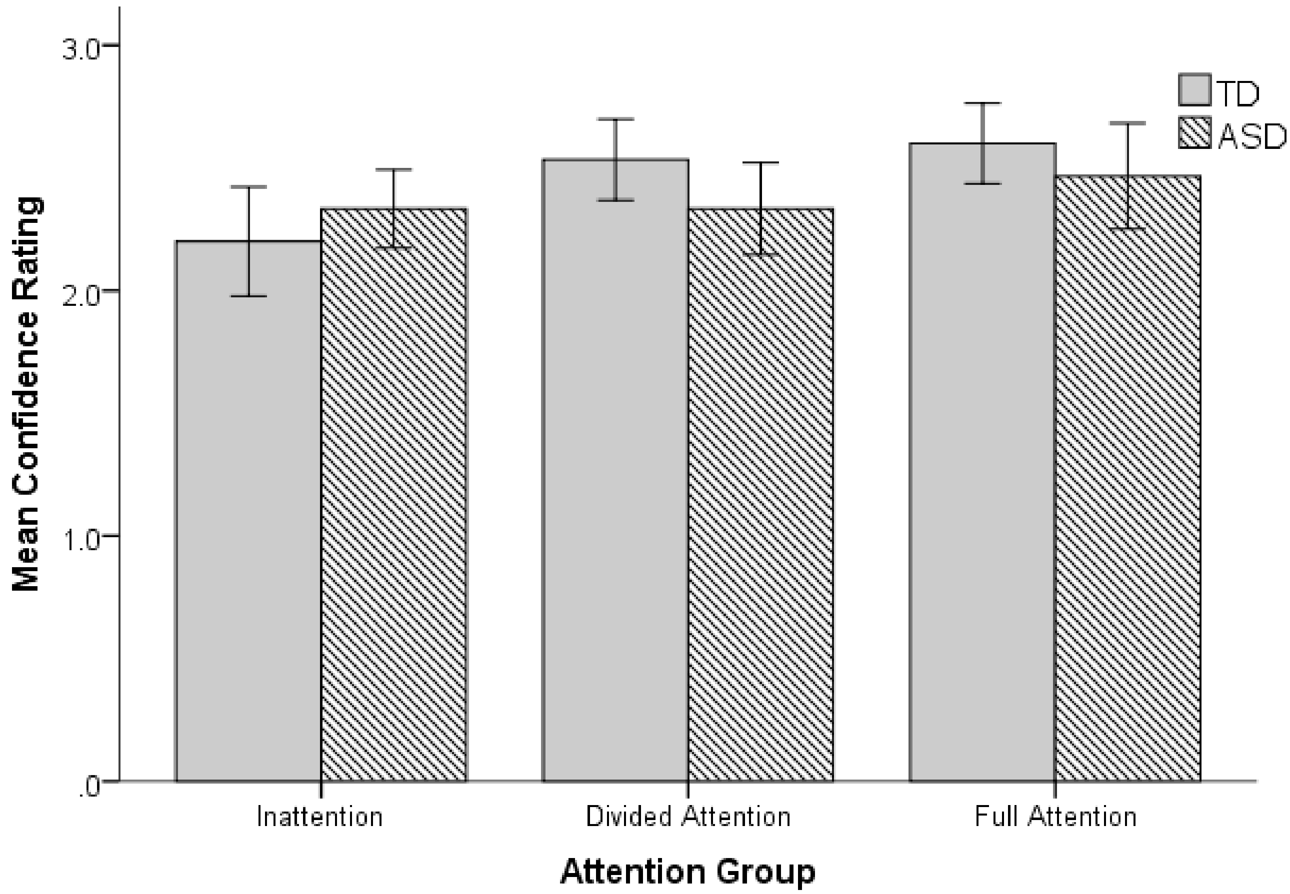
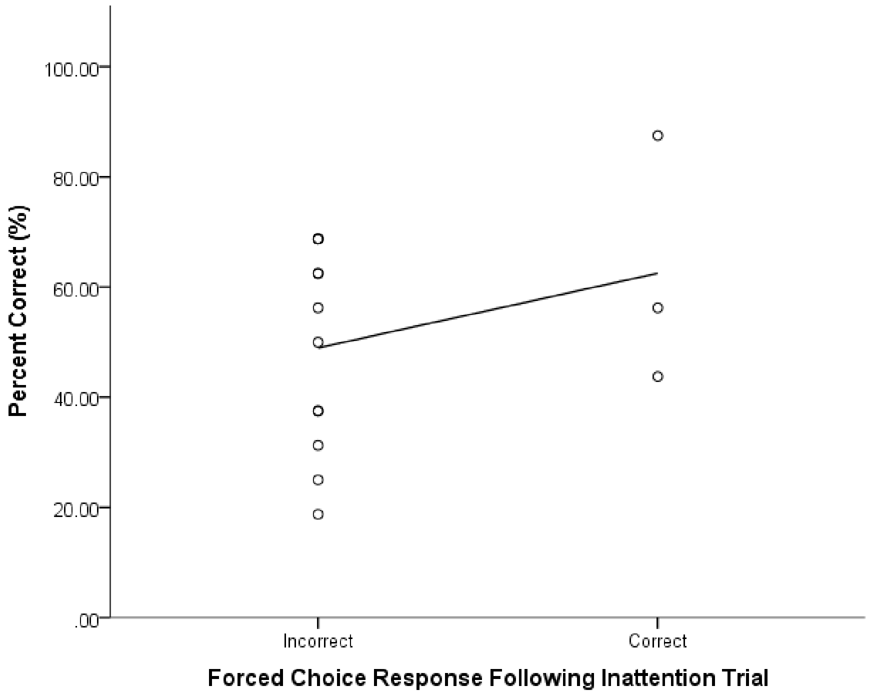


Figure 7. Attention Trials: Confidence Ratings. Error bars represent SEM.

A



B

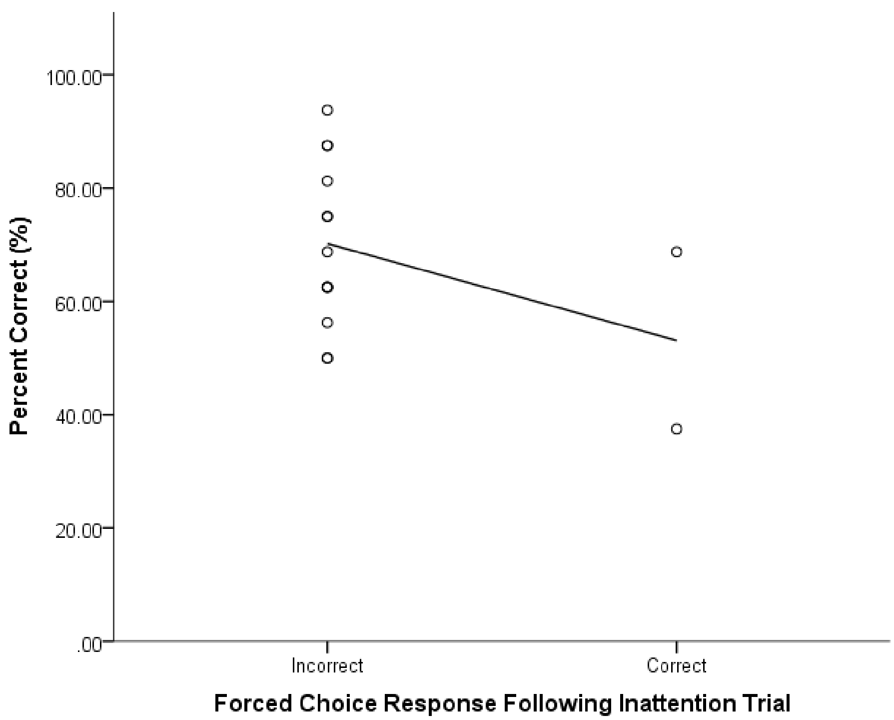


Figure 8. Correlation Between Forced-Choice Question and Experience of the Illusion. No significant relationship between these two variables were observed for the TD group (A) or ASD group (B).

Discussion

The Perceptual Grouping Task examined susceptibility to the Ponzo illusion at preattentive levels of visual processing in individuals with ASD and compared those results to TD individuals. Results showed that individuals in the TD group were susceptible to the Ponzo illusion, as indicated by their responses in which the line segment that was closer to the converging end was reported as longer than the line segment that was farther from the converging end, while individuals with ASD did not show this same susceptibility and were equally as likely to choose either of the two line segments in the pattern matrix trials. These results suggest that the Gestalt principle of grouping by similarity occurred for individuals in the TD group, since perceiving the Ponzo illusion required individuals to perceptually group the black dots together to form a pattern of converging lines. Individuals with ASD did not appear to be influenced by the pattern in the background, which may indicate difficulties in Gestalt perception at preattentive levels, as shown by a lack of grouping by similarity.

These results are supported by previous research showing that individuals with ASD are less likely to be susceptible to visual illusions. Happé (1996) and Ishida et al., (2009) found that children with ASD were less likely to succumb to visual illusions than other TD children, suggesting abnormalities in integrating visual information in low-level processing. Similarly, Bolte et al. (2007) showed that adults with high-functioning ASD process Gestalt stimuli less in accordance with Gestalt laws and succumb to visual illusions less than TD individuals, suggesting that decreased Gestalt perception in individuals with ASD is associated with a local visual processing bias. It has been well established that grouping based on Gestalt principles is necessary to perceive global structures made up of individual local elements (Han & Humphreys, 1999; Han, Humphreys & Chen, 1999; Zaretskaya, Anstis & Bartels, 2013). Thus, difficulties in

Gestalt perception may explain why individuals with ASD have issues with global processing very early in perception. Problems with global processing at preattentive levels would result in a more locally focused form of visual processing, allowing individuals with ASD to see the local elements of a visual scene for what they really are, which would decrease their susceptibility to visual illusions. Considering the various models proposed to explain the Ponzo illusion may help explain how global processing is affected in ASD.

Cognitive Models and the Ponzo Illusion

Several models have been proposed to explain how visual illusions are processed in the TD brain, which may help determine where deficits lie in visual processing in the autistic brain. One account is Gregory's theory of inappropriate constancy scaling (1963). In three-dimensional space, visual information is filtered so that objects that are closer are perceptually reduced and objects that are further away are perceptually enlarged. When three-dimensional objects are viewed as flat, two-dimensional projections, our minds simulate depth cues based on our three-dimensional viewing experience, causing us to perceptually expand the parts of figures corresponding to distant objects and perceptually reduce parts corresponding to closer objects (Gregory, 1963). In the case of the Ponzo illusion, the converging lines drawn in two-dimensional space correspond with a typical three-dimensional representation of our visual environment, such as a hallway or a set of railroad tracks with the converging lines receding into the distance. These converging lines induce depth cues, which causes the perceptual system to treat the two-dimensional representation inappropriately as a three-dimensional view. As a result, the upper horizontal line appears as further away than the lower one, causing it to be perceived as longer. Based on this theory, the reduced susceptibility to the Ponzo illusion in individuals with ASD may be due to an inability to perceive the two-dimensional illusion as three-dimensional.

The integration field theory (Pressey & Epp, 1992) focuses on the contextual elements between the two horizontal lines. According to this theory, the center of the attentive field is located between the two horizontal lines. This theory proposes that it is the nature of the binding of these elements – as opposed to contextual elements outside of the attended field – that causes the two lines to be perceived as different. Since the horizontal line segment at the converging end appears closer to the converging oblique lines, it will be overestimated in length compared to the other horizontal line segment. This theory would suggest that individuals with ASD have difficulties binding the elements together to perceive that the line segment at the converging end is closer to the oblique lines.

