The Role of Selective Attention in Perceptual Switching

By

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Abstract

When viewing ambiguous figures, individuals can exert selective attentional control over their perceptual reversibility behaviour (e.g., Strüber & Stadler, 1999). In the current study, we replicated this finding but we also found that ambiguous figures containing faces are processed quite differently from those containing objects. Furthermore, inverting an ambiguous figure containing faces (i.e., Rubin's vase-face) resulted in an "inversion effect". These findings highlight the importance of considering how we *attend to* faces in addition to how we perceive and process faces. Describing the perceptual reversal patterns of individuals in the general population allowed us to draw comparisons to behaviours exhibited by individuals with Asperger Syndrome (AS). The group data suggested that these individuals were less affected by figure type or stimulus inversion. Examination of individual scores, moreover, revealed that the majority of participants with AS showed an atypical reversal pattern, particularly with ambiguous figures containing faces, and an atypical inversion effect. Together, our results show that ambiguous figures can be a very valuable tool for examining face processing mechanisms in the general population and other distinct groups of individuals, particularly those diagnosed with AS.

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CHAPTER 1: General Introduction

The way humans process faces has captivated the attention of a number of prominent researchers conducting behavioural and imaging studies. Researchers in the field of face processing may be enthralled with this particular research area because faces provide humans with a unique identity, are a medium for expressing emotions, and are important in the communication of important information. It is not surprising, then, that searches for peer-reviewed articles using the phrase "face processing" result in thousands of hits. The studies comprising this extensive face processing literature can be grouped into several general categories, including those investigating the face inversion effect, face recognition/memory, and expertise/specialization for faces to name a few. In the current research, we present findings from observations of participants' responses to ambiguous stimuli that add to the evidence that faces are a special type of visual stimuli.

The current research is motivated by two key observations. The first of these relates to dissociations found between face and (nonface) object processing in the general population. In the general population, faces appear to capture attention much more easily than objects (e.g., Hershler & Hochstein, 2005; Langton, Law, Burton, & Schweinberger, 2007). In the current research, this finding was explored in a unique way – by using several types of ambiguous figures and by combining perceptual reports with recording of eye movements. The first general goal of the proposed research was to determine whether ambiguous figures containing faces result in different patterns of perceptual reversal behaviours compared to ambiguous figures that do not contain faces.

The second key observation motivating the current research relates to the fact that the patterns of behavioural and hemodynamic responses seen during face processing tasks in a variety of clinical populations, including those with an autism spectrum disorder (ASD), have been shown to be markedly distinct from those seen in the neurotypical population. For example, some researchers have found that individuals with ASD show normal recognition for objects but not faces (Trepagnier, Sebrechts, & Peterson, 2002) and this may be because they use areas of the brain typically involved in processing objects to process faces (Schultz et al., 2000). To our knowledge, no one has yet explored face processing in ASD using ambiguous figures combined with eye-tracking. The second general goal of the current study, therefore, was to explore perceptual reversal behaviours in a group of individuals on the autism spectrum, specifically those with Asperger Syndrome (AS). In the sections that follow, we review the literature relating to face processing in neurotypical individuals, and in individuals with ASD, in more detail.

Face processing in the general population

Faces are a unique class of visual stimuli that are astonishingly “homogenous and stereotypical” (Sagiv & Bentin, 2001, p. 946). This set of visual stimuli share a similar structure, always consisting of the same parts (e.g., eyes, nose, and mouth) in the same configuration (e.g., two eyes with a nose and mouth centered below them). Despite this similarity, humans are able to easily distinguish between even highly similar faces, and this likely reflects our ability to process faces holistically (Farah, Tanaka, & Drain, 1995a; Bartlett & Searcy, 1993; Singer & Sheinberg, 2006). In other words, the parts of a face are not seen and represented as discrete elements, but rather as a grouping of related components arranged in a particular way, unique to each human face. Sensitivity to these multiple relationships between the individual parts allows one to recognize that one face is distinct from another (Joseph & Tanaka, 2003).

The ‘face inversion effect,’ originally describe by Yin (1969), indirectly supports the notion that faces are processed holistically. Behaviorally, this effect refers to the decreased ability to match, name, and classify upside-down faces versus upright faces (Farah, Levinson, & Klein, 1995; Marotta, McKeeff, & Behrmann, 2002; Ross & Turkewitz, 1981; Tanaka et al., 1998). A “whole-part” paradigm is often employed to study the face inversion effect, working on the hypothesis that the effect is caused by the inability to decompose patterns into parts when the pattern is presented upside-down. In the whole-part method, participants study upright whole faces (holistic versions) and upright fragmented faces presented as a set of isolated features (parts versions). In the test phase, participants are asked to identify the holistic and parts versions of the faces, which are presented in either an upright or inverted orientation. In the neurotypical population, a robust inversion effect is typically observed for the faces that are initially encoded in their holistic versions, but no inversion effect occurs for the faces encoded in their parts versions (Farah, Wilson, Drain, & Tanaka, 1995b). The inversion effect is likely due to our strong tendency to engage in holistic processing when presented with intact faces. This tendency is diminished either by fragmenting the stimulus face and/or by presenting it in an unusual (inverted) orientation; in either case, a component-based analysis may be triggered.

Findings from neuroimaging research complement the results of behavioural studies. When matching whole upright faces, a significantly larger signal is produced over the right fusiform face area (FFA; a region of the ventral temporal cortex) than the left FFA (Yovel & Kanwisher, 2004), a result that supports the widely-held belief that the right hemisphere is specialized for holistic processing. The left FFA shows preferential activation when face parts are matched (Rossion et al., 2000), supporting the general claim that the left hemisphere is specialized for local (parts-based) processing. Differences in signal change during the viewing of upright and inverted faces have also been found to be smaller on the left than on the right, suggesting that a more sizable face inversion effect occurs in the right FFA (Farah et al., 1995b; Leehey, Carey, Diamond, & Cahn, 1978; Ross & Turkewitz, 1981; Rossion et al., 1999; Vermeire & Hamilton, 1998; Yovel & Kanwisher, 2004).

The encoding of inverted faces may be taxing for the holistic processor of the right hemisphere. This suggestion is supported by the fact that event-related potentials (ERPs) have been found to be significantly larger and more delayed when participants view inverted faces compared to upright faces, particularly in the right hemisphere (Sagiv & Bentin, 2001; Latinus & Taylor, 2005). One interpretation of this result is that, although the right FFA may not “recognize” the inverted face as a canonical face, other areas of the right hemisphere may still be trying to process the stimulus in a holistic manner.

Face processing in individuals with autism spectrum disorders

Individuals on the autism spectrum have been shown to have a bias towards processing complex information, including faces, in a parts-based manner (Mottron & Belleville, 1993; Mottron, Peretz, & Menard, 2000; Mottron, Belleville, & Menard, 1999; Boucher & Lewis, 1992; Happé, 1999). This finding, combined with the fact that upright faces are processed most efficiently using a holistic approach, puts individuals with autism at a disadvantage for processing faces. Indeed, evidence from studies using face matching and identity recognition tasks (which draw upon holistic face processing mechanisms) show that individuals with ASD are impaired relative to neurotypical controls (Hobson, Ouston, & Lee, 1988; Corden, Chilvers, & Skuse, 2008; Boucher & Lewis, 1992; Klin et al., 1999; Langdell, 1978). A number of researchers argue that these face processing difficulties contribute to more general impairments in social functioning seen in individuals on the autism spectrum (Critchley et al., 2000; Pierce et al., 2001; Hobson et al., 1988), including difficulties detecting agents or agency (Castelli, Frith, Happe, & Frith, 2002).

Abnormal processing of faces may be due, in part, to the fact that those on the spectrum fixate more on the mouth of a face, whereas neurotypical controls have been shown to focus on the eyes of faces (Spezio, Adolphs, Hurley, & Piven, 2007; Pelphrey et al., 2002; Klin et al., 2002; but see Bar-Haim, Shulman, Lamy, & Reuveni, 2006). They also exhibit a reduced face inversion effect and in some respects show superior processing of objects – further evidence that the use of a part-by-part strategy to process information is a characteristic of ASD (Langdell, 1978).

Atypical face processing strategies observed in ASD may be the result of abnormal brain development (for review see Happé & Frith, 1996; Van Kooten et al., 2008). Abnormally weak activation in the FFA and a pattern of activation consistent with that seen when neurotypical individuals view objects (i.e., heightened activation in the inferior temporal gyri) occurs when individuals with autism and AS view faces (Schultz et al., 2000; Pierce et al., 2001; Critchley et al., 2000). These particular hemodynamic responses are typically seen as evidence that individuals on the autism spectrum use feature-based processing strategies to discriminate faces as well as nonface objects.

Using ambiguous figures to study face processing

In the present study, we used ambiguous figures to study face processing specifically. Only two other studies, that we are aware of, have used this particular approach (Andrews et al., 2002; Hasson, Hendler, Ben, & Malach, 2001). Both groups of researchers tested whether the different patterns of activation associated with face and object processing in human occipito-temporal cortex would also be observed while participants viewed Rubin’s vase-face. Their interest in this particular figure stems from the fact that the same local contours can result in two category-specific global perceptions. Interestingly, both research groups discovered that when participants perceived the faces interpretation of the figure, face-related regions of the fusiform gyrus showed relatively more activation than that seen when participants perceived the vase interpretation. This finding is an important one as it shows that even when a face shares a common feature (i.e., the same edge) with an object it is still processed in a way that is distinct from that seen when processing the object.

Given that faces are processed differently than objects, we anticipated that differences in perceptual reversal patterns would be observed when participants viewed ambiguous figures containing faces and those not containing faces. Ambiguous figures provide a unique way to look at how we direct (and shift) our attention to objects of interest. In the current study, the Maltese cross (consisting of two object interpretations), Rubin’s vase-face (one face and one object interpretation) and Boring’s young girl-old woman (two face interpretations) were presented to participants. Responses to these content-reversible figures were contrasted with responses to the Necker cube. Unlike with the other figures, switching between the two interpretations of this latter figure requires a change in perspective or viewpoint.