The tilt-constancy theory (Prinzmetal et al., 2001) proposes that the Ponzo illusion is caused by the misperception of orientation induced by local visual cues. This is due in part to the tilt induction effect, in which a vertical line placed overtop of two parallel lines slanted to either the right or left appears as slightly slanted in the direction opposite to the parallel lines. In the case of the Ponzo illusion, connecting the ends of the horizontal line segments to perceptually form two vertical lines (rather than two horizontal lines) would cause a tilt induction effect, making the edge of the perceived vertical line segment closest to the converging end appear as slanted slightly outward from the bottom edge. The consequence of this misperception of the location of the endpoints is that the horizontal line segment closer to the converging end appears as longer than the other line segment, giving rise to the Ponzo illusion. Since individuals with ASD are not susceptible to the illusion, this suggests that they may show deficits in the mechanism responsible for inducing the tilt induction effect. All of these theories suggest potential explanations for reduced illusion susceptibility in ASD, and demonstrate the various mechanisms that may drive Gestalt perception. Further examination of neural mechanisms responsible for perception of the Ponzo illusion will help to determine the cognitive operations affected in ASD, leading to a better understanding of how visual illusions are processed.

Orientation and the Ponzo Illusion

When the illusion trials were separated according to the orientation of the illusion (whether the lines converged at the top or bottom of the screen), it was found that TD individuals were significantly more affected by the illusion when the lines converged downwards, while individuals with ASD did not show susceptibility to the illusion in either orientation. These results are contrary to what has been shown in research examining the effects of orientation on visual illusion susceptibility, which has found that TD individuals are most susceptible to the Ponzo illusion when the lines converge upwards (Brislin, 1974; Leibowitz et al., 1969; Miller, 1997). This has been explained by the inclination to use depth cues and linear perspective cues to make judgments in one's visual environment (Gregory, 1963). When the lines converge upwards, this produces the greatest magnitude of perceived depth, while lines converging downwards the least (Miller, 1997). This is in part due to the tendency to perceive details that are placed higher in the visual field as more distant than details appearing lower. Based on this reasoning it would be expected that TD individuals would be more susceptible to the Ponzo illusion when the lines converge upwards since the line segment closest to the converging end would be perceived as further away than the other line segment both because of its placement at the point where the two lines converge and its placement higher in the visual field.

The fact that our results showed a stronger susceptibility to the illusion when the lines converged downwards rather than upwards might be partly attributable to differences in stimulus presentation and methodology. In this study, the black dots in the background first needed to be grouped by similarity to form the converging lines, and then these grouped lines needed to be integrated with the rest of the presented stimuli (the two horizontal lines) for the illusion to be perceived. Other visual illusion studies tend to show the converging lines as solid black lines (Happé, 1996; Hoy et al., 2004; Ishida et al., 2009; Ropar & Mitchell, 1999, 2001), removing the added cognitive demand of first grouping the dots together to perceive the converging lines. Similarly, differences in methodology may have also affected the results. Most, if not all, of the research on visual illusions and orientation have required participants to make some form of a line judgment in which they are aware of and can observe the converging lines used to induce the illusion (Kincade & Wilson, 2000; Miller, 1997; Pressey & Epp, 1992; Prinzmetal et al., 2001; Schiffman & Thompson, 1978). This study examined illusion susceptibility at preattentive levels, as participants were unaware of the illusion patterns formed in the background and were required to make line judgments after only seeing the line segments for a very brief period of time (250 ms). Since participants were still found to be susceptible to the illusion, this suggests that overall illusion susceptibility may occur preattentively, but orientation differences may not be as apparent until higher-order attentional processes are engaged.

Preattentive Processing

To ensure that the illusion was being processed preattentively, a point-biserial correlation was carried out to show that the bias to report that the line consistent with the illusion is longer in the illusion block was unlikely due to participants noticing the pattern. In both groups, participants who indicated that they noticed a pattern when asked the forced-choice question following the inattention trial in block 3 were no more likely to show susceptibility to the illusion than those who indicated that they did not noticed a pattern.

Previous research confirms our finding that Gestalt grouping occurs without attention in TD individuals, thus causing illusion susceptibility at preattentive levels of perceptual processing (Moore & Egeth, 1997; Shomstein, Kimchi, Hammer & Behrmann, 2010). Although participants in the TD group showed illusion susceptibility on the pattern matrix trials in block 2, the patterns could not be recalled for subsequent report, as shown by a high percent of inaccuracy in reporting which pattern was seen when asked after the inattention trial in block 3. It is possible that the patterns were never successfully encoded in memory (Moore & Egeth, 1997). However, it is unlikely that the inability to identify the pattern was due to issues in the way the stimuli were presented because participants showed increased accuracy in identifying the patterns following the divided and full attention trials.

Individuals in the ASD group also showed a high percent of inaccuracy in reporting which pattern they had seen following the inattention trial in block 3, which is likely due to difficulties grouping by similarity during preattentive levels of processing. If these individuals were not able to perceive the illusion in the first place, then it makes sense that they would have a hard time identifying the pattern in the background. Similar to TD individuals, individuals with ASD were also able to more correctly identify the background pattern of the divided and full attention trials, which was coupled with increased susceptibility to the illusion in the inattention and divided-attention trials. This could be indicative of grouping by similarity occurring in individuals with ASD as more attentional processes are required to carry out the task. Previous research supports this notion (Hayward et al., 2012; Koldewyn, Jiang, Weigelt, & Kanwisher, 2013; Plaisted et al., 1999), suggesting that Gestalt perception may be occurring later in the visual stream for individuals with ASD. While TD individuals can use Gestalt perception preattentively, perhaps individuals with ASD show different perceptual organization, requiring attentional processes to be recruited in order for Gestalt perception to occur. Although more research is needed to determine if this is the case, since only one divided attention and one full attention trial were included in the study design, this finding may also help to address some of the inconsistencies in ASD related research involving visual illusions.

Inconsistencies in ASD Related Visual Illusion Research

Previous examination of illusion susceptibility in individuals with ASD has yielded mixed results. Research on the processing of visual illusions has shown that compared to TD individuals, individuals with ASD are just as susceptible to visual illusions (Hoy et al., 2004; Ropar & Mitchell, 1999, 2001), while other research has shown that individuals with ASD are resistant to visual illusions (Bolte et al., 2007; Happé, 1996; Ishida et al., 2009). Part of this may be attributed to the way the illusions are presented, which could influence the degree of susceptibility to the illusion. Some studies show the horizontal line segments between the converging lines (Happé, 1996; Hoy et al., 2004), while other studies have shown the horizontal line segments at the converging end of the illusion as connected to the oblique lines (Ishida et al., 2009), or surpassing the oblique lines (Chouinard et al., 2013; Walter et al., 2009). Some studies even used circles rather than horizontal line segments as comparison stimuli (Ropar & Mitchell, 1999, 2001). Thus, it is possible the susceptibility to the illusion is affected by the way the illusion stimuli are presented.

Another explanation may relate to the types of visual illusions studied, and how these results have been interpreted. Although previous work has examined a variety of illusions, conclusions tend to be generalized across all illusions, and illusion susceptibility is determined based on whether or not individuals succumbed to the majority of visual illusions tested. As a result, global processing tends to be treated as a singular construct, suggesting that all visual illusions evoke similar cognitive responses. For example, Walter et al. (2009) compared susceptibility to illusions with the Autism Quotient (AQ), which is a scale that measures the degree to which TD adults show autism-related traits, concluding that there is no relationship between AQ and illusion susceptibility. However, prior to correlating results the illusion susceptibility measures were first aggregated across illusions treating the visual illusions as one construct, which may have masked the effect of illusion susceptibility for specific illusions. Chouinard et al. (2013) performed a similar correlation between illusion susceptibility and AQ but did not aggregate the illusion measures and found that susceptibility to the Müller-Lyer illusion but not the Ebbinghaus and Ponzo illusions decreased as a function of AQ, suggesting that different cognitive operations underly the processing of different visual illusions. If the perceptions of different visual illusions are driven by different cognitive operations, then generalizing results across visual illusions will not be the most informative way of addressing global processing deficits in ASD.

Inconsistencies in research may also be explained by the amount of attention focused directly at the visual illusion. Studies have shown that individuals with ASD will process stimuli in a global nature when their attention is directed to it during selective attention tasks (Hayward et al., 2012; Koldewyn, Jiang, Weigelt, & Kanwisher, 2013; Plaisted et al., 1999), but tend to show a reduced preference for global processing when given a choice in divided attention tasks (Koldewyn et al., 2013; Plaisted et al., 1999). Thus, the amount of attention directed towards the visual illusion may determine whether or not individuals with ASD show susceptibility to the illusion. If individuals with ASD are instructed to use methods of adjustment to compare lines and circles overlaid on the illusion inducing stimuli to make them appear to be the same size, as in the study by Ropar and Mitchell (1999; 2001), then it is likely they will have recruited some forms of attentional processes towards the illusion inducing stimuli when performing the task, which may result in the recruitment of global processing strategies and increased susceptibility to the visual illusion. However, if individuals are required to make quick categorical judgments, as in the study by Happé (1996) where individuals were simply asked whether two lines were the same length, they will likely have recruited less attentional processes, adopting a more locally focused processing strategy, which may be responsible for their decreased susceptibility to the illusion. As a result, the amount of time and attention paid to the illusion may affect the degree of susceptibility. In this study, participants were required to make quick categorical line judgments without being aware of the illusions presented in the background, testing their susceptibility to the illusions at a preattentive stage of visual processing. Results showing that individuals with ASD are not susceptible to the illusion at a preattentive level, but appear to become more susceptible to the illusion as more attentional processes are recruited, support the weak central coherence theory, suggesting that coherence may be lacking at low levels of the visual processing stream for these individuals with ASD.

Weak Central Coherence and the Ponzo Illusion

The ability to perceive visual illusions is influenced by our experience with the world (Gregory, 1963). Although visual illusions provide a distorted view of ones visual environment, they should be viewed as more of an adaptation of our visual processing abilities rather than a malfunction. Segall et al. (1963) demonstrated this adaptation of visual processing abilities in a classic study examining illusion susceptibility across different cultures, showing that susceptibility the Müller-Lyer, Sander-parallelogram, and horizontal-vertical illusions were either absent or reduced in indigenous African tribes living in circular huts. Since the African tribes had minimal exposure to a world filled with horizontal and vertical lines coming together to create angles, such as what is the foundation of many Western buildings, rooms, houses and furniture, the linear perspective cues and depth cues required to perceive the illusions were missing from their visual repertoire (Segall et al., 1963). This suggests that some prior knowledge of the "rules of how the world operates" is required in order to integrate local elements to form a Gestalt. These "rules" require an understanding of Gestalt perception, which are necessary to perceive visual illusions. Since the processing of visual illusions and Gestalt perception are both considered early preattentional functions (Happé, 1996; Duncan & Humphreys, 1989), the results from this study showing an absence in illusion susceptibility in individuals with ASD suggests that abnormalities in perceptual processing are already appearing early in perception, providing evidence for the Weak Central Coherence account.

Neuroimaging studies have provided evidence for the Weak Central Coherence theory, showing that neural activation in the primary visual cortex during the presentation of illusions correlates with the perceived rather than the retinal size of the image (Fang et al., 2008; Murray et al., 2006; Schwarzkopf et al., 2011). If visual processing solely relied on bottom-up processing, then when information is sent from the retina to the cortex, two identical objects of the same size should activate the same cortical areas. However, research has shown that object size is perceived in relation to contextual cues in the surrounding environment, suggesting that feedback from higher visual areas also contributes to the visual perception of objects in the environment. More specifically it has been shown that the retinotopic representation of an object in area V1, one of the earliest stages in the visual system, changes according to an objects perceived size such that objects that are perceived as further away and appear to make up a large portion of the visual field activates a larger area of V1 than an object that appears to be closer and smaller (Fang et al., 2008; Murray et al., 2006). Consistent with these findings, Schwarzkopt et al., (2011) have found that the surface area of V1 predicts inter-individual differences in visual awareness of size, thus extending previous research to demonstrate a relationship between subjective experience and cortical organization. In order to perceive the size of an object, depth cues responsible for perceiving the size difference must be extracted from linear perspective and texture cues, which are processed beyond area V1 in higher visual areas (Fang et al., 2008; Murray et al., 2006). This supports the weak central coherence theory because linear perspective and texture cues must be integrated together to form an overall perception of the environment, from which depth cues can then be extracted. Thus, top-down modulation may help explain how object size is perceived at such a low-level of processing.

Studies examining the magnocellular pathway **(**Milne et al., 2002; Spencer et al., 2000; Sutherland & Crewther, 2010) has helped to explain this modulatory mechanism, and to provide further evidence for the weak central coherence theory to explain perceptual differences in autism. This pathway is more sensitive to the processing of low spatial frequencies, like visual illusions, (Merigan & Maunsell, 1993) and has a faster conduction speed than its counterpart, the parvocellular visual pathway (Livingstone & Hubel, 1988; Schroeder et al., 1989). It is able to rapidly process visual information, sending signals from early visual areas to higher regions of the visual processing stream and back again in enough time to influence one's visual experience, before information from the parvocellular stream has even been processed (Bar, 2004). This has been coined as 'the magnocellular advantage' (Laycock et al., 2007) and is thought to be important for integrating global information sent from the retina to early dorsal stream areas of the cortex back to areas V1 and V2, which allows for visual signals to become further integrated for ventral stream recognition processes (Sutherland & Crewther, 2010). The importance of the magnocellular advantage has been demonstrated by Sutherland and Crewther (2010), who showed that TD individuals scoring high on the AQ (ie: more tendency to show Autistic traits) also showed a delay in primary visual processing of magnocellular input, diminishing the advantage of its early arrival to the primary visual cortex. This was found to be associated with impaired global visual perception, and suggests that the delay in magnocellular processing found in individuals with high AQ decreases the ability to perceptually benefit from top-down modulation associated with the magnocellular advantage.

Taken together, these studies indicate that size perception is influenced by differences in brain structure (Fang et al., 2008; Murray et al., 2006; Schwarzkopt et al., 2011) and that abnormalities in the magnocellular pathway may explain deficits in global processing in individuals with ASD (Sutherland & Crewther, 2010). Thus, decreased susceptibility to visual illusions in individuals with ASD may be explained by difficulties in Gestalt perception arising from differences in brain architecture. However, these studies focus on illusions relying on size perception, and the neural underpinnings of global processing for different types of visual illusions still have yet to be identified with fMRI. If different visual illusions are driven by different cognitive mechanisms, and if some of these mechanisms but not others are affected in ASD, then future studies using visual psychophysics combined with fMRI are necessary to provide further neurological insights into how global processing is affected in ASD.

Future Research

Future studies examining how Gestalt perception is affected in individuals with ASD under conditions requiring more attention, such as divided attention and full attention trials, as well as using different types of visual illusions will help increase our understanding of cognitive functions responsible for local and global processing in ASD. Relating these results to neurobiological measures will also help to clarify the physiological basis of Gestalt perception and local processing in ASD, extending our knowledge of perceptual organization in the human visual system. This research is important because if individuals with ASD do fail to integrate information at low levels of the visual processing stream, then it will be necessary to integrate the knowledge of these perceptual abnormalities into the way behavioral therapies and interventions are administered to individuals with ASD.

Conclusion

In summary, these results suggest that individuals with ASD are not susceptible to the Ponzo illusion at preattentive levels of visual processing. Although TD individuals were not able to report which pattern they saw on inattention trials, their behavior was still influenced by the pattern presented on the screen. In contrast, line judgments were not influenced by the pattern on the screen for individuals with ASD, suggesting that Gestalt perception is impaired at preattentive levels. These results reveal that the way visual scenes are processed preattentively differs between TD and ASD individuals, which in turn affects how attention is allocated within the scene. This supports the weak central coherence theory, indicating a lack of coherence at low levels of the visual processing stream for individuals with ASD.

CHAPTER IV

VIEWING WINDOW PARADIGM

Experiment 2 was designed to evaluate the parts-based visual processing strategies of individuals with ASD using a paradigm developed in-house called the *Viewing Window* (Baugh & Marotta, 2007). This paradigm assessed the visual processing strategies of individuals with ASD when only a restricted view of an object was available. By using a focus-window, which limits the viewer to a small part of the image at a time, it was expected that all participants used a parts-based processing strategy. Participants were shown blurry objects and were required to either actively move a small focus-window showing the underlying object in perfect clarity over a computer screen to try to identify the object, or passively watch the scan patterns of a typically developing individual who completed the task previously. Since individuals with ASD tend to show problems in global, but not parts-based processing, this paradigm was able to assess how these individuals process objects in their environment using local processing strategies, and how their processing strategies may differ from those of typically developing individuals.

Previous research has established that individuals with ASD tend to focus on local, parts-based processing. This has been demonstrated in tasks requiring parts-based processing strategies such as the block design task of the Wechsler Intelligence test (Shah & Frith, 1993), the hidden figures task (Jolliffe & Baron-Cohen, 1997) and visual search task (O’Riordan et al., 2001; Plaisted et al., 1998b). However, the precise nature of these atypicalities in processing remains unclear. It has been suggested that individuals with ASD are impaired in their ability to process global information, showing a deficit or disability in global processing (Behrmann et al., 2006; Frith & Happé, 1994; Happé & Frith, 1996; Happé & Booth, 2008). Contrary to this notion, it has been suggested that these individuals show enhanced local processing abilities

(Mottron et al., 2003, 2006; Plaisted et al., 2003), and/or a bias or default preference towards local processing (Happé & Frith, 2006; Plaisted et al., 1999). This has also been characterized as a disinclination rather than a disability in global processing (Koldewyn et at., 2013). The Viewing Window is a novel way to assess these atypicalities in visual processing by looking at the visual processing strategies of individuals with ASD and how they compare to typically developing individuals.

Since the *Viewing Window* paradigm (Baugh and Marotta, 2007) forces individuals to rely on parts-based processing strategies to identify the objects, the local processing strategies used by these individuals as they move the window around the screen to identify the object can be determined. In order to accurately identify the object, the "parts" of the object seen through the clear window must be integrated to form a coherent "whole". If individuals with ASD have difficulties identifying the objects, this may suggest impairments in integrating the parts of the object seen through the window into a complete representation of the object. Accurate identification of the objects would suggest intact integration mechanisms in object perception. Visual processing strategies were evaluated by comparing an individual's ability to accurately identify the objects during a condition in which they can create their own scan path to a condition requiring them to watch a pre-determined scan path of a typically developing individual. It was hypothesized that if individuals with ASD and typically developing individuals used similar processing strategies, then they would show similar performance in accuracy and response time in both conditions. However, if individuals with ASD used different processing strategies compared to typically developing individuals, then it was hypothesized that they may show difficulties identifying the objects in the passive condition. Since previous research has shown that individuals with ASD tend to use different processing strategies in face processing compared to those of typical controls (Pelphrey et al., 2002; Spezio, Adolphs, Hurley, & Piven, 2007; Riby and Hancock, 2008), it was expected that this might be the case for object recognition as well.

Experiment 2

Stimuli. In each condition, participants were presented with 40 different common and easily identifiable objects. Pilot work has shown these objects to be equally identifiable in both young and aged participants while using the viewing window paradigm (Baugh, 2010), thus item specifics were not considered to confound this study. Four of these objects were used for practice trials so that correct use of the touchscreen could be established, while the remaining 76 were used for the experimental trials (Table 1). In order to ensure that none of the objects were recognizable without the use of the viewing window, each object was blurred by converting digital images (1024 x 768 resolution) of the objects into a greyscale format presented on a grey background. This also removed any potential color information that may have been present. A Gaussian blur algorithm was then used to modify each image so that no object could be identified based on the peripheral information presented alone (Baugh & Marotta, 2007).

Table 1. Viewing Window Object Stimuli.

Practice Items:			
Harmonica	Phone	Remote Control	Typewriter
Experimental Items:			
Razor	Kiwi	Corkscrew	Pumpkin
Spoon	Scissors	Vicegrips	Lightbulb
Pencil	Tape Measure	Lipstick	Pepper
Screwdriver	Apple	Diamond Ring	Watering Can
Pen	Fork	Coffee Cup	Banana
Cowboy Boot	Electric Guitar	Yarn	Work Gloves
Dice	Lemon	Tambourine	Walnut
Pushpin	Notebook	Muffin	Envelope
Shoes	Laptop	Timer	Wrench
Pocket Watch	Floppy Disk	Rolodex	Paperclip
Stethoscope	Drill	Hole Punch	Water Jug
Top Hat	Three Hole Punch	Binder Clip	Toothbrush
Lighter	Tape Dispensor	Wrist Watch	Toaster
Sunglasses	Piggy Bank	Stapler	Hardhat
Mallet	Camera	Clamp	Shirt
Strawberry	Office Chair	Frying Pan	Safety Pin
Highlighter	Dagger	Lamp	Tomato
Hairbrush	Teapot	Saw	Beer
Potato Peeler	Pills	Pencil Sharpener	Eye Glasses

The Viewing Window. Objects were shown in the center of the monitor, taking up as much of the viewable surface as possible. The “window” consisted of a small circular region displaying the underlying image in normal clarity and was constructed in such a way that at its outermost region it showed the underlying image at full blur and the innermost region at normal clarity, using a smooth Gaussian based transition between these two regions (Figure 9). This allowed for the participant to have a more natural viewing experience (for a complete description of the viewing window, see Baugh & Marotta, 2007).

Procedure. Participants either actively moved a small circular “window” that displayed the underlying image in normal clarity, or passively watched the “window” move along a predetermined path. Participants were tested on a 15” IBM Tablet PC, seated approximately 50 cm from a touch-sensitive monitor running at a resolution of 1024 x 768 at 60Hz.

Prior to beginning the experiment, participants were given verbal instructions, and correct use of the touchscreen and viewing window were demonstrated by the experimenter. In the active viewing condition participants were told that they could move the window around on the screen using a stylus held in their dominant hand, which would show the underlying image in perfect clarity. A stylus was used to ensure that enough pressure was being maintained on the touch-screen surface, and to prevent smudges on the screen. To avoid obstruction of the image, the tip of the stylus corresponded with the bottom of the image. In the passive viewing condition, participants were instructed to watch the window move along a predetermined path. This predetermined path consisted of the scan pattern of a typically developing individual who had previously completed the task. The predetermined path was set to loop continuously until the participant indicated that they were ready to make a response. In each of the two conditions, participants were instructed to identify the object as quickly but as accurately as possible, and to indicate their response by pressing the "Enter" key on the keyboard. Participants were also told that for cases in which the object was difficult to figure out, to take a "best-guess" or to type "don't know" in the response box. Following this indication, the stimulus was removed from the screen and a response box appeared with a message prompting the participant to type their answer in the box, pressing "Enter" when finished. After pressing enter, the next trial began. Participants were not given any feedback or accuracy and were told to complete the experiment at their own pace. In total, 80 objects were presented (40 per condition), and each object was presented only once.