The experiments described in Chapter 2 address several questions relating to ambiguous figures and face processing in the neurotypical population. First, do individuals show differences in the ways that they process and alternate between different interpretations of content-reversible ambiguous figures that contain faces or agents, and those that do not? Second, do their responses to the content-reversible figures differ from those exhibited while they process the perspective-reversible Necker-cube figure (a nonface ambiguous figure)? Third, how do perceptual reversal behaviours change in response to changes in task instructions (e.g., passive viewing, alternate interpretations slowly, and alternate interpretations quickly) for different categories of ambiguous figures? Finally, does inversion of an ambiguous figure containing faces alter participants' looking behaviour (i.e., lead to an "inversion effect") and, if so, does this effect vary in magnitude depending on task instructions?

The experiments described in Chapter 3 explored the perceptual reversal behaviours of a group of individuals with AS. Specifically, the objectives were to determine whether individuals with AS respond differently than controls when viewing ambiguous figures containing faces, and whether turning a figure containing a face interpretation upside-down results in a smaller inversion effect than that seen in controls.

CHAPTER 2: The Effects of Figure Type, Task Instructions, and Stimulus Inversion on Perceptual Reversal Patterns

Ambiguous figures have fascinated artists, philosophers, and psychologists for over a century (see Long & Toppino, 2004 for a review). Interest in these figures comes from the fact that, while the physical configuration of these types of stimuli remains constant on the retina, viewers often perceive two or more alternative interpretations during continuous free viewing. Classic examples of figures displaying perceptual ambiguity are Boring's young girl-old woman[1], Rubin's vase-face[2], the Maltese cross, and the Necker cube (see Figure 1). While viewing Rubin's vase-face, for example, the white vase is at times perceived as the main figure, while at other times the flanking black faces are perceived in the foreground. This phenomenon of switching back and forth between two interpretations of an ambiguous figure is most commonly known as perceptual reversibility (Hochberg & Peterson, 1987). Studying observers' ability (or inability) to switch between the figures' interpretations has allowed researchers to study how the human visual system selects particular interpretations of the visual world. The primary goal of the present research was to determine whether different types of ambiguous figures result in different patterns of perceptual reversal behaviour.

[1] Although the young woman/old woman figure bears the name of E. G. Boring (an experimental psychologist at Harvard University from 1924 to 1949), it was created by artist W. E. Hill. The figure originally appeared in the magazine *Puck* in 1915 (Fisher, 1967).
[2] Rubin's vase-face (also known as the 'chalice and faces') and the Maltese cross were first made popular by Gestalt psychologist E. J. Rubin (Fisher, 1967).

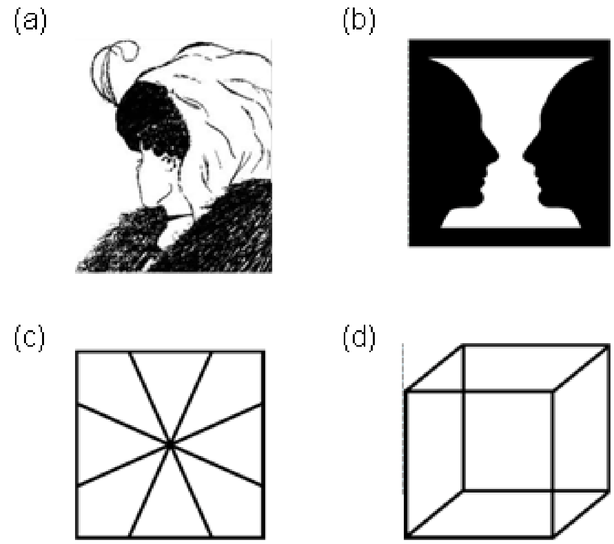

Figure 2.1. Ambiguous figures, each with two interpretations: (a) Boring's young girl-old woman; (b) Rubin's vase-face; (c) the Maltese cross; and (d) the Necker cube.

Factors affecting perceptual reversals

Researchers believe that understanding the multistable nature of ambiguous figures provides insights into the function of basic perceptual mechanisms; however, in the past, little agreement concerning these underlying mechanisms has been reached. Whether the mechanisms involved in perceptual reversals are low-level (bottom-up) or high-level (top-down) in nature has been a contentious issue. Although this dichotomy has been described in the corpus of literature built up over more than a century of research, some level of agreement that switching behaviour involves a combination of low- and high-level processes is emerging. This agreement is, in part, due to new insights gained through the application of sophisticated psychophysical, physiological, and neuroimaging technology by contemporary researchers (Pitts, Nerger, & Davis, 2007; Parker, Krug, & Cumming, 2002; Müller et al., 2005; Toppino, 2003; Mitroff, Sobel, & Gopnik, 2006; Meng & Tong, 2004; Gao et al., 2006; Zhou et al., 2004).

Low-level explanations suggest that reversals may be due to changes in neural components of early vision that may be out of the viewer's control (Babich & Standing, 1981; Toppino & Long, 1987). The neural satiation and recovery model purports that one brain mechanism will support one interpretation of an ambiguous figure. When fatigued, however, it gives rise to the alternative interpretation which is then supported by another mechanism (Hock, Schoner, & Hochstein, 1996). The Necker cube (presented as either static or dynamic/rotating form) has traditionally been used to demonstrate this low-level effect, which can manifest in a number of ways. For example, during free viewing of an ambiguous figure, viewers often report an increase in the number of reversals per unit of time (Babich & Standing, 1981; Toppino & Long, 1987; Ross & Ma-Wyatt, 2004). Additionally, immediately after viewing a biased version of an ambiguous figure, viewers will often report perceiving the alternative interpretation (Mitroff et al., 2006; Parker & Krug, 2003; Long & Moran, 2007; Long, Toppino, & Mondin, 1992; Long & Toppino, 2004).

The presentation of biased versions of ambiguous figures can influence the low-level effects listed above (Harris, 1980; Virsu, 1975; von Grünau, Wiggin, & Reed, 1984; Long & Moran, 2007). Long and colleagues (1992) presented a biased Necker cube prior to the presentation of the ambiguous counterpart, for durations ranging from 0 s to 150 s. For durations greater than 90 s, viewers were more likely to perceive the alternative interpretation of the ambiguous (unbiased) figure, suggesting that neural components were fatigued and could not support the interpretation that was the same as the biased version. Conversely, brief exposures (< 90 s) to the biased cube prior to the presentation of the ambiguous cube produced the opposite results. Viewers were more likely to report that the biased and ambiguous Necker cubes were the same, suggesting that short presentations of a biased figure prime the observer for perceiving the interpretation of the ambiguous figure that is consistent with the biased version. The authors suggested that neural components were not fatigued after brief presentations of the biased cube, and were able to support the same interpretation when the ambiguous Necker cube was shown.

High-level (top-down) explanations propose that reversals are caused by high-level cognitive networks (including intention, concentration, imagining, and matching of memory representations) acting on lower level sensory mechanisms. Through these mechanisms, switching from one interpretation to another interpretation of an ambiguous figure can come under the control of the viewer. In support of this idea, when participants are given specific instructions to do so, they can control their switching rates (Babich & Standing, 1981; Ito et al., 2003; Leopold & Logothetis, 1999; Meng & Tong, 2004; Strüber & Stadler, 1999; van Dam & van Ee, 2006; Einhäuser, Martin, & Konig, 2004). Thus, when instructed to do so, viewers can increase or decrease the duration of particular interpretations, relative to those observed during free viewing.

The impact of task instruction can vary as a function of the semantic information contained in the ambiguous figures (Strüber & Stadler, 1999; Peterson, Harvey, & Weidenbacher, 1991; Gibson & Peterson, 1994; Peterson & Gibson, 1994). Strüber and Stadler found that the reversibility of figures with more “meaningful” content (e.g., Jastrow’s duck-rabbit) was greater than those with less “meaningful” content (e.g., the Maltese cross). Furthermore, when instructed to alternate between interpretations as quickly as possible, the reversal patterns seen with these content-reversible (or semantic) ambiguous figures could be controlled to a greater extent than those seen with more abstract, perspective-based figures (e.g., Necker cube and Schröder staircase; Strüber & Stadler, 1999). The authors suggested that these effects occur because it is easier to imagine, and thus turn one's attention toward, more meaningful figures. Peterson and colleagues (Gibson & Peterson, 1994; Peterson & Gibson, 1994; Peterson et al., 1991) have reported that, when the two interpretations of a particular figure vary in their "denotivity" (i.e., the degree to which viewers agree on their "meaning"), the interpretation that is high in denotivity can be maintained as figure longer under "hold" instructions, provided it is presented in its canonical (upright) orientation.

The findings described above raise several interesting questions regarding how "meaningfulness" influences the nature of perceptual reversals. For instance, what is it about content-reversible ambiguous figures that makes them easier to reverse than those classified as perspective-reversible? Why are some classes of content-reversible figures that involve a reversal of figure-ground relationships (e.g., Rubin's vase-face) easier to switch between than others (e.g., Maltese cross)? Are both interpretations of all types of ambiguous figures perceived for an equal amount of time, or are some interpretations perceived longer than others? Although the questions listed above have been partially addressed in previous research (e.g., Strüber & Stadler, 1999), discriminating between figures based on their "meaningfulness" is somewhat arbitrary, and does not adequately explain why switching between interpretations for some types of ambiguous figures is easier than others.

A more useful approach might be to provide an operational definition for what is meaningful. Stimuli that capture one's attention can be thought of as meaningful or important. For example, stimuli that appear unexpectedly (Jonides & Yantis, 1988; Yantis & Jonides, 1984), move, or are of a different colour than the other stimuli in an array (Treisman & Gelade, 1980) generally “pop out” during tasks requiring divided attention or visual search. These stimulus properties, however, do not invariably capture attention when observers are neither searching for them nor expecting to see them (Mack, Pappas, Silverman, & Gay, 2002). Interestingly, this attentional blindness does not occur for face stimuli (Downing, Bray, Rogers, & Childs, 2004; Mack et al., 2002), suggesting that detecting faces may be unavoidable because of their biological and social significance (Palermo & Rhodes, 2007). Related research by Suzuki and Cavanagh (1995) has demonstrated that participants are also slower to detect the curvature of a single line when it appears in a face configuration of three curved arcs than in a meaningless configuration, indicating that facial configurations cannot be ignored even when it would be advantageous to do so. This research complements other work demonstrating that viewers show a general attentional bias favouring “animate” stimuli (e.g., faces, bodies, agents) over inanimate objects (Cavanagh, Labianca, & Thornton, 2001; Langton et al., 2007; Nummenmaa, Hyona, & Calvo, 2006; Stanley, Gowen, & Miall, 2007; Hershler & Hochstein, 2005; Vuilleumier & Schwartz, 2001; but see VanRullen, 2006).

Further evidence that faces may preferentially engage attentional resources comes from infant research. Eye and head movement studies have shown that newborns will follow a schematic face farther into the periphery than other types of stimuli (Easterbrook, Kisilevsky, Muir, & Laplante, 1999a; Johnson, Dziurawiec, Ellis, & Morton, 1991; Goren, Sarty, & Wu, 1975). Goren and colleagues (1975) presented different two-dimensional, head-shaped forms to 40 healthy newborns soon after birth (Goren et al., 1975). Infants as young as three minutes old turned their head and eyes further for forms depicting a face than those depicting a scrambled face or a blank pattern. The newborns also turned their heads more to view the scrambled face than to view the blank stimulus. The latter result suggests that, in addition to configural information, some aspects of the facial features themselves are important for preferential tracking (Johnson et al., 1991). Other researchers have also reported that newborns look longer at nonface patterns that nonetheless resemble faces than at those that do not (Valenza, Simion, Cassia, & Umilta, 1996), and prefer to look at faces that engage them in eye contact (Farroni, Csibra, Simion, & Johnson, 2002). Research such as this provides evidence that the preference to view human faces and the ability to process them may be innate and experience-independent (Simion et al., 2007).

In light of the evidence indicating that faces recruit or “capture” attentional resources, we tested whether or not individuals would show differences in the ways that they process and alternate between the interpretations of ambiguous figures containing faces, and those that do not. First, we compared the number of spontaneous reversals that participants made for content-reversible figures (where both interpretations were of faces or agents) and perceptive-reversible figures (where both interpretations were of objects). If faces do capture attention then one might expect to see that participants would focus in on the first face they perceive and fail to spontaneously generate the alternative; on the other hand, if both interpretations compete for attention equally, they might find it relatively easy to spontaneously generate both interpretations (compared to their response to perspective-reversible figures).

Second, we compared the informed, perceptual reversal behaviours for three categories of content-reversible ambiguous figures: (a) figures containing two face interpretations (Boring's young girl-old woman); (b) figures containing one face and one object (Rubin's vase-face); and (c) figures in which both interpretations are of objects (the Maltese cross). In addition, we compared participants' responses to figures in each of these categories to those exhibited while they processed the perspective-reversible Necker cube. Finally, we explored whether the type of ambiguous figure being viewed affected participants' responses to an instruction manipulation; specifically, we compared their reversal rates for each class of figure under passive viewing conditions to those seen following instructions to alternate either slowly or quickly.

Exploring the effect of inversion on perceptual reversals

Humans' ability to quickly and easily recognize faces is thought to arise, in large measure, from our ability to process faces holistically. The term holistic has a number of definitions that are fairly similar to one another (Gauthier & Tarr, 1997; Maurer, Grand, & Mondloch, 2002). For example, Gauthier and Tarr describe three types of holistic processing: (a) in holistic-configural processing the relative spatial locations of individual facial features are extracted; (b) holistic-inclusive processing occurs when identification of a part is influenced by the processing of other, nearby parts even when these are not shown in the correct configuration; and (c) in holistic-contextual processing, parts are recognized better in context than in isolation. Other researchers suggest that holistic face processing involves the extraction of featural or first-order relations (e.g., the nose is above the mouth) and second-order spatial relations (e.g., the eyes are separated by 5.5 cm) (Maurer et al., 2002; Rakover, 2002; Simion et al., 2007).

Faces are more than a collection of component parts, and the holistic processing that they undergo does not occur to the same degree for (nonface) objects without extensive training (Gauthier & Tarr, 1997). Some researchers have even suggested that configural information alone is sufficient for face recognition, and that the specific facial features of particular people are not needed to identify them (Harmon, 1973; Haig, 1984). Harmon demonstrated that even when high-frequency information in photographs of faces was blurred (thus degrading the individual features but maintaining the global information), the faces were still recognizable. Many other classes of stimuli, however, are remembered on the basis of a single feature (i.e., they are processed in a parts- or feature-based manner). For example, a particular house can be remembered by the colour of its front door, or a certain car might be remembered by the dent it has on its bumper. These observations are supported by studies demonstrating that more high-frequency information is needed to be able to discriminate between pairs of nonliving objects that are similar to one another in global form but differ in local features (e.g., pliers and scissors) than to discriminate between pairs of living things that are similar to one another (Vannucci, Viggiano, & Argenti, 2001; Viggiano, Righi, & Galli, 2006; Viggiano, Costantini, Vannucci, & Righi, 2004).

Because faces are embedded with configural or global information and are processed holistically (Gauthier & Tarr, 2002; Lobmaier et al., 2008; Letourneau & Mitchell, 2008; Farah et al., 1995a; Marotta et al., 2002; Ross & Turkewitz, 1981; Diamond & Carey, 1986), face matching, recognition, and classification are highly sensitive to inversion (Farah et al., 1995b; Farah et al., 1995a; Leehey et al., 1978; Ross & Turkewitz, 1981; Rossion et al., 1999; Vermeire & Hamilton, 1998; Yovel &

Kanwisher, 2004). In other words, turning faces upside down results in a proportionally larger decrement in performance than that seen when one inverts objects (Williams & Henderson, 2007; Yin, 1969; Yin, 1970; Diamond & Carey, 1986). This performance decrement may reflect the fact that inverted faces are being treated, not as faces, but as objects by the visual system. Studies exploring the impact of inversion on neural responses in the fusiform face area (FFA) have shown that , although upright and inverted faces produce similar amounts of neural activity within the FFA (Gauthier et al., 1999; Aguirre, Singh, & D'Esposito, 1999; Kanwisher, Tong, & Nakayama, 1998), the FFA responds hundreds of milliseconds later to inverted than to upright faces (Susac, Ilmoniemi, Pihko, & Supek, 2004). This electrophysiological delay is hypothesized to occur because inverted faces are first processed by other regions (object regions such as the lateral occipital cortex) before eventually being perceived as faces (Aguirre et al., 1999). Like the FFA, object processing areas also show differential activation associated with stimulus inversion. However, whereas object processing regions show an increase in evoked response when participants view inverted faces or objects, the presentation of inverted objects does not have any effect on the activity of face regions (Aguirre et al., 1999; Epstein et al., 2006; Haxby et al., 1999). These results suggest that inverted faces are initially processed like objects (Aguirre et al., 1999; Epstein et al., 2006; Haxby et al., 1996).

A question that arises is whether inversion of an ambiguous figure containing faces would alter participants' looking behaviours (i.e., lead to an "inversion effect") and, if so, whether this effect would vary in magnitude depending on task instructions. Indeed, previous research using *figure-ground displays* has shown that high denotative regions are perceived longer when presented in upright than when presented upside-down (Gibson & Peterson, 1994; Peterson et al., 1991; Peterson & Gibson, 1994). Peterson and colleagues have suggested that this inversion effect occurs because the overall shape of a high denotative region is more easily accessed from memory when it is presented in its canonical orientation.

We hypothesized that individuals would respond differently (e.g., in terms of the number of switches they exhibit or in their eye gaze behaviours), when viewing upright versus inverted versions of the Rubin's vase-face (see Figure 2.2). Specifically, viewers were expected to perceive the faces interpretation for a shorter period of time when viewing the inverted than when viewing the upright ambiguous figure, resulting in relatively more time being spent perceiving the vase interpretation. In other words, they were expected to exhibit an "inversion effect." It is important to note, here, that this use of the term "inversion effect" differs from the classical definition. As described above, in the classical definition of the face inversion effect, upside-down presentation of faces causes a significant *decrement* in performance. Our definition refers simply to a *change* in performance or responding that is associated with stimulus inversion.

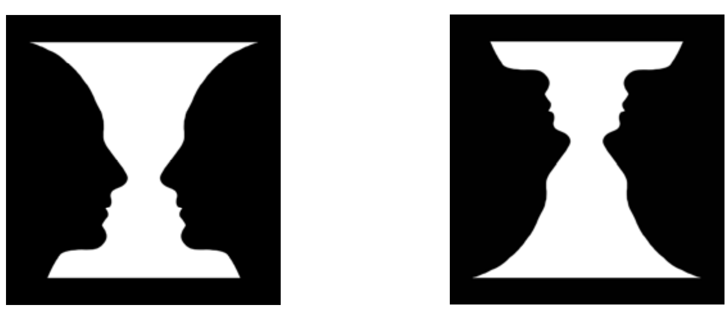

Figure 2.2. **Rubin's vase-face figures: (a) upright and (b) inverted.**

Summary

Two different tasks were used to investigate both perceptual reversibility and face processing mechanisms – the Spontaneous Reversals Task and the Informed Reversals Experiment. In the Spontaneous Reversals Task, individuals were not informed that the figures they were viewing were perceptually ambiguous; they were simply asked to tell the experimenter what each figure depicted. We predicted that individuals would show a difference in the number of spontaneously generated interpretations for two classes of ambiguous figures – content-reversible figures involving faces or agents, and perspective-reversible figures. In the Informed Reversals Experiment, participants were explicitly made aware of the fact that the figures they were viewing were ambiguous. By using the novel approach of using ambiguous figures to study face processing, we were able to investigate individuals' ability to generate reversals and selectively control their attention with face vs. nonface stimuli, under a variety of conditions. What we expected to find was that their ability to do so would vary as a function of figure type, instructional set, and (in the case of the Rubin's vase-face) stimulus inversion.