Upon completion of the active and passive viewing tasks, participants were also asked to identify each of the images presented in normal clarity. Participants were presented with each image one at a time, and instructed to identify the object by pressing the enter key, which took them to a response screen where they typed in their response. If unable to identify certain objects in the Viewing Window paradigm, this clear identification task indicated whether this was because the participant did not know what the image was, or if this was because the participant was unable to accumulate the parts of the image into a coherent whole.

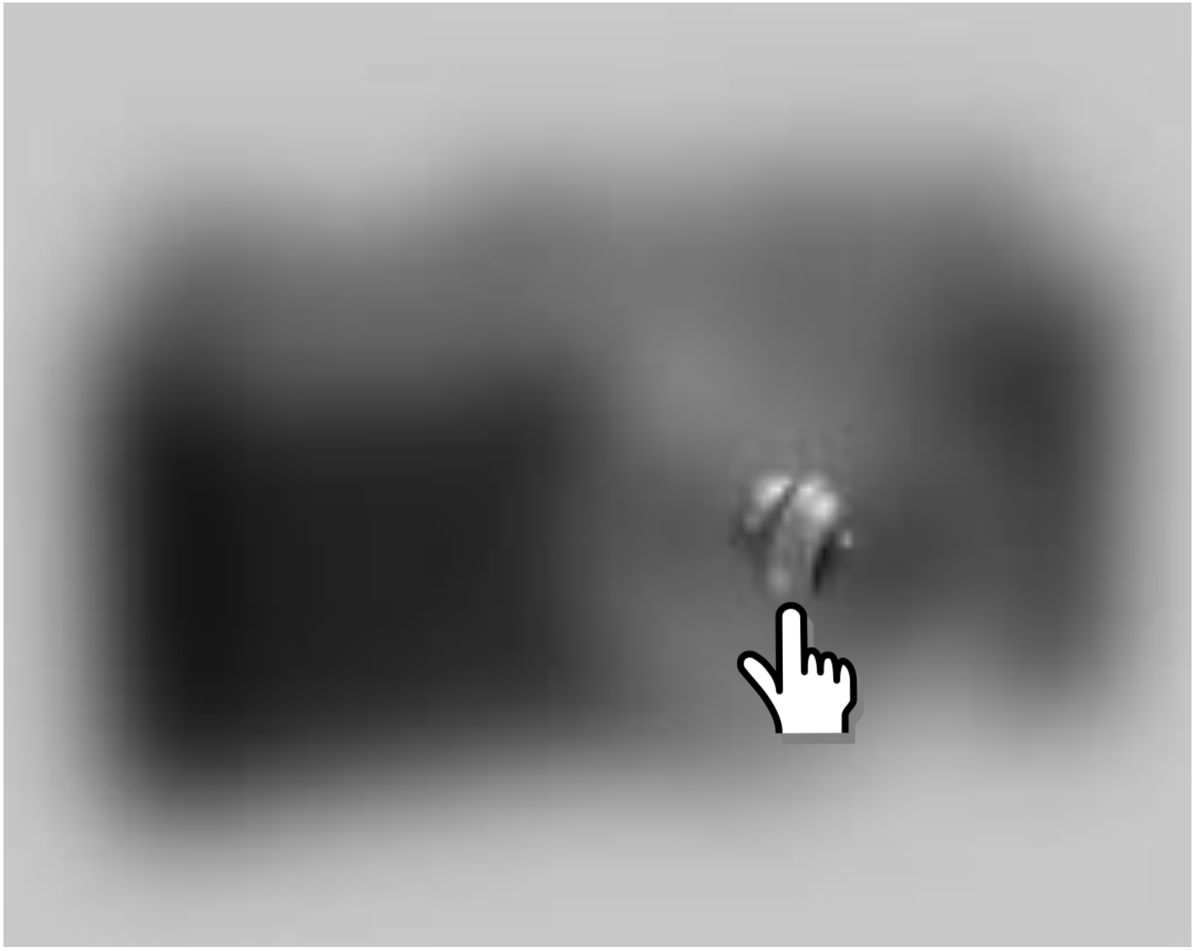


Figure 9. Viewing Window Illustration. The circular viewing window displays the underlying image in normal clarity, while the remainder of the image is blurred.

Results

All analyses were carried out using a repeated-measure analysis of variance (rMANOVA) with an alpha level equal to .05. When indicated as necessary by omnibus tests, corrected (Bonferroni) post-hoc analyses were made. Incorrect responses were omitted from the analysis. This resulted in the elimination of 10.32% of trials for the TD group and 15.89% of trials for the ASD group. On average, individuals in the ASD group made more errors (M = 6.038 words) than those in the TD group (M = 3.923 words), however this difference in accuracy was not significant, [$F(1, 24) = 3.532$, $p = .072$]. No significant difference in accuracy was found when error rates were compared across active and passive conditions, [$F(1, 24) = .028$, $p = .868$] and no group by condition interaction was observed, [$F(1, 24) = .706$, $p = .409$].

The response time (RT) data were separated into three distinct categories: 1) The amount of time taken before movement of the viewing window occurred (pre-movement RT); 2) The amount of time spent moving the viewing window (movement RT); 3) The total amount of time required for identifying the presented object (total RT). A correlational analysis was performed to ensure that pre-movement times did not show a significant, negative correlation with movement times, which would have indicated that diagnostically useful information was present outside of the viewing window region. This correlation was accomplished by calculating mean pre-movement and movement times for each object, and correlating this composite score, resulting in a non-significant result for both the ASD group, ($r(74) = -.056$, $p = .634$) and TD group, ($r(76) = .005$, $p = .966$).

Four separate analyses of the correct response data were conducted. First, participants' viewing window response time was analyzed by evaluating differences in response times across groups and conditions. Next, window movement scanpaths were examined to determine if there were any differences between groups regarding the parts of the objects on which participants fixated. Following the scanpath analysis a boundary analysis was carried out to evaluate the amount of time spent moving the window on the objects compared to off the objects. Finally, a movement analysis was administered to determine the amount of time spend moving and stopping the window while viewing the objects.

Response time. Data was analyzed using a 2 (Group: ASD, TD) by 2 (Condition: Active, Passive) repeated measures ANOVA. Kolmogorov-Smirnov tests of normality indicated that the response time distributions of the active group (ASD: $D_{13} = .235$, $p = .047$; TD: $D_{13} = .261$, $p = .016$) significantly departed from normal: both were skewed to the right. Response time distributions of the passive group (ASD: $D_{13} = .121$, $p = .200$; TD: $D_{13} = .184$, $p = .200$) showed a normal distribution. To reduce skew found in the active data, all response times were log-transformed. Komogorov-Smirnov tests on the log-transformed distributions demonstrated that this transformation was effective in reducing the violation of the normality assumption in the response time data: (Active: ASD: $D_{13} = .176$, $p = .200$; TD: $D_{13} = .204$, $p = .141$; Passive: ASD: $D_{13} = .174$, $p = .200$; TD: $D_{13} = .144$, $p = .200$). Subsequent analyses were therefore performed on log RT's for all groups, through which the assumption of homogeneity of variances was also verified using Levene's Test of equality of error variances (Active: $F(1, 24) = 1.710$, $p = .203$; Passive: $F(1, 24) = 2.846$; $p = .105$).

Results showed intact ability in the participants with ASD for viewing the objects in both the active and passive conditions as indicated by a main effect of condition [$F(1, 24) = 7.251$, $p = .013$]. However, no main effect of group on response time [$F(1, 24) = .678$, $p = .418$] and no significant group by condition interaction [$F(1, 24) = 1.710$, $p = .203$] was found. The main effect of condition (Figure 10) revealed that participants were able to more quickly identify the object when they actively moved the window (ASD: *mean log RT* = 2.17; TD: *mean log RT* = 2.18) compared to passively viewing it (ASD: *mean log RT* = 2.53; TD: *mean log RT* = 2.30).

Scanning pattern. A participant's individual visuomotor scanning pattern (a series of X-axis and Y-axis coordinates directly related to the arm movements used to control the viewing window) was recorded for each object, with a sampling rate of 66 Hz. These coordinates were then parsed into four 800 x 600 pixel quadrants, and the amount of time spent viewing each object in each quadrant was recorded for all participants. The time spent viewing the object in each quadrant was then averaged across participants for each object. Kolmogorov-Smirnov tests of normality indicated that the amount of time spent viewing the objects in each of the 4 quadrants significantly departed from normal: all distributions were skewed to the right. Log transformations of the data were used to reduce the skew, which was effective in reducing the violation of the normality assumption. Subsequent analyses were therefore performed on log-transformed data for all groups.

A 2 (Group: ASD vs. TD) by 4 (Quadrant: Q1, Q2, Q3, Q4) repeated-measures ANOVA by item revealed a significant main effect of quadrant, $F(3, 62) = 50.344$, $p < .001$ and a significant group by quadrant interaction, $F(3, 62) = 10.246$, $p < .001$. However, no significant effect of group ($F(1, 64) = .521$, $p = .473$) was observed. Post-hoc analyses revealed that there were no significant differences between groups at each level of quadrant. Both groups followed a similar pattern of viewing times in each quadrant, and spent a significantly greater amount of time viewing the objects in the bottom right quadrant (Quadrant 2) than any other of the quadrants ($p < .001$) (Figure 11).

Boundary Analysis. A 2 (Group: ASD vs. TD) by 2 (Boundary: In vs. Out) repeated-measures ANOVA by item was used to determine the amount of time spent moving the viewing window on the object (In) compared to off of the object (Out). First, the amount of time that the window was on and off the object was averaged across participants for each object, and then averaged across objects to obtain two aggregated values representing the average time the window was on and off the objects for both the ASD and TD groups separately. The ANOVA revealed a significant main effect of boundary, $F(1, 73) = 82.422$, $p < .001$. However, no significant effect of group ($F(1, 73) = 1.993$, $p = .162$) or group by boundary interaction ($F(1, 73) = 1.842$, $p = .179$) was observed. In both groups, a significantly greater amount of time was spent with the window on the object compared to off of the object (Figure 12).

Since it is possible that time spent on and off the object may be affected by how long it took the participant to start moving the window, and how long it took the participant to press enter to end a trial, the same ANOVA was carried out on the data in which the participant was only moving the window. Results were similar to the analysis on total response time, revealing a significant main effect of boundary, $F(1, 73) = 63.437$, $p < .001$ and no significant effect of group ($F(1, 73) = 3.058$, $p = .085$) or group by boundary interaction ($F(1, 73) = 2.865$, $p = .095$). Both groups showed a significantly greater amount of time was spent with the window on the object compared to off of the object.

Movement Analysis. A 2 (Group: ASD vs. TD) by 2 (Movement: Yes vs. No) repeated-measures ANOVA by item was used to determine the amount of time the window remained static compared to dynamic for each object in each group. Similar to the boundary analysis above, the amount of time that the window was moving and static during each trial was averaged across participants for each object, and then averaged across objects to obtain two aggregated values representing the average time the window was moving and static for both the ASD and TD groups separately. The ANOVA revealed a significant main effect of movement, $F(1, 73) = 36.343$, $p < .001$ as well as a significant group by movement interaction, $F(1, 73) = 4.479$, $p = .038$. However, no significant effect of group ($F(1, 73) = 1.993$, $p = .162$) was observed. In both groups, a significantly greater amount of time was spent moving the window compared to keeping it static (Figure 13).