Method

Participants

Twenty participants (10 female, 10 male; mean age: 19.65 years; *SD* = .88 years; range: 18-21 years)[3] were recruited through the Introductory Psychology participant pool at the University of Manitoba and were given credit toward a course requirement for their

[3] Group size was determined from the results of a pilot study (using five participants from the Introductory Psychology participant pool). In that pilot study, the mean percentage of time that participants reported (via a key press) that they were perceiving the face of both the upright and inverted Rubin's vase-face figures were entered into a power analysis. A mean difference of approximately 20 percentage points (*SD* = 10 points) for this variable was estimated to have an effect size of approximately 1.88 for the neurotypical viewer (G*Power 3.1.10, Faul, Erdfelder, Lang, & Buchner, 2007). By Cohen's conventions (Cohen, 1988), this effect size is considered large. In order to obtain power of at least .80, a sample size of at least 15 was required to see differences between the upright and inverted Rubin's faces.

participation. All participants had normal or corrected-to-normal vision, and had no known history of neurological or developmental problems.

The testing protocol was approved by the Human Research Ethics Board at the University of Manitoba.

Materials and Procedure

Participants were tested in individual sessions. During the experimental session, each participant read and signed a consent form, completed a General Information Questionnaire (see Appendix A), had his/her visual acuity assessed, and completed the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) before beginning the experimental tasks. The General Information Questionnaire was designed to provide relevant demographic information. Collecting this information is deemed necessary in order to determine whether any subsequent variables (e.g., parental education, academic problems) contribute to the participants' performance on the measures, as these factors have been shown to be related to cognitive development (Sommerfelt, Ellertsen, & Markestad, 1995).

The near point acuity card (AMG Medical Inc.) was placed 14 inches from the participant. Each near point acuity card has rows of numbers; font size decreases across rows. The participant was asked to read the numbers shown to the right eye (left eye closed), to the left eye (right eye closed), and then to both eyes. The test was discontinued if the participant responded incorrectly to three items in a given line. The highest acuity line for which the participant received fewer than three items incorrect was recorded as the acuity for the tested eye. This test was used to ensure that the participants had adequate corrected vision (at least 20/40 or better for both eyes) for this task.

The WASI was administered according to the standardized procedure and was used for the purposes of matching this group of participants to a group of individuals with Asperger Syndrome (AS; see Chapter 3).

Following the assessment measures described above, participants completed two ambiguous figures reversal experiments – the Spontaneous Reversals Task and the Informed Reversals Experiment. To ensure clarity, the procedures for both experiments were described verbally and presented to each participant in writing. Participants also had the opportunity to ask for clarification during the presentation of the instructions and practice trials.

Spontaneous Reversals Task. The Spontaneous Reversals Task was administered first and tested the participant's ability to spontaneously switch between different interpretations of each ambiguous figure in a set. The stimuli for the spontaneous reversals experiment were presented on 8.5" x 11" cards in a standard order. The stimuli consisted of eight different black and white ambiguous figures, each with two possible interpretations. Four of the ambiguous figures were members of the content-reversible category; both interpretations of each of these figures included a face or full body (face/saxophone player, father-in-law/son-in-law, chef/dog, and Boring's young girl-old woman). The remaining four figures were perspective-reversible figures (two cubes, folded paper, Schröder staircase, and the Necker cube). On each trial, the participant was asked to indicate what they saw initially, and then if they saw anything else on further inspection (these instructions are similar to those used by Sobel, Capps, & Gopnik, 2005). The participant's responses were recorded on a scoring sheet (see Appendix B). The maximum total score was 16 points, a score that would indicate that both interpretations of each of the eight figures had been spontaneously generated. Two subtotals were also calculated – one for the content-reversible subset and one for the perspective-reversible subset of ambiguous figures.

Informed Reversals Experiment. The participants' ability to control their attention in order to influence the timing of their perceptual reversals was tested with the Informed Reversals Experiment. The stimuli consist of seven ambiguous figures, each with two possible interpretations: Boring's young girl-old woman, upright and inverted versions of the Rubin's vase-face figure, the Maltese cross, the Necker cube (see Figures 2.1 and 2.2, above), and two other figures administered for pilot-testing purposes (results from these two figures will not be described in the present thesis). The Rubin's vase-face figure used in the present study was created in Adobe Illustrator using the profile image of the experimenter (see Figure 2.3). The profile was copied and the copy was flipped along the vertical axis and pasted next to the original. The inverted vase-faces figure was created by flipping the upright version along the planar axis.

***Figure 2.3.* The version of Rubin's vase-face figure that was used in the present experiment was created using a real human face profile.**

The stimuli for the Informed Reversals Experiment were presented on the 17 inch monitor of the Tobii 1750 eye-tracking system using Tobii Studio Enterprise experimental software. The Tobii 1750 eye-tracker records the reflection patterns of near infra-red light on the cornea of both eyes of the viewer (frame rate = 70 Hz, accuracy = 0.5°, spatial resolution = 0.25°). The eye-tracker camera is embedded in the monitor below the screen. The camera measures 20 x 15 x 20 cm (width x height x depth) at 55 cm from the screen and allows data to be recorded from a freely moving viewer. Head motion of approximately 30 x 15 x 20 cm is compensated for by the Tobii 1750 eye-tracking system. During each trial, the three-dimensional position in space of each eyeball, and the gaze point on the screen (i.e., where the viewer is looking), are calculated. If the eye-tracker fails to capture the corneal reflection, it can recover in less that 100 ms to continue eye tracking (Tobii User Manual, 2003).

Each ambiguous figure subtended approximately 14º x 14º and all figures were the same contrast (i.e., black on white backgrounds) as these characteristics have been shown to affect perceptual reversals (Babich & Standing, 1981; Calvert et al., 1988; García-Pérez, 1989; Hasson et al., 2001; Scotto, Oliva, & Tuccio, 1990). Participants made key press responses on the keyboard of a PC computer, and gaze information was collected by the high resolution eye-tracking camera. The participant was seated approximately 55-60 cm from the computer screen. Because the system compensates for large and rapid head movements, participants can sit entirely unrestrained (e.g., helmets, head-rests, or markers were not used).

Prior to the experimental trials, participants completed a 5-point calibration trial. Participants were asked to look at a black dot on a white background. The dot moved relatively slowly and randomly to five locations on the screen. At each screen location, the dot appeared to grow and shrink in size before moving to the next location. Upon completion of the calibration trial, immediate feedback is given regarding the quality of the calibration.

The experiment involved completion of a control task and three experimental conditions. The purpose of the control task was to familiarize participants with the response keys on the computer, and to allow measurements to be made of their response latencies (Einhäuser et al., 2004) in each part of the experiment. The control task was presented prior to each of the three parts of the informed reversals experiment and then once more after part three, for a total of four presentations. During each administration of the control task participants were asked to press a red key with their left hand when they saw the word 'LEFT' on the screen and to press a green key with their right hand when they saw the word 'RIGHT'. These words appeared in black type on a white background (width approximately 1° visual angle). The words 'LEFT' and 'RIGHT' were presented three times each in a pseudo-random order, every 3 s; the same word did not appear more than twice in a row in any given administration. In order to control for expectancy effects in the control task, the trials were presented in a different order each time that the control task was administered. Response latencies measured during the control tasks administered immediately before and after a given experimental condition were averaged, and this measure served as the estimated response latency for each trial in that experimental condition (as per Einhäuser et al., 2004).

Prior to the first experimental trial, participants were presented with a 30-s practice trial in order to familiarize them with the type of stimuli to be shown in the remainder of the experiment, and the response keys. Jastrow's duck-rabbit figure was presented during the first practice trial, and if participants had difficulty understanding the instructions of the task a second practice trial (employing the Schröder staircase) was administered.

During the experiment, specific instructions preceded the presentation of each test figure and were given both visually and orally. Participants were shown each stimulus figure prior to viewing it on the computer screen to be certain that they could see both interpretations. If participants indicated that they were only able to see a single interpretation of a given ambiguous figure, further instructions were provided. In addition, instructions regarding which keys should be pressed for each interpretation of the presented figure were made explicit. Participants then viewed a test figure that appeared on the computer screen for 90 s and made the appropriate key press responses to indicate which interpretation of the figure they were perceiving at any given point in time (see below). Short breaks between trials were given as needed to prevent fatigue. The procedures followed in the Informed Reversals Experiment were similar to those employed by Meng and Tong (2004) and Einhäuser et al. (2004).

Participants viewed each stimulus figure three times – that is, once in each of three conditions. In the *passive viewing* condition, participants were asked to view the figure that was shown to them and to press the red key when they perceived one of the two interpretations, and the green key when they perceived the other interpretation[4]. In the *alternate slowly* condition, participants were asked to try to alternate between seeing the two interpretations as slowly as possible. In other words, participants were

[4] Participants in experiments such as this can be asked to make either a two-button response or a three-button response (cf. Einhäuser et al., 2004). In the present study, the option to have participants report a third or indeterminate percept was considered; nevertheless, the decision to proceed with the two-button response was used for two reasons. First, it is easier for participants to learn. Second, Wolfgang Einhäuser (personal communication, October 21, 2007) indicated that, for naïve participants, the indeterminate percept is unlikely to dominate, and that it is only in expert viewers that the indeterminate percept becomes necessary to track.

encouraged to prevent the figures from reversing. Again participants indicated with a key press which interpretation they perceived at any given time. Finally, in the *alternate quickly* condition, participants were asked to try to alternate between seeing the two interpretations as quickly as possible. They were asked to indicate with a key press when a switch occurred. The three conditions were always run in the order described above; however, the different stimulus figures were presented in random order within each condition. After the Informed Reversals Experiment, participants were asked to indicate, by placing a mark on a copy of the stimulus figure, where on the figure they believed they had focused their attention when perceiving a particular interpretation. They were also asked to comment on anything else they may have noticed about each of the stimulus figures presented.

Data Analysis. Data points showing poor validity, including off-screen gazes, were excluded from data analysis. A number of dependent variables were extracted for each trial in a given condition. First, the total number of fixations made during presentation of each figure, and the number made while subjects' reported holding a given interpretation, were calculated. Here, a fixation was defined as a set of consecutive gaze coordinates, confined within a diameter of 1° of visual angle for a minimum duration of 200 ms (Ellis & Stark, 1978; Noton & Stark, 1971a). Next, the time participants spent perceiving each of two interpretations of each figure was measured (based on duration of key press responses). Finally, perceptual reversal rates were computed. A perceptual reversal was indicated each time participants switched between one key press response and the other. On each trial, the total number of reversals was divided by the time that the figure was presented (i.e., 90 s) to give a perceptual reversal rate (expressed as the number of reversals made per minute).