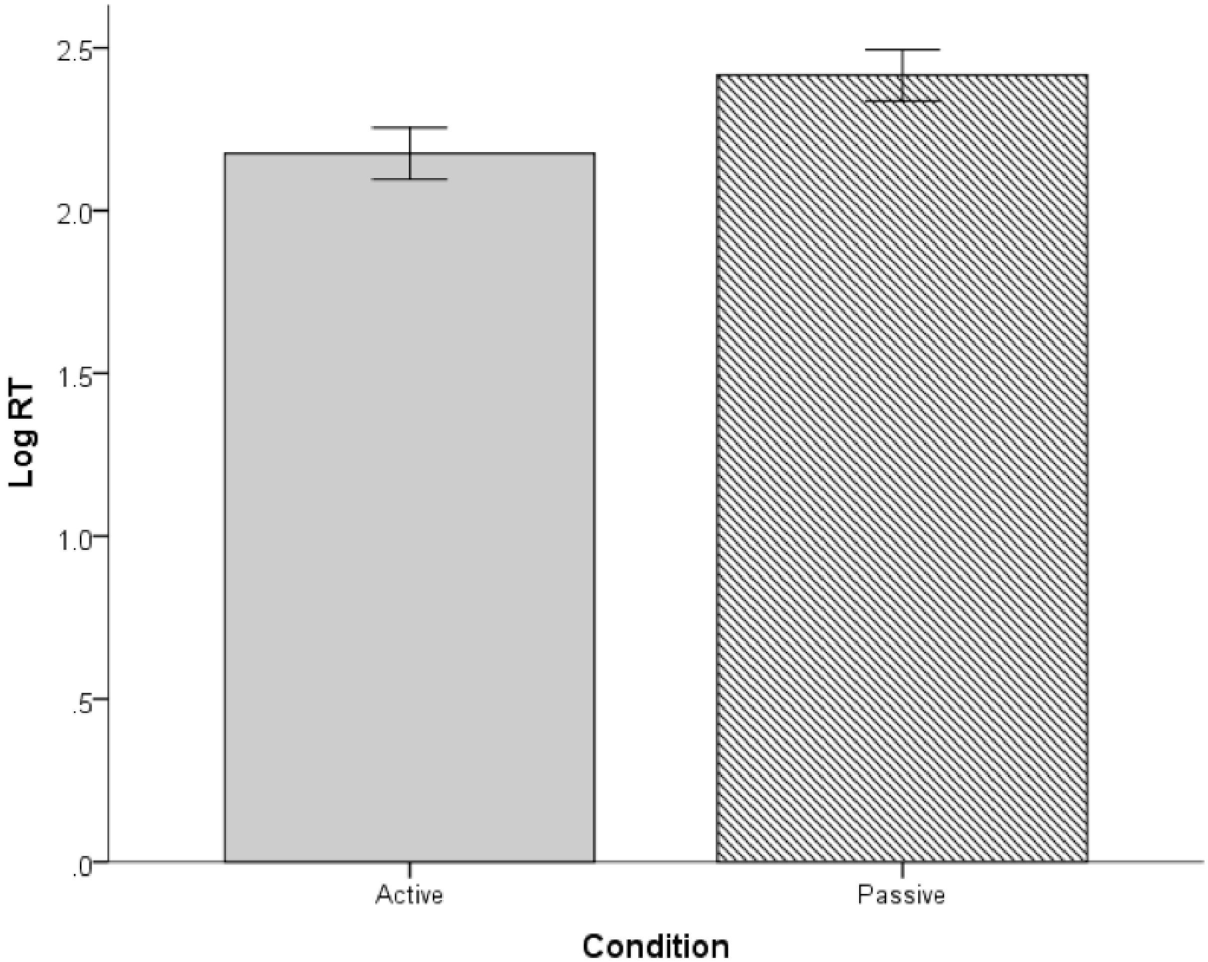


Figure 10. Response Time Analysis. Log RTs in the response time analysis as a function of condition. Error bars represent SEM.

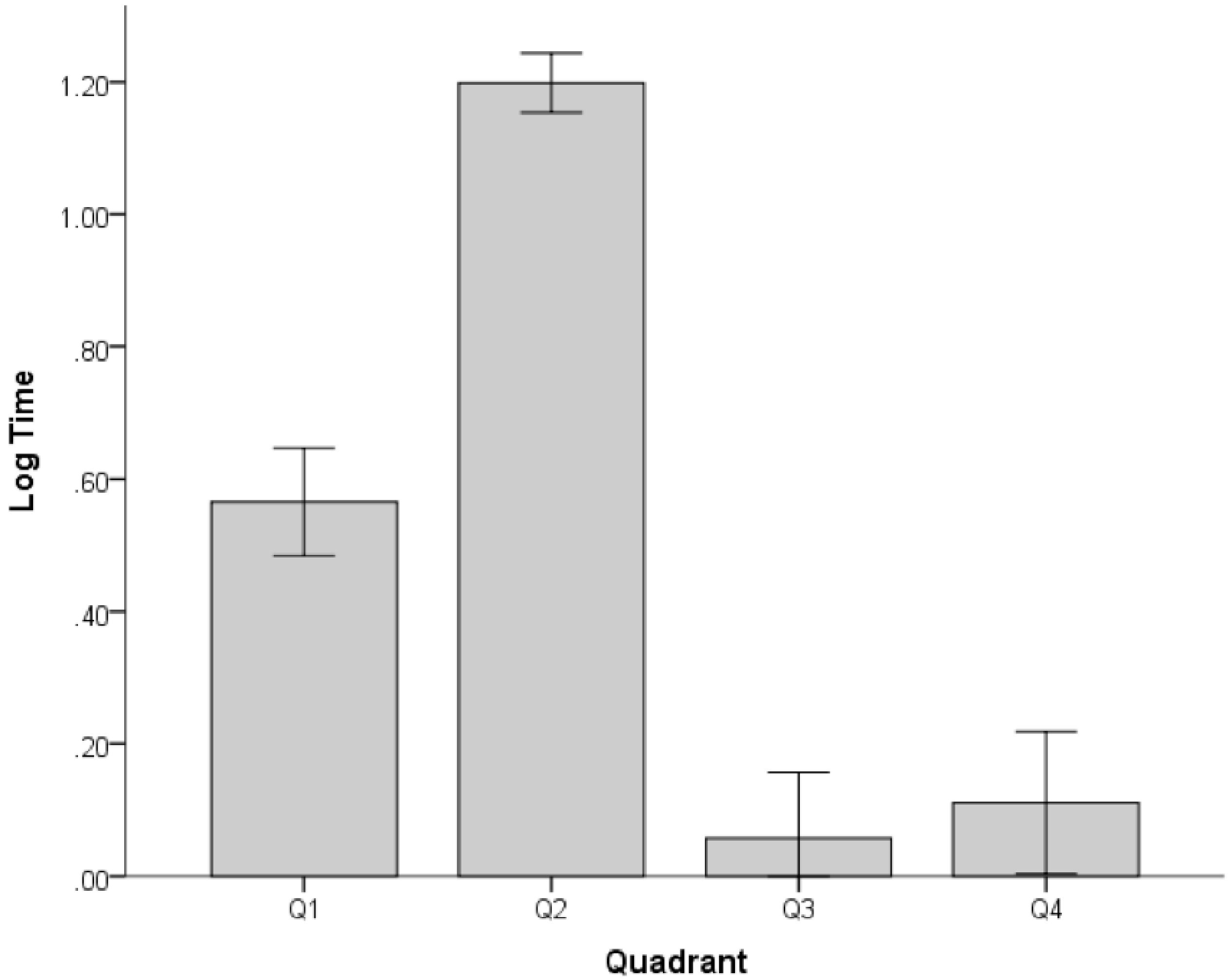


Figure 11. Quadrant Analysis. Log time spent viewing the objects as a function of quadrant. Error bars represent SEM. Quadrants are defined as 1: bottom left, 2: bottom right, 3: top right, 4: top left.

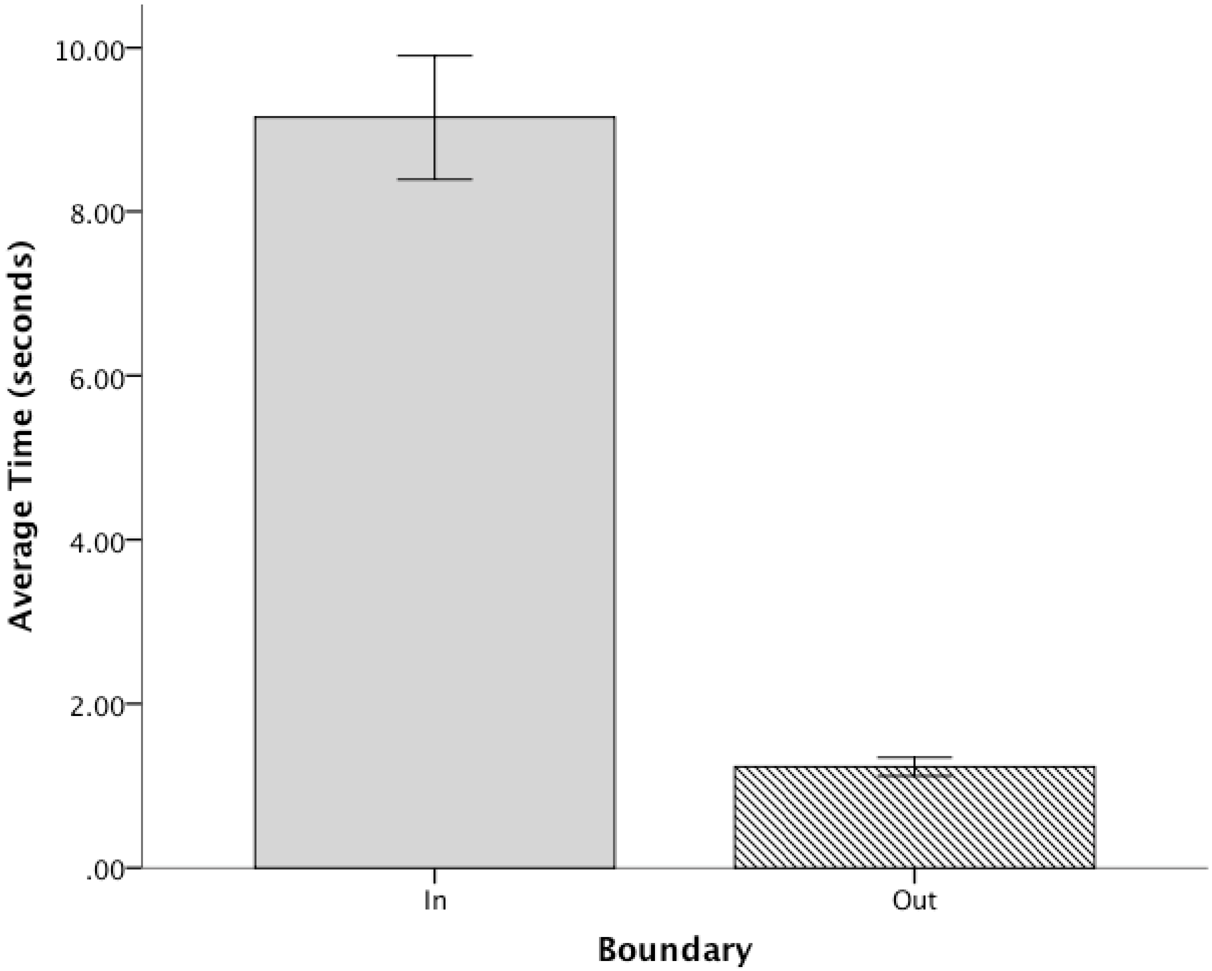


Figure 12. Boundary Analysis. Amount of time (ms) spent moving window on the object (Boundary: In) compared to off of the object (Boundary: Out). Error bars represent SEM.