Results

Spontaneous Reversals Task

In the present study, eight ambiguous figures (each with two possible interpretations) were shown to participants in order to examine their ability to produce spontaneous reversals. On average, participants reported 10.5 (*SD* = 2.01) out of a total of 16 possible interpretations. A one-sample *t*-test (comparing the scores to eight) confirmed that participants were able to spontaneously generate more than one interpretation per figure, $t(19) = 5.55$, $p < .001$. We hypothesized that individuals in the general population might show a difference in the number of spontaneously generated interpretations for two classes of ambiguous figures – content-reversible and perspective-reversible. The results of a paired samples *t*-test did not confirm this particular hypothesis: the subscores for the content-reversible figures (*M* = 5.30, *SD* = 1.38) did not differ from the scores for the perspective-reversible figures (*M* = 5.20, *SD* = 1.15), $t(19) = .33$, $p = .75$. Additional planned analyses comparing each of the two subscores to four (i.e., the score suggesting that viewers can only perceive one interpretation per figure) indicated that participants were able to generate more than four interpretations for the set of content-reversible, $t(19) = 4.21$, $p < .001$, and more than four interpretations for the set of perspective-reversible figures, $t(19) = 4.66$, $p = < .001$.

Summary. We sought to answer two questions with this task: (a) Are individuals able to perceive more than one interpretation per figure when uninformed about its ambiguity; and (b) if so, do they show differences in the number of interpretations made between content-reversible and perspective-reversible figures? The answers to these questions are: yes and no, respectively. Participants were able to generate more than one interpretation per figure on the task as a whole, but they did not show differences in the number of interpretations they generated between categories of figures.

Informed Reversals Experiment: Passive Viewing Condition

One of the goals of the present study was to determine whether or not individuals would show differences in the way that they process and alternate between two interpretations of ambiguous figures in each of three content-reversible categories: (a) figures depicting two face interpretations (Boring’s young girl-old woman); (b) figures containing one face and one object (Rubin’s vase-face); and (c) figures in which both interpretations are of objects (the Maltese cross). In addition, participants’ responses to these content-reversible ambiguous figures were hypothesized to differ from those exhibited while they processed the perspective-reversible Necker-cube. For the purpose of the present study, four key variables were examined: perceptual reversal rate, time spent perceiving each of two interpretations, total number of fixations made (per figure), and the number of fixations made for each interpretation of a given figure.

Perceptual reversal rates for the passive viewing condition were entered into a one-factor repeated measures ANOVA. No main effect of Figure was observed, $F(3, 57) = 2.15$, $p > .10$, $\eta_p^2 = .10$. Thus, participants showed comparable perceptual reversal rates for each of the different types of figures in the passive viewing condition.

To determine whether participants would show a “preference” for a given interpretation of any of the figures, we conducted planned comparisons to test for differences in the time spent perceiving each interpretation, for each of the test figures. (This approach was also used in Chapter 3.) Note that, here and below, we arbitrarily designated the two interpretations of a given figure as Interpretation 1 and Interpretation 2. For Boring's young girl-old woman, the old woman was designated as Interpretation 1, and the young girl was designated as Interpretation 2. Interpretation 1 of Rubin's vase-face was the faces and the vase comprised Interpretation 2. For the Maltese cross, the vertically oriented cross was Interpretation 1 and the oblique cross was Interpretation 2. Finally, the top view of the Necker cube was Interpretation 1 and the bottom view was Interpretation 2.

The results of the planned comparisons showed that, as expected, participants did not *consistently* divide their time evenly between the two interpretations of a given figure (see Figure 2.4). Specifically, participants reported perceiving one of the two interpretations significantly longer than the other (i.e., they showed a "preference") for three of the four figures. Thus, participants reported a preference for perceiving the top view of the Necker cube, $t(19) = 2.42$, $p < .03$, the upright interpretation of the Maltese cross, $t(19) = 3.38$, $p < .004$, and the face interpretation of the Rubin's vase-face, $t(19) = -3.25$, $p < .005$. No preferences were observed for the Boring's young girl-old woman figure. In other words, only when participants alternated between two faces were they able to distribute their attention equally between the two interpretations.

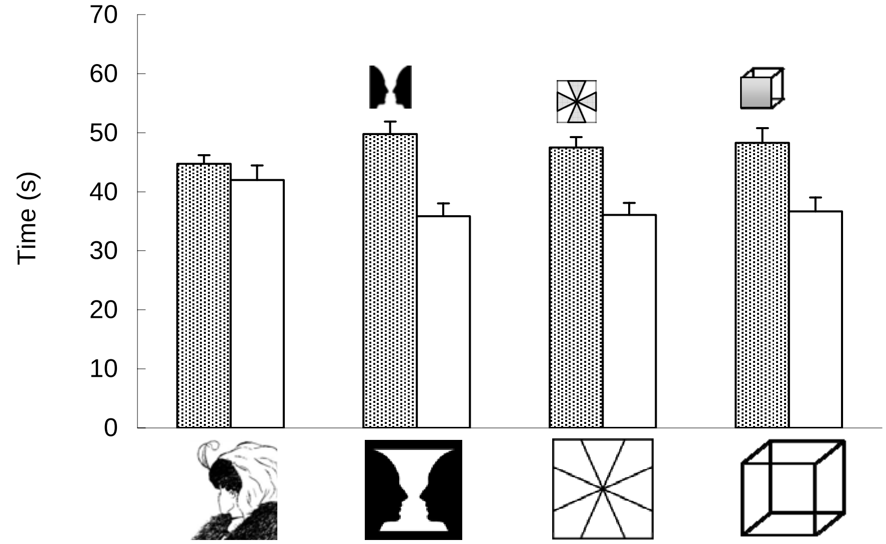

Figure 2.4. **Time spent perceiving each interpretation of Boring's young girl-old woman, Rubin's vase-face, the Maltese cross, and the Necker cube as reported by key presses made during the passive viewing condition of the Informed Reversals Experiment. Standard errors indicated.**

The total number of fixations made when viewing each of the four figures were submitted to a one-factor, repeated measures ANOVA. This analysis revealed a significant main effect of Figure, $F(3, 57) = 8.91$, $p < .001$, $\eta_p^2 = .32$ (see Figure 2.5). Follow-up tests (least squares difference, LSD) showed that participants made fewer fixations when viewing the Maltese cross than when viewing any other figure ($p < .007$ in all cases). They also tended to make fewer fixations ($p < .06$) when viewing Rubin's vase-face than when viewing the Necker cube.

Planned comparisons revealed that when viewing Rubin's vase-face, they made more fixations when perceiving the (preferred) face interpretation than when perceiving the (nonpreferred) vase interpretation, $t(19) = -2.94$, $p < .01$. Similarly, for the Necker cube, participants tended make more fixations while perceiving the (preferred) top view than the (nonpreferred) bottom view, $t(19) = 1.77$, $p = .09$. Despite the fact that there was a clear preference for the vertical interpretation of the Maltese cross figure (in terms of time spent perceiving each interpretation), no significant differences in fixations were seen for the two interpretations of this figure. Again, for Boring's young girl-old woman no significant differences in the number of fixations were seen for the two interpretations, consistent with the fact that no preference (in terms of time spent perceiving each interpretation) were observed for this figure (see Figure 2.6).

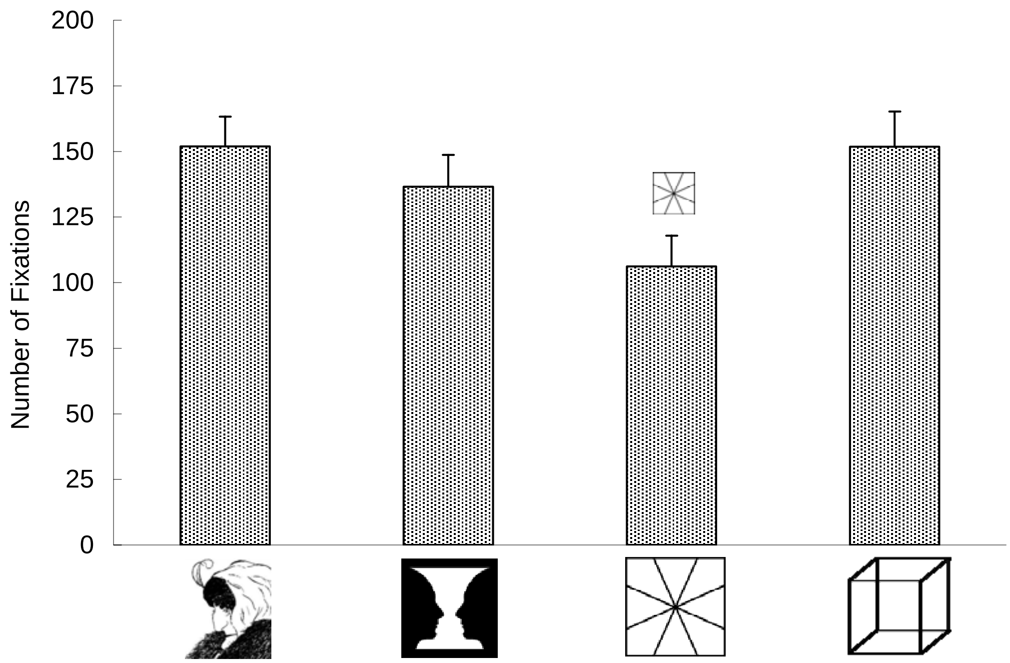

Figure 2.5. **The total number of fixations that participants made for each ambiguous figure in the passive viewing condition of the Informed Reversals Experiment. The number of fixations made while viewing the Maltese cross was significantly lower than for the other three figures.**

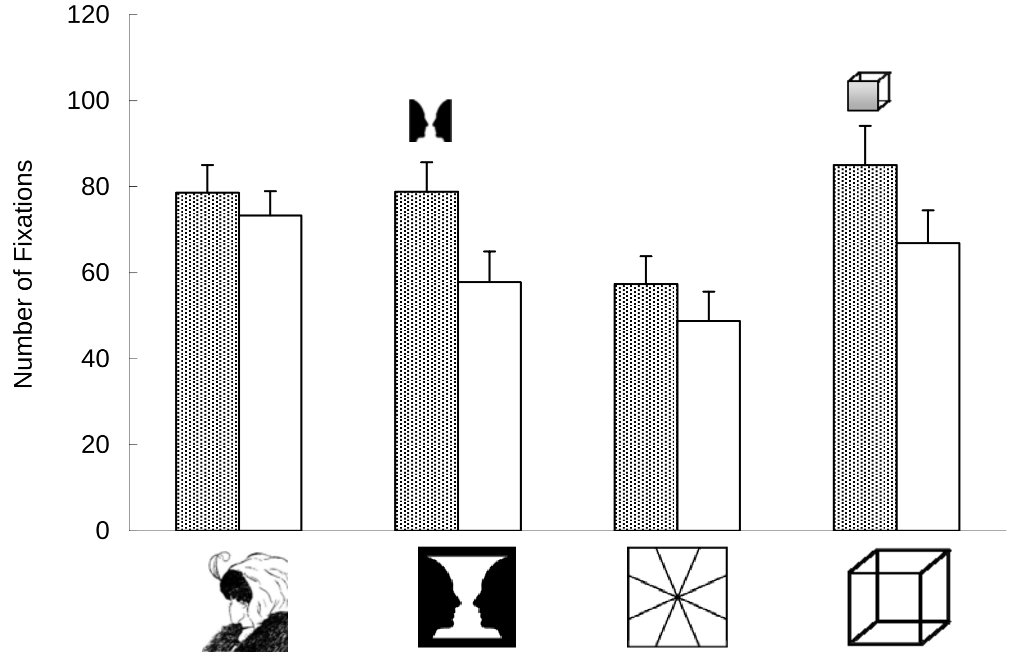

Figure 2.6. **The number of fixations made while participants reported perceiving each interpretation of Boring's young girl-old woman, Rubin's vase-face, the Maltese cross, and the Necker cube. Significant differences between the two interpretations of a given figure are indicated with a picture of the interpretation that had the highest number of fixations associated with it. Standard errors are indicated.**

Further inspection of the data suggested that, in fact, a systematic relationship was observed between eye movements and perceptual preferences for each of the four figures. This can be seen by examining the correlations between two sets of difference scores. The first score, which we call a *preference score*, is computed by subtracting the time spent perceiving Interpretation 2 from the time spent perceiving Interpretation 1. Here, positive scores indicate a preference for Interpretation 1, while negative scores indicate a preference for Interpretation 2. The second score, a *fixation bias score*, is computed by subtracting the number of fixations made while perceiving Interpretation 2 from the number of fixations made while perceiving Interpretation 1. In this case, positive scores indicate that relatively more fixations were made when perceiving Interpretation 1, while negative scores indicate that relatively more fixations were made when perceiving

Interpretation 2. A positive correlation between these two difference scores would be seen if participants made relatively more fixations when perceiving their own “preferred” view. A negative correlation between these two difference scores would be seen if participants made relatively more fixations when perceiving their own “nonpreferred” view. As can be seen in Figure 2.7, for each of the four ambiguous figures we see a strong, positive correlation between these variables: Boring’s young girl-old woman, $r(20) = .64$, $p < .003$; Rubin’s vase-face, $r(20) = .83$, $p < .001$; Maltese cross, $r(20) = .55$, $p < .01$; and the Necker cube, $r(20) = .86$, $p < .001$.

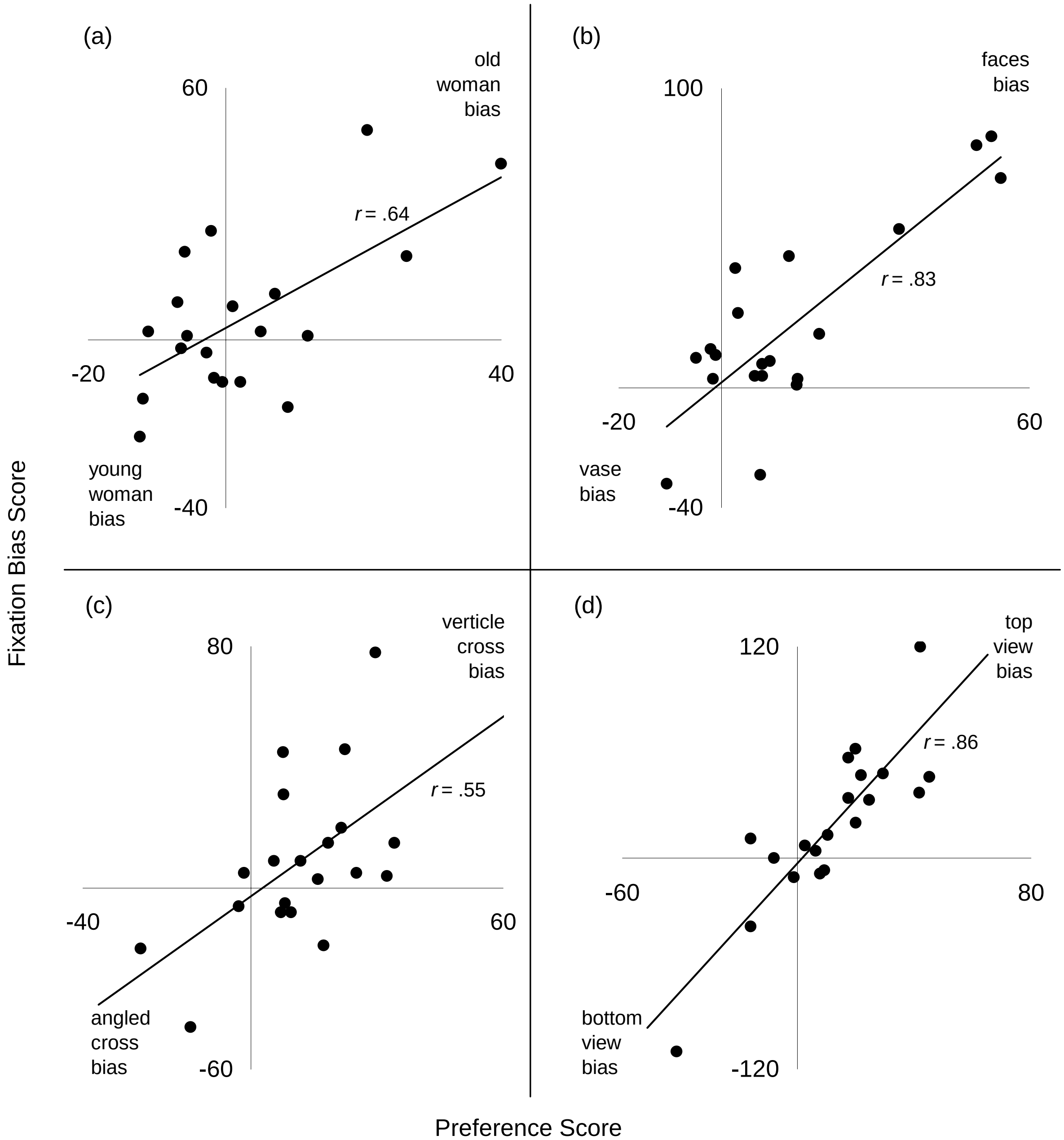

Figure 2.7. **Correlations between the preference scores and fixation bias scores for: (a) Boring's young girl-old woman; (b) Rubin's vase-face; (c) Maltese cross; and (d) Necker cube.**

Summary. In this analysis of the Informed Reversals Experiment, we obtained the answers for two main questions. First, do the perceptual reversal patterns for the three categories of content-reversible ambiguous figures differ from each other? Second, do the perceptual reversal patterns for the content-reversible figures differ from the patterns for the perspective-reversible Necker cube? We found that the answers to these questions differed depending on the dependent variable being examined.

In terms of the perceptual reversal rates, we found no differences across the four figures in the passive viewing condition. In addition, the correlation analyses showed that, with all four figures, participants made more fixations when perceiving their own “preferred” view than when perceiving their own “nonpreferred” view. In this sense, then, participants also responded similarly to all four figures. Clear differences did emerge, however, for two other variables. First, participants showed preferences (in terms of time) to perceive the faces in Rubin’s vase-face, the vertical cross of the Maltese cross, and the top view of the Necker cube, but showed no preference for either interpretation of Boring’s young girl-old woman. So, for this variable, Boring’s young girl-old woman stands apart from the other two content-reversible figures, and also from the perspective-reversible Necker cube. Significant differences between the figures were also seen in participants’ fixation behaviours. Specifically, fewer fixations were made for the Maltese cross than for either of the other two content-reversible figures, or for the perspective-reversible Necker cube.

Informed Reversals Experiment: Effect of Instruction

Perceptual reversal rates were entered into a 3 (Instruction: slow alternating, passive viewing, fast alternating) x 4 (Figure: Rubin’s vase-face, Necker cube, Boring’s young girl-old woman, Maltese cross) ANOVA, with repeated measures on both factors. As expected, a main effect of Instruction was observed, $F(2, 36) = 64.17$, $p < .001$, $\eta_p^2 = .78$. Follow-up tests (LSD) indicated a significant difference between the slow and passive viewing conditions, the slow and fast conditions, and the passive and fast conditions ($p < .001$ for all three comparisons).

The rates of participants' switches in perception also differed between Figures, $F(3, 54) = 7.09$, $p < .001$, $\eta_p^2 = .28$. This main effect must be interpreted in the context of a significant Instruction x Figure interaction, $F(6, 108) = 6.35$, $p < .001$, $\eta_p^2 = .26$ (see Figure 2.8). Follow-up tests (LSD) for this interaction revealed that there was a significant effect of instruction for each figure. In addition, the perceptual reversal rates were similar for all four figures in both the slow instruction and the passive viewing conditions. It was only for the fast instruction condition that differences between the perceptual reversal rates were observed across figures. Switching rates were comparable for the Rubin's vase-face and the Boring's young girl-old woman figures ($p > .40$), and faster than those seen with either the Necker cube or the Maltese cross ($p < .01$ in both cases). No differences were found between the Necker cube and the Maltese cross ($p > .60$).