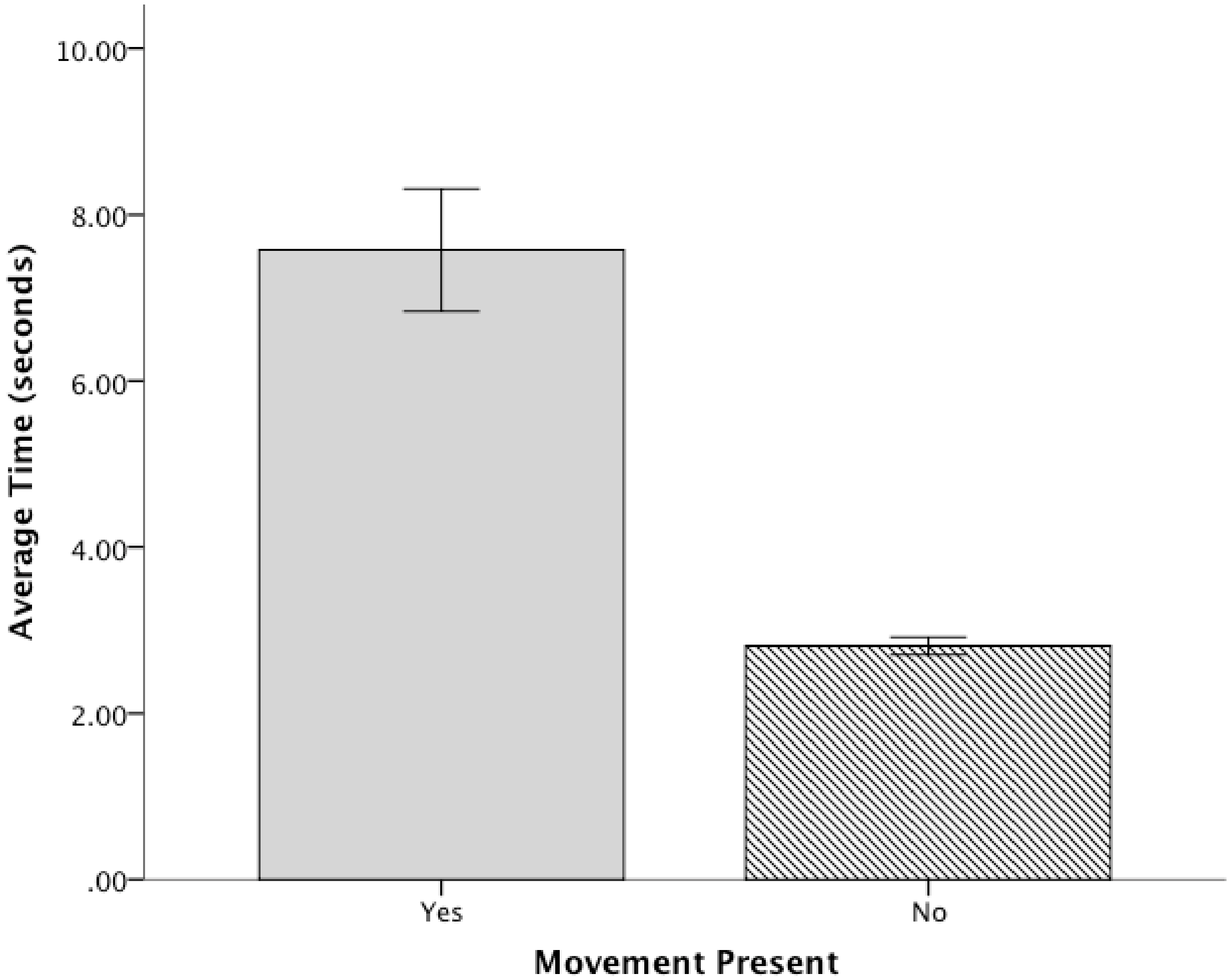


Figure 13. Movement Analysis. Amount of time (ms) spent moving the window (Movement Present: Yes) compared to not moving the window (Movement Present: No). Error bars represent SEM.

Discussion

The Viewing Window paradigm compared parts-based processing strategies of individuals with ASD to TD individuals. Results of this study showed a number of similarities between groups in the way objects are viewed. First, the correlational analysis between pre-movement and movement times showed that for both groups, the information presented outside of the viewing window aperture did not reveal any diagnostically useful information. Less time spent viewing the object in the movement stage was not a result of spending more time viewing the object in the pre-movement stage. Second, the analysis of response time data showed that there were no differences between groups in the amount of time required to identify the object, but that response time did differ according to condition. Both groups showed significantly slower response times in the passive viewing condition than in the active viewing condition. Third, no differences in scan patterns during the active viewing condition were observed between groups. Both groups spent a greater amount of time viewing the objects in the bottom right quadrant (Quadrant 2). When the amount of time spent moving the aperture on versus off the object was compared, it was found that both of the groups spent significantly more time moving the aperture on the object. Finally, analysis of the movement data showed that both groups spent significantly more time moving the aperture compared to keeping it static. These results together suggest that individuals with ASD use parts-based processing strategies that are similar to those of TD individuals.

Face vs. Non-Face Processing of Stimuli

Much has been learned about how individuals with ASD view stimuli in their environment by examining visual attention to human faces. However, less focus has been given to examining visual attention in ASD to non-face stimuli. It is difficult to even infer from face processing studies the types of visual processing strategies that might be associated with non-face stimuli because fundamental differences exist between the perception of faces and objects. As such, visual scanning associated with non-face stimuli in ASD remains a largely unexplored area of visual processing research.

Research on visual processing strategies of face and non-face stimuli in TD individuals suggests that scan patterns used in face processing cannot be generalized to non-face processing. TD individuals use different methods of scanning these two types of stimuli, adopting a more holistic approach for scanning faces (Tanaka & Sengco, 1997), and a more featural approach for scanning non-face stimuli (Biederman, 1987; Tanaka & Farah, 1993; Tanaka & Sengco, 1997). However, it is unclear how well this notion generalizes to individuals with ASD since they tend to show differences in face processing strategies compared to TD individuals, signifying a unique processing mechanism for face processing. Most commonly, individuals with ASD across all ages tend to show diminished fixation on the eyes compared to TD individuals (Hanley, McPhillips, Mulhern & Riby, 2013; Hernandez et al., 2009; Klin, Jones, Schultz, Volkmar & Cohen, 2002b; Norbury, Brock, Cragg, Einav, Griffiths & Nation, 2009; Pelphrey, Sasson, Reznick, Paul, Goldman & Piven, 2002; Rice, Moriuchi, Jones & Klin, 2012; Speer, Cook, McMahon & Clark, 2007), although gaze fixations have been found to vary according to whether the stimulus is a familiar or unfamiliar face (Sterling et al., 2008), dynamic or static (Speer et al., 2007) or when faces are viewed in isolation or in the context of a social scene (Hanley et al., 2013). As a result, face processing mechanisms not only differ from TD individuals, but are highly influenced by the context in which the stimuli are presented. With the variability that ensues from face processing under different conditions, it seems plausible that non-face processing in ASD may also differ from TD individuals. Understanding how individuals with ASD process non-face stimuli will shed light on how visual processing may differ depending on face and non-face stimuli conditions, giving a better indication of whether atypical scanning patterns are elicited by the distinct properties of faces, or are associated with a more generalized visual processing deficit.

Of the limited research that exists on gaze behaviours associated with processing non-face stimuli in individuals with ASD, findings indicate that both individuals with ASD and TD individuals show comparable visual processing strategies of non-face stimuli. McPartland, Webb, Keehn and Dawson (2011) used eye tracking techniques to record gaze behaviours associated with passive viewing of images of human faces, inverted human faces, monkey faces, three-dimensional curvilinear objects and two-dimensional geometric patterns in adolescents with ASD and TD adolescents and found that both groups showed similar patterns of fixation across all stimulus categories. Although they expected to find differences in face processing across groups, their findings were consistent with a small sub-domain of face processing research showing similar gaze behaviours for static face stimuli across groups (Sterling et al., 2008; van der Geest, Kemner, Verbaten & van Engeland, 2002). More importantly, McPartland et al. (2011) found similar gaze behaviours across groups in the viewing of non-face stimuli, suggesting that a similar visual processing mechanism is responsible for viewing non-face stimuli in both individuals with ASD and TD individuals.

However, an eye-tracking study by Anderson, Colombo and Shaddy (2006) that examined gaze behaviours associated with face and non-face stimuli in young children (12 – 72 months) with ASD showed a significant decrease in scanning landscapes, the non-face stimuli presented in the study. Since the landscape slides consisted of high-spatial frequency features, or "local" elements without a dominant low spatial frequency component or global configuration, Anderson et al. (2006) suggested that decreased time spent looking at the landscape stimulus in the ASD group might reflect faster processing time of the stimuli, supporting previous research showing that individuals with ASD may be superior to controls in their processing of parts over whole objects (Happé, 1996; Shah & Frith, 1993). However, since the participants in this study were young children, results may not be generalizable to an older population. Results from the current study are in line with McPartland et al. (2011), showing that individuals with ASD use similar scanning strategies as TD individuals when exploring non-face stimuli. Thus, it is likely that differences between the results of this study and Anderson et al's (2006) study are due to developmental differences. Research on object processing has shown that object processing appears adult like by 4-5 years (Pallet & Dobkins, 2013). Since participants in Anderson et al.'s (2006) study ranged from 1-6 years old, developmental differences may have been affecting gaze behaviour. As such, generalizing gaze behaviours to non-face stimuli associated with young children to adults may not be an accurate depiction of gaze behaviour in the older population, emphasizing the importance of replicating findings across ages.

Although research on gaze behaviour related to non-face stimuli specifically is limited, knowledge about visual scanning of non-face stimuli can be further investigated by looking at studies involving face and non-face recognition. Through these types of studies many of the underlying theories separating face from non-face processing have been developed, and although they do not address visual scanning strategies associated with non-face stimuli per se, they do offer insight about the mechanisms that may be driving resulting gaze behaviours.

Face vs. Non-Face Recognition

Understanding the similarities and differences associated with face and non-face recognition in ASD offers insight into the cognitive processes responsible for gaze behaviour.

Previous research has shown that in children, adolescents and adults with ASD, recognition memory for faces is poor (Arkush, Smith-Collins, Fiorentini & Skuse, 2013; Barton et al., 2004; Boucher & Lewis, 1992; Boucher, Lewis, & Collis, 1998; Hauck, Fein, Maltby, Waterhouse, & Feinstein, 1998; Teunisse & de Gelder, 1994), but recognition of complex objects and patterns is unaffected (Arkush et al., 2013; Boucher & Lewis, 1992; Hauck et al., 1998; McPartland et al., 2011). The current research supports this latter finding, showing that individuals with ASD use similar parts-based processing strategies as TD individuals in identifying objects. This suggests that both groups use similar cognitive processes for processing non-face stimuli. More so, deficits in face processing and an intact ability to process objects suggests that these two cognitive processes may not be domain specific as they are in TD individuals.

Wallace, Coleman and Bailey (2008) proposed that different cognitive mechanisms exist for face processing and object processing in TD individuals. The main factor responsible for this difference involves holistic processing, which requires features to be integrated into a coherent whole – a necessary processing strategy for face processing but not object processing in TD individuals. This holistic processing strategy used in face recognition requires the interdependent processing of both second-order configural information (the spatial relationship amongst features) and featural information in order to form a coherent “whole” (Tanaka & Sengco, 1997), while non-face processing requires more of a feature-by-feature (parts-based) processing strategy (Biederman, 1987; Tanaka & Farah, 1993; Tanaka & Sengco, 1997). However, individuals with ASD appear to use a parts-based processing strategy regardless of whether the stimuli represents a face or non-face. Since the way individuals recognize stimuli will depend on how they take in information relative to that stimuli (ie: gaze behaviours), this suggests that individuals with ASD perceive objects in a similar manner to faces, indicating that the processing of faces and objects relies on common cognitive processes (Arkush et al., 2013; Wallace et al., 2008).