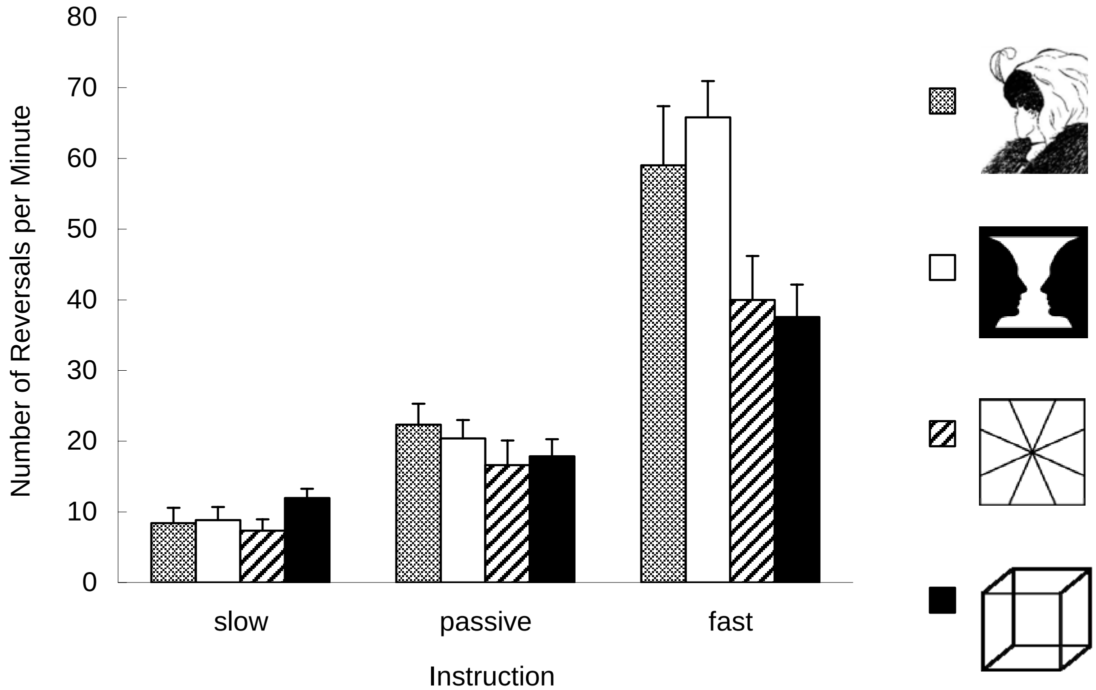

Figure 2.8. **Mean perceptual reversal rate for each ambiguous figures in the three instruction conditions. Perceptual reversal rates were calculated as the number of switches that participants reported per minute. Standard errors are indicated.**

Summary. The final question regarding content-reversible and perspective-reversible ambiguous figures was whether perceptual reversal rates seen with the four figures would change in different ways in response to the instruction manipulation. Firstly, we found that all four figures showed effects of instruction, and showed comparable reversal rates in the alternate slowly and passive viewing conditions. Differences between the figures emerged in the alternate quickly condition. With the three content-reversible figures, reversal rates were found to be higher for Boring's young girl-old woman and Rubin's vase-face than for the Maltese cross. In addition, reversal rates were higher for Boring's young girl-old woman and Rubin's vase-face than for the perspective-reversible Necker cube. In other words, the only content-reversible figure that showed a similar reversal rate to the Necker cube in the alternate quickly condition was the Maltese cross.

Informed Reversals Experiment: Effect of Inversion

The final set of analyses conducted on data collected in the Informed Reversals Experiment were designed to compare the perceptual reversal patterns associated with upright and inverted versions of the Rubin's vase-face.

Passive viewing condition. The first analyses in this set were based on data from the passive viewing condition. For stimuli presented in each orientation we calculated preference scores and fixation bias scores. Preference scores were computed by subtracting the length of time participants reported perceiving the vase from the length of time that they reported perceiving the faces. Fixation bias scores were computed by subtracting the number of fixations made while perceiving the vase from the number of fixations made while perceiving the faces. Positive values of either variable indicate a face preference or face bias, respectively.

Preference scores for upright and inverted stimuli were first compared using a repeated measures ANOVA. A significant difference between upright and inverted preference scores was revealed, $F(1, 19) = 5.84$, $p < .03$, $\eta_p^2 = .26$. Next, preference scores for upright and inverted stimuli were each compared to zero using one sample *t*-tests. When viewing upright stimuli, participants showed a significant face preference [$t(19) = 3.25$, $p < .005$], but this preference was eliminated by stimulus inversion [$t(19) = -0.45$, $p = .66$] (see Figure 2.9). A corresponding pattern was observed for the fixation bias scores. Participants made more fixations while perceiving the faces in the upright than in the inverted Rubin's vase-face figures, $F(1, 19) = 4.57$, $p < .05$, $\eta_p^2 = .19$. Again fixation bias scores were compared to zero. When viewing upright stimuli participants showed a significant bias to make more fixations when perceiving the faces [$t(19) = 2.94$, $p = .008$], but this bias is eliminated by stimulus inversion [$t(19) = -0.277$, $p = .785$] (see Figure 2.10).

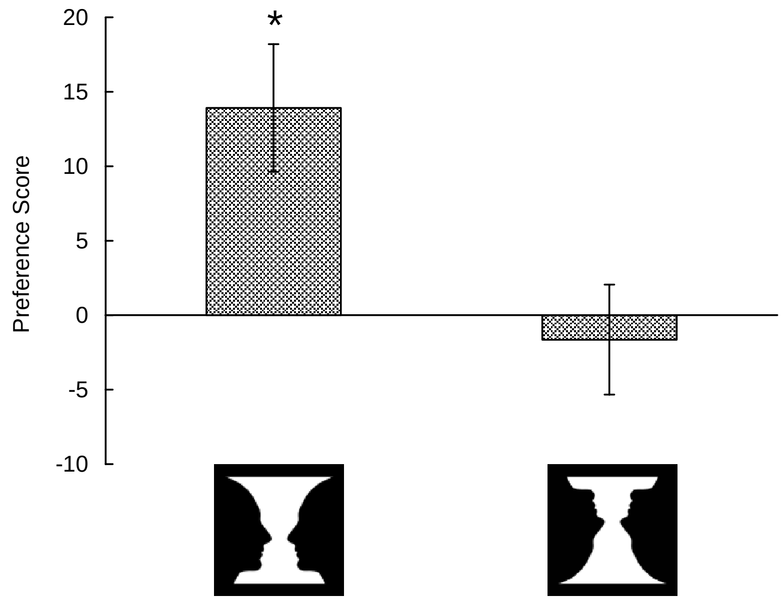

***Figure 2.9.* Rubin's vase-face preference scores in the passive viewing condition. Positive scores indicate a preference to perceive the face and negative scores indicate a preference to perceive the vase. Standard error indicated.**

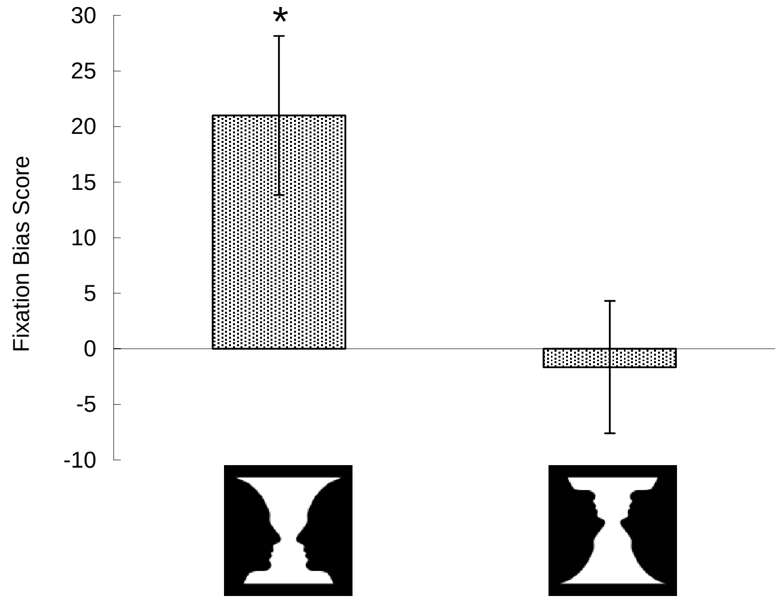

Figure 2.10. **Rubin's vase-face fixation bias scores for the passive viewing condition. Positive scores indicate that more fixations were made when perceiving the face and negative scores indicate that more fixations were made when perceiving the vase. Standard error indicated.**

Effect of instruction. In the final analysis, perceptual reversals rates were entered into a 3 (Instruction: slow, passive, fast) x 2 (Orientation: upright, inverted) ANOVA with repeated measures on both factors. A main effect of Instruction was revealed, $F(2, 34) = 38.30$, $p < .001$, $\eta_p^2 = .69$, with significant differences observed between slow, passive, and fast instructions ($p < .002$ for all comparisons) indicating that participants were able to selectively control their switching rate based on instruction (see Figure 2.11). The rates of participants' switches in perception also differed as a function of the figure's orientation, $F(1, 22) = 6.34$, $p = .02$, $\eta_p^2 = .27$. This main effect must be interpreted in the context of a significant Instruction x Orientations interaction, $F(2, 34) = 5.19$, $p < .03$, $\eta_p^2 = .23$ (see Figure 2.11). Follow-up tests (LSD) for this interaction revealed that it was only in the fast instruction condition that differences between the perceptual reversal rates for upright and inverted figures were observed, $t(26) = 2.17$, $p <$

.04, with participants showing significantly faster switching rates for upright figures.