The combination of impaired face and intact object processing has led researchers to propose that individuals with ASD have impaired or absent second-order configual processing abilities (Barton et al., 2004; Davies, Bishop, Manstead & Tantam, 1994; Teunisse & de Gelder, 2003) or holistic processing abilities (Deruelle, Rondan, Gepner & Tardif, 2004; Josepth and Tanaka, 2003; Lopez, Donnelly, Hadwin & Leekam, 2004; Serra, Althaus, de Sonneville, Stant, Jackson & Minderaa, 2003; Teunisse & de Gelder, 1994), causing them to rely more heavily on feature processing (Davies et al., 1994; Deruelle et al., 2004; Lahie, Mottron, Arguin, Berthiaume, Jemel & Saumier, 2006; Langdell, 1978). This is consistent with previous research showing that normal cortical specialization for faces during adolescence does not occur in ASD and that face-selective processing takes place in regions of the brain that usually respond in object-related activation, indicating that perceptual processing of faces in ASD may be more like perceptual processing of common objects in TD individuals (Scherf, Luna, Minshew & Behrmann, 2010). Reduced activation to face stimuli has also been shown not only in the fusiform face area (responsible for face processing in TD individuals) but also in the superior temporal sulcus and the occipital face area, suggesting that the ventral visual cortex may be organized differently in ASD compared to TD individuals (Humphreys, Hasson, Avidan, Minshew, & Behrmann, 2008).

Taken together, these studies provide evidence that similar neural processes in ASD underlie recognition of both face and non-face stimuli. This indicates that TD individuals use domain-specific cognitive processes for face and object processing, while individuals with ASD use a more general cognitive process for both types of stimuli.

Active vs. Passive Viewing

Object recognition was examined under two conditions of aperture viewing: active viewing, and passive viewing replays of a TD participant's movements. Although there were no group differences, results showed that for both groups objects were identified more quickly when actively controlling the aperture compared to the passive condition. This is consistent with previous research involving TD individuals (Craddock, Martinovic & Lawson, 2011; Harman, Humphrey & Goodale, 1999; James, Humphrey & Goodale, 2001; James, Humphrey, Vilis, Corrie, Baddour & Goodale, 2002) and extends this research to show the same outcome in individuals with ASD.

Studies using aperture viewing have generally concluded that object recognition is facilitated by active exploration in TD individuals. Harman et al. (1999) measured response latency and accuracy of participants performing an old/new discrimination task and found that actively explored objects were recognized faster than passively viewed objects. This finding was replicated in a similar study by James et al. (2002). A consistent finding by James et al. (2001) also showed that active exploration of three-dimensional objects leads to faster performance in a mental rotation task. However, in each of these studies participants were presented 2-dimensional objects that could be rotated around their axis, allowing participants to view the objects from different angles. As a result, this added rotation feature may differ from active exploration of a stationary object seen from a fixed viewpoint. Craddock et al. (2011) investigated how active exploration affects recognition performance using an aperture-viewing task in which TD individuals made a familiarity judgment when viewing stationary objects through a viewing aperture, which was either controlled actively or viewed passively. Results showed that familiarity judgments were made significantly faster in the active condition, confirming the results of Harman et al. (1999) and James et al. (2001, 2002). In the current study, participants were also presented with stationary objects and given the opportunity to actively move or passively watch the aperture, and similar to previous studies, participants performed quicker during the active condition compared to the passive condition. Thus, active viewing appears to be advantageous regardless of whether or not the object rotates. One possible reason is that active viewing allows the viewer to focus on informative parts of the object, which may be defined by relatively low-level factors such as salience (Itti & Koch, 2000), or by specific object parts (ie: tip of a pencil). However, since the passive viewing condition was a previous participants active view, it is likely that they would have focused on informative positions as well. Alternatively, it is also possible that active viewing may have been faster because in the passive movement condition, participants were not able to accurately judge various factors related to movement such as the extent, speed, and direction of the aperture's movements (Craddock et al., 2011). The advantage of free movement allows viewers to see the parts of the object they feel is necessary to make an informed judgment about the object, leading to better recognition performance (Craddock et al., 2011; Lee & Wallraven, 2013). As a result, overall active movement may have provided more direct information about the object and been a more efficient way of encoding important object features.

Previous research also has shown that active exploration offers important insights into how TD individuals view objects using parts-based processing strategies. Craddock et al. (2011) found that participants tended not to distribute their looking time uniformly across the objects and focused more on distinctive areas (ie: the head of a hammer). Furthermore, when objects were larger than could be fully visible within the aperture, participants tended to first outline the object, spending more time following the outside contour of the object and only briefly scanning the inside of that contour. This supports previous research suggesting that inspection strategies depend on the geometry of the object to provide the maximum amount of information (James et al., 2002; Dopjans, Bülthoff, & Wallraven, 2012). The current study also demonstrated non-uniform viewing time of the objects, as evidenced by a significantly increased amount of time spent viewing the object in the bottom right quadrant, suggesting that participants focused their attention on more distinctive areas of the object.

These results confirm previous research suggesting that there is an advantage to object recognition when active exploration is used (Craddock et al., 2011; Harman et al., 1999; James et al., 2001, 2002). As an extension to these findings, this is the first study to show that this advantage holds for individuals with ASD as well as TD individuals. This further indicates similarities between the two groups in object processing, suggesting similar cognitive mechanisms are responsible for parts-based processing.

Mechanisms Involved In Visual Object Recognition

These findings indicate that fundamental mechanisms responsible for object recognition are influenced by active exploration, leading to faster object recognition. However, it is unclear how active exploration influences these processes. Passive viewing seems more advantageous from a cognitive standpoint, since passive viewing decreases the cognitive load, requiring less planning demands and movement execution, freeing up cognitive efforts to focus solely on object recognition. However, it is possible that the added motor demands of active viewing actually helps increase object recognition processes. It could be that having control over the parts of the object that are seen provides an efference copy and /or proprioceptive information that helps to more quickly integrate the different views by allowing participants to anticipate the upcoming view and relate it to previously viewed object parts (Harman et al., 1999).

Alternatively, active exploration could allow participants to test ‘predictions’ about what they would expect to see if the object was viewed in a certain way (Harman et al., 1999). Active exploration of an object may provide a more realistic and relatable experience to how we would visually examine an actual object being held in our hands.

As we view objects in our environment, a fundamental problem arises. As we, or objects in our environment move, the retinal projection of our environment also changes, resulting in changes in size and orientation in the retinal projection of our environment. Yet, despite all of these environmental changes, our visual system is able to achieve object constancy, keeping objects as appearing constant in our environment. Two distinct approaches to achieving stability across view changes are view-invariant recognition processing (Biederman, 1987) and view-dependent processing (Bülthoff & Edelman, 1992). View-invariant recognition processing involves selective encoding of features of our environment that do not depend on viewpoint, and uses those features to identify objects. An example of this is the representation of an object according to the spatial relationships among the parts of that object. Alternatively, view-dependent processing (or the transformation approach) concentrates on visually compensating for changes in the retinal projection as the viewpoint changes. An example of this is mentally rotating an object until it is aligned with a previous representation. Both of these approaches have been found to be important for object recognition.

The invariants-based approach focuses mainly on local as opposed to global geometric properties, and proposes that objects are visually represented as structural descriptions consisting of primitive parts (ie: cylinders & spheres) and according to the spatial relationships between those parts (Biederman, 1987). This approach to object processing is associated with a cascade of steps leading to object recognition. The first stage is an early edge extraction stage, which is sensitive to surface characteristics such as luminance, texture and colour, and provides a line drawing description of the object. From this description, non-accidental properties (ie: image properties that remain stable over a range of viewpoints such as collinearity and symmetry) of the objects edges are detected, which occurs simultaneously with parsing of the object, particularly at concave regions. These two stages together provide critical constraints on the identity of the components, resulting in an arrangement of the components that is then matched to a representation in memory, and object identification occurs (Biederman, 1987).

By contrast, the view-dependent approach assumes that objects are visually represented as a set of two-dimensional templates, one for each position of the object (Logothetis, Pauls, Bülthoff & Poggio, 1994; Poggio & Edelman, 1990; Tarr & Bülthoff, 1995). Matching with such templates is dependent on the metric properties of the templates, such as length or aspect ratio, angles of intersections, and degrees of curvature. This theory holds that slight rotations in depth can be compensated for relatively quickly using direct generalizations from the templates, but that greater orientation differences sustain a cost because slower and more deliberate cognitive processes, such as mental rotation, are required to achieve recognition (Tarr, Bülthoff, Zabinski & Blanz, 1997).

Both of these processes have been found to be important in object processing (Foster & Gilson, 2002). Each of the two approaches of object recognition seems to capture some aspects of how the visual system accommodates view changes. For example, view-dependent object recognition may be required when the object is relatively complicated and difficult to name, while view-invariant object recognition may be required when objects are made of distinct parts whose spatial relationship can be easily coded and when the task requires abstract knowledge, such as naming objects. In the current study, it is likely that the object recognition relies more on view-invariant processing. Since participants are required to view objects under restricted viewing conditions of greyscale images, this limits the primary source of information to identify objects to the object's texture and the visible relationship among unique components of the object. As a result, identifying the object requires participants to integrate the distinct parts of the object based on their spatial relationship, and more abstract, view-independent knowledge is required to carry out the task. Thus, the cognitive processes associated with view-independent object processing are likely to be intact in individuals with ASD considering that these individuals performed in a similar manner to TD individuals on the viewing window task. Future research should use a similar paradigm that focuses on view-dependent strategies to determine if object processing related to the view-dependent approach is also intact in individuals with ASD. This will give a better indication of whether or not typical object processing is specific to view-invariant processing or is generalized across the two approaches.

Taken together, the advantage of active viewing seems to rely on the interdependence of action (proprioception) with perception (view integration), both of which are important in object processing. As a result, the visual input to the brain during active exploration of objects consists of a series of views as the object is being manipulated. In order to form a consistent object representation, this series of views must be integrated to form a coherent whole. This is dependent on the assumption that the object remains the same while different views are being processed. Both view-invariant and view-dependent approaches offer distinctive explanations regarding how object constancy is achieved across view changes, although more extensive research is required to determine how these approaches work together to explain object representation, as well as how these approaches may vary across different populations of individuals.

Conclusion

Results from this experiment showed that when parts-based processing strategies are required, individuals with ASD explore objects in a similar manner to TD individuals. This finding is specific to non-face stimuli, as previous research has shown that TD individuals use a holistic processing strategy in face recognition, while individuals with ASD rely more heavily on a parts-based processing strategy regardless of whether the presented stimuli are face or non-face stimuli. As a result, similar cognitive mechanisms may drive object processing in both individuals with ASD and TD individuals. Both groups also showed quicker recognition abilities of objects when allowed to actively explore their environment compared to passive watching, indicating that mechanisms underlying object recognition are more efficient when the action/motor system is involved. Mechanisms underlying object recognition consists of both view-invariant and view-dependent processing, and results of this study demonstrate an advantage in active exploration in object recognition in terms of view-invariant processing. Further examination of the action/motor system in the context of both view-invariant and view-dependent processing will provide a better understanding of how object recognition functions in the autistic brain.

CHAPTER V

GENERAL CONCLUSIONS

The experiments conducted in this study demonstrate that although preattentive issues with Gestalt processing do arise in ASD (Experiment 1), parts-based processing strategies do not appear to differ from TD individuals (Experiment 2). In the perceptual grouping task, individuals with ASD showed decreased susceptibility to the Ponzo illusion compared to TD individuals. More so, the likelihood of indicating an illusion-based response did not differ from chance in the ASD group. Since perceiving the illusion required that individuals would group the background stimuli to form the converging lines used to induce the illusion, less susceptibility to the illusion suggests that grouping according to Gestalt principles did not occur. As a result individuals with ASD were more likely to perceive the stimuli according to its parts rather than as an overall configuration, demonstrating a tendency towards parts-based processing. In the viewing window paradigm, both individuals with ASD and TD individuals showed similar response times, viewing patterns, amount of time spent moving the aperture on versus off the object, and amount of time spent moving the aperture versus keeping it static in an object identification task. Furthermore, both groups showed quicker recognition times when they were allowed to move the aperture compared to passively watching it. These results suggest that both groups use similar parts-based processing strategies to identify objects. Together these findings demonstrate that individuals with ASD show a tendency towards parts-based processing strategies regardless of whether the task requires global or parts-based processing strategies, which may be explained in part by the weak central coherence theory.

The importance of these studies is two-fold. First, evaluating the visual processing abilities of individuals with ASD using visual illusions provides more insight into their perceptual abilities, by highlighting their difficulties grouping stimuli using Gestalt grouping principles. Second, evaluating the parts-based processing strategies used in object recognition revealed that both individuals with ASD and TD individuals use similar processing strategies to view objects in their environment. Since visual information plays a crucial role in everyday life, one of the goals of this research was to improve the general understanding of how individuals with ASD perceive their environment. Knowledge gained from this research should be used to guide how behavioural therapies and interventions are designed and used to assess visual processing abilities, taking into consideration the unique way that individuals with ASD process the world. Additionally, educating those individuals who adopt a more globally focused processing strategy about how individuals with ASD process their visual world may also lead to improved quality of life in the classroom, work force, and society in general.

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APPENDIX A

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INFORMED CONSENT FORM FOR INDIVIDUALS WITH AUTISM SPECTRUM DISORDERS

PRINICIPAL INVESTIVGATORS:	Dr. Jonathan Marotta University of Manitoba (204) 474-7057	Tiffany Lazar University of Manitoba (204) 480-1248	Dr.Janine Montgomery University of Manitoba (204) 474-8306

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

PURPOSE: We are interested in how individuals with and without high-functioning forms of autism spectrum disorders process visual information. The way visual information is processed is important because it allows us to identify and attach meaning to our surroundings.

DESCRIPTION: This experiment will take place over two sessions; each session will be less than an hour in length. You will first be asked to fill out a short questionnaire about your general health. You will then be asked to complete two pre-tests, the Peabody Picture Vocabulary Test, which will assess your vocabulary ability, and the Raven's Progressive Matrices Test, which will assess your reasoning ability. During the first session, you will be shown a blurry image on a computer screen, and asked to identify it by viewing it through a small window that shows the image clearly. At the end of this task you will be asked to identify each of the clearly presented images by selecting one of two answers. During the second session, you will judge the length of two parallel lines, which will be displayed on a background of patterned dots on a computer screen.

RISKS AND BENEFITS: There are no evident risks inherent in the tasks you will perform but some of the tests may be difficult. While this may be frustrating to you, there will always be an investigator with you to assist you and support you. We find most individuals completing these tasks enjoy the process.

COSTS AND PAYMENTS: There are no fees or charges to participate in this study. Participants will be reimbursed for any travel expenses (e.g. parking or taxi).

CONFIDENTIALITY: Your information will be kept confidential. You will be referred to by a code number. All files containing identifying information will be stored in a locked cabinet separate from data with your code number. Your files will only be accessible by the investigators and will be destroyed 5 years after the completion of the study. All papers containing personal information will be shredded. All electronic files will be deleted. Any cds or dvds containing data will be physically destroyed.

VOLUNTARY CONSENT: Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

This research has been approved by the Psychology/Sociology Research Ethics Board of the University of Manitoba. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 204.474.7122. A copy of this consent form has been given to you to keep for your records and reference.

________________________ ____________ ________________________ ____________

Signature of the Participant Date Signature of Investigator Date

APPENDIX B

UNIVERSITY OF MANITOBA | Department of Psychology

190 Dysart Road
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9338
Fax (204) 474-7599

INFORMED CONSENT FORM FOR CONTROLS – PERCEPTUAL GROUPING TASK

PRINICIPAL INVESTIVGATORS:	Dr. Jonathan Marotta University of Manitoba (204) 474-7057	Tiffany Lazar University of Manitoba (204) 480-1248	Dr.Janine Montgomery University of Manitoba (204) 474-8306

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

PURPOSE: We are interested in how individuals with and without high-functioning Autism process visual information. The way visual information is processed is important because it allows us to identify and attach meaning to our surroundings.

DESCRIPTION: This experiment will be less than an hour in length. First, you will be asked to fill out a short questionnaire that will provide us with demographic information that will help us with our statistical analysis. Next, you will be administered a perceptual grouping task in which you will be presented two equal parallel lines, either on a background of randomly patterned dots or on a background of dots representing a V or inverted V pattern, and will be asked to identify which of the 2 lines are longer.

RISKS AND BENEFITS: There are no evident risks inherent in the tasks you will perform but some of the tests may be difficult. While this may be frustrating to you, there will always be an investigator with you to assist you and support you.

COSTS AND PAYMENTS: There are no fees or charges to participate in this study. Introductory Psychology students will receive 2 experimental credits that are a requirement of their Introductory Psychology course for their participation per experimental session.

CONFIDENTIALITY: Your information will be kept confidential. You will be referred to by a code number. All files containing identifying information will be stored in a locked cabinet separate from data with your code number. Your files will only be accessible by the investigators and will be destroyed 5 years after the completion of the study. All papers containing personal information will be shredded. All electronic files will be deleted. Any cds or dvds containing data will be physically destroyed.

VOLUNTARY CONSENT: Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

This research has been approved by the Psychology/Sociology Research Ethics Board of the University of Manitoba. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 204.474.7122. A copy of this consent form has been given to you to keep for your records and reference.

________________________ ____________ ________________________ ____________
Signature of the Participant Date Signature of Investigator Date

If you would like to receive general summary of the results from this study when it is completed, please complete your email or mailing address below:

Email or Mailing Address: ____

____

Thank you for your participation!

APPENDIX C

UNIVERSITY OF MANITOBA | Department of Psychology

190 Dysart Road
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9338
Fax (204) 474-7599

INFORMED CONSENT FORM FOR CONTROLS - VIEWING WINDOW PARADIGM

PRINICIPAL INVESTIVGATORS:	Dr. Jonathan Marotta University of Manitoba (204) 474-7057	Tiffany Lazar University of Manitoba (204) 480-1248	Dr.Janine Montgomery University of Manitoba (204) 474-8306

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

PURPOSE: We are interested in how individuals with and without high-functioning forms of autism spectrum disorders process visual information. The way visual information is processed is important because it allows us to identify and attach meaning to our surroundings.

DESCRIPTION: This experiment will be less than an hour in length. First you will be asked to fill out a short questionnaire that will provide us with demographic information that will help us with our statistical analysis. Next you will be presented with a degraded image on a computer monitor, and asked to identify what that image is by either actively or passively viewing it through a small, circular area that displays the underlying image in normal clarity. At the end of this task you will be asked to identify each of the images presented in normal clarity by choosing between two choices.

RISKS AND BENEFITS: There are no evident risks inherent in the tasks you will perform but some of the tests may be difficult. While this may be frustrating to you, there will always be an investigator with you to assist you and support you.

COSTS AND PAYMENTS: There are no fees or charges to participate in this study. Introductory Psychology students will receive 2 experimental credits that are a requirement of their Introductory Psychology course for their participation per experimental session.

CONFIDENTIALITY: Your information will be kept confidential. You will be referred to by a code number. All files containing identifying information will be stored in a locked cabinet separate from data with your code number. Your files will only be accessible by the investigators and will be destroyed 5 years after the completion of the study. All papers containing personal information will be shredded. All electronic files will be deleted. Any cds or dvds containing data will be physically destroyed.

VOLUNTARY CONSENT: Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

This research has been approved by the Psychology/Sociology Research Ethics Board of the University of Manitoba. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 204.474.7122. A copy of this consent form has been given to you to keep for your records and reference.

________________________ ____________ ________________________ ____________

Signature of the Participant   Date   Signature of Investigator   Date

If you would like to receive general summary of the results from this study when it is completed, please complete your email or mailing address below:

Email or Mailing Address: ____

____

Thank you for your participation!

APPENDIX D

UNIVERSITY OF MANITOBA | Department of Psychology

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Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9338
Fax (204) 474-7599

PARTICIPANT DEMOGRAPHICS

PRINICIPAL INVESTIVGATORS:	Dr. Jonathan Marotta University of Manitoba (204) 474-7057	Tiffany Lazar University of Manitoba (204) 480-1248	Dr.Janine Montgomery University of Manitoba (204) 474-8306

This information is used to assist us in conducting our study. Please note that there is no personally identifiable information kept, and you are only referred to by an arbitrary participant number. All information will be kept confidential. Your files will only be accessible by the investigators and will be destroyed 5 years after the completion of the study. You may refrain from answering any questions you choose.

Participant # ___________ Test Date: _______________________

Experimental Condition: ______________________

Vision: Normal: _________ Corrected: _________ Glasses? _________

Gender: _________ Age: _________

Hand Used: _____________

Handedness Inventory: Which hand do you use to do the following?

1. Throw a ball. L R
2. Brush your teeth. L R
3. Eat soup with a spoon. L R
4. Comb your hair. L R
5. Swing a Hockey Stick. L R
6. Swing a racquet. L R
7. Hammer a nail. L R
8. Point to something. L R
9. Write your name. L R

Is there anything you do with your left hand? ___________________________

Medical History: (This information will only be used to determine if medications, other conditions, or injury may affect your visual skills)

Are you on any medications? ______YES _______NO

If YES, please list: ____

Have you been diagnosed with any other medical or psychological conditions? _______YES ________NO

If YES, please list: ____

Have you ever had a head injury? ________YES ________NO

Have you ever had a seizure? ________YES ________NO

APPENDIX E

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Fax (204) 474-7599

DEBRIEFING FORM

PRINICIPAL INVESTIVGATORS:	Dr. Jonathan Marotta University of Manitoba (204) 474-7057	Tiffany Lazar University of Manitoba (204) 480-1248	Dr.Janine Montgomery University of Manitoba (204) 474-8306

Thank you for participating in this study. In this study we are interested in how visual information is processed. More specifically, we are interested in how individuals with and without high-functioning forms of autism spectrum disorders see the “big picture”, and whether it is processed piece by piece, or as a whole image. In the first task, by blurring the image and observing how you control the window, we are able to see features of the object that you use to identify it. By varying how you interact with the window, either by moving it or watching it, we can determine how the way you look at the image might affect how long it takes you to identify it. The second task allows us to observe whether or not you were fooled by the visual illusion called the Ponzo illusion. By showing you the two lines overlaid on a background pattern of dots, we can see how you may or may not have used the background to influence how you judged the lines. The way visual information is processed is important because it allows us to identify and attach meaning to our surroundings. If you have any questions later on, please feel free to contact me – my contact information is on your consent form. Thank-you again for participating, and have a great day.