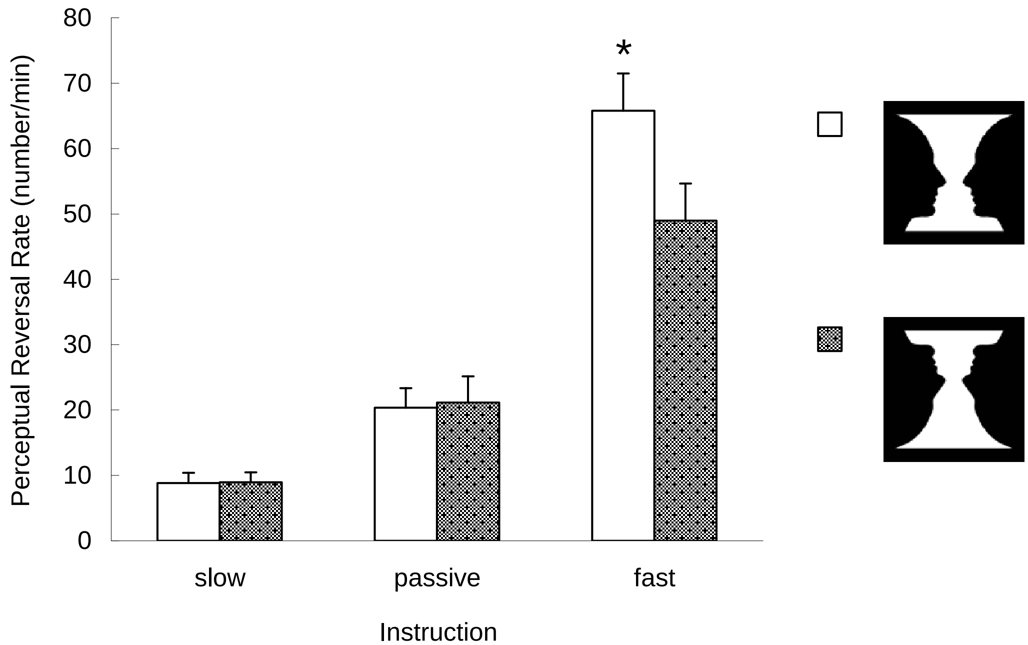

Figure 2.11. **Mean perceptual reversal rates for the upright and inverted Rubin's vase-face figures at each level of instruction. Standard error indicated.**

Summary

One of the objectives of the present study was to determine whether inversion of an ambiguous figure leads to an "inversion effect" and, if so, whether this effect would vary in magnitude depending on task instructions. In the passive viewing condition, participants showed a face bias for upright, but not inverted figures in terms of both the time spent perceiving a given interpretation, and the number of fixations made. In other words, participants showed an "inversion effect" in the sense that their reversal behaviours changed as they went from viewing upright to inverted displays; specifically, they went from showing a face preference or bias, to showing no preference or bias. Despite this, their perceptual reversal rates in the alternate slowly and passive viewing conditions were similar for stimuli displayed in either orientation. When instructed to alternate quickly, however, participants were able to generate faster switching rates for upright than for inverted displays.

Discussion

The general goal of the present research was to determine whether viewers would exhibit unique perceptual reversal patterns for different types of ambiguous figures. Specifically, participants were expected to spontaneously generate a different number of interpretations for figures involving faces than for those involving only objects. In addition, after participants were informed about the perceptual ambiguity of the figures, we expected to find that they would exhibit distinct switching patterns for content-reversible figures in which both interpretations were of faces (i.e., Boring's young girl-old woman), one interpretation was a face and the other an object (i.e., Rubin's vase-face), or both interpretations were of objects (i.e., the Maltese cross). It was also expected that the perspective-reversible Necker-cube would elicit a different reversal pattern than any of the content-reversible figures. Finally, we sought to determine if upright and inverted versions of the Rubin's face-vase would be processed in similar or different ways. Differences in perceptual reversal patterns were investigated by using the Spontaneous Reversals Task and the Informed Reversals Experiment. The latter task utilized eye tracking technology in addition to key press responses.

Spontaneous Reversals Task

Previous research has demonstrated that uninformed (naïve) individuals are generally unable to perceive more than one interpretation of an ambiguous figure (Girgus, Rock, & Egatz, 1977; Rock & Mitchener, 1992; Rock, Hall, & Davis, 1994).

When spontaneous reversals do occur, they occur only between 25 and 40 percent of the time in adults (Girgus et al., 1977; Rock & Mitchener, 1992; Rock et al., 1994). Our results appear to be largely consistent with this finding; thus participants did spontaneously generate more than one interpretation per figure, on average, but their scores certainly did not approach ceiling. Rock and colleagues argue that a high rate of spontaneous reversals is seen only when participants have had some prior knowledge pertaining to the ambiguity of the figures; in fact, it is possible that some of the participants in the current study had prior experience with some (or all) of the ambiguous figures that were presented to them. Unfortunately, no data were gathered to verify this. However, a few of the comments that participants made were recorded. They mentioned that although they had seen some of the figures before and they knew that there were two interpretations for the figures, they were unable to make the switches. These comments suggest that perhaps prior exposure to ambiguous figures may not be the only variable influencing one’s ability to spontaneously generate alternative interpretations (cf. Sobel at al. (2005).

Gopnik and colleagues have shown that children ages 4 years and younger are unable to understand that a picture can have multiple representations, however, the ability to spontaneously reverse occurs for a majority of children age 5 years and older (Mitroff et al., 2006; Sobel et al., 2005; Gopnik & Rosati, 2001; Rock, Gopnik, & Hall, 1994). These previous studies have typically used a maximum of three ambiguous figures and, incidentally, the figures that the researchers reported using were all content-reversible ambiguous figures containing faces. In the Spontaneous Reversals Task, we used four content-reversible figures (containing faces or agents) and four perspective-reversible figures (containing objects). Contrary to our expectations, we found that adults spontaneously generated a similar number of interpretations for figures in both categories. It may be that, in adults, differences only emerge when participants are informed about the ambiguity of the figures, and/or when they are pushed to try to switch between alternative interpretations as quickly as possible (cf. Strüber & Stadler, 1999). This may not be the case for children as perception of depth is under-developed at the age of five years (Simons, 1981) and may, in fact, still be developing up to the age of 12 years (Simons, 1981; Walraven & Janzen, 1993). Given this, it might be interesting in further research to test children to see if they would show different reversal patterns for figures requiring a shift in depth or perspective, and those that do not.

Informed Reversals Experiment: Passive Viewing Condition

Although we did not find a difference in the number of interpretations that were perceived in content-reversible and perspective-reversible ambiguous figures in the Spontaneous Reversals Task, we did find differences in reversal patterns in the Informed Reversals Experiment for the different types of figures. One of our hypotheses was that individuals would show differences in the way that they process and alternate between the two interpretations of each of three types of content-reversible ambiguous figures, and that the reversal patterns they exhibited with these figures would differ from those exhibited while processing the perspective-reversible Necker-cube figure. While we did not find differences between figures in terms of reversal rates under passive viewing conditions, differences on this variable did emerge when participants were instructed to alternate quickly. Here, reversal rates were much quicker for content-reversible figures containing faces than for either the Maltese cross or the perspective-reversible Necker cube. In addition, important differences did emerge in the passive viewing condition in reversal patterns seen with two other variables: time spent perceiving each interpretation, and the number of fixations made.

Participants reported perceiving one of the two interpretations for longer than the other for three of the four figures. On average, viewers showed a preference to perceive the top view of the Necker cube, the vertical cross of the Maltese cross, and the faces in Rubin's vase-face. Interestingly, it was only for Boring's young girl-old woman that no preference materialized. The fixation bias scores were consistent with the viewing time preferences. Thus, participants generated relatively more fixations when perceiving their own preferred view than when perceiving their nonpreferred view. These results appear to suggest that viewers engage in more active exploration of the figure when perceiving their preferred interpretation.

The fact that a preference to perceive one interpretation over the other was seen for Rubin's vase-face but not for Boring's young girl-old woman suggests that it may be easier for individuals to divide their attention equally between two faces than between a face and an object. Indeed, previous research has demonstrated that, in visual search tasks, participants take longer to find a nonface target when a face appears as one of the distractors (Langton et al., 2007). This is presumed to be due to the fact that the presence of a face (or facial features) captures attention (i.e., attention is preferentially drawn to faces over other stimuli). Interestingly, the face preference was seen with Rubin's vase-face even though only 11 of our 20 participants (55%) reported perceiving the faces interpretation of Rubin's vase-face *first*. Thus, even though the faces did not appear to capture participants' attention initially, clearly over time they did so. In other words, once a face has been attended to, it may be difficult to disengage attention from it, whether or not it was preferentially attended to in the first place (Fox, Russo, Bowles, & Dutton, 2001).

Alternatively, a preference for Rubin's vase-face but not for Boring's young girl-old woman may be due, in part, to the fact that Rubin's vase-face has figure-ground organization, with figure and ground differing in luminance. While it may be that the black faces simply draw one's attention more than the white vase, Peterson and Gibson (1994) have shown that the highly denotative "profile" interpretation can be held for an equivalent amount of time whether the figure and ground regions differ in polarity (as in the present study), or are of equal luminance but separated by a real or illusory contour. This group has also shown that it is easier to "hold" the profile interpretation in an upright Rubin's vase-face type figure when the center vase is shown in black and the profiles are white (Peterson et al., 1991). This is true despite the fact that a variety of additional cues, such as symmetry and enclosure, favor the vase as the figure (c.f. Driver & Bayliss, 1996). Peterson and colleagues attribute these findings to the fact that the profile interpretation is more meaningful (Gibson & Peterson, 1994; Peterson & Gibson, 1994; Peterson et al., 1991). In Boring's young girl-old woman, of course, both interpretations are faces and are arguably meaningful on these grounds, which may explain the lack of a clear preference for one interpretation over another for this figure. Of course, another factor that may have contributed to differences in responding to the two figures is that Boring's young girl-old woman contains more detail in the form of a greater number of lines and different shaded areas than Rubin's vase-face.

When viewing the Maltese cross, participants made fewer fixations than when they perceived any other figure, suggesting that eye movements were not needed to facilitate switches for this particular figure (a conclusion that was borne out by participants' self-report). They also showed a preference to perceive the vertically oriented over the oblique cross. This latter result may be explained by the "oblique effect". The oblique effect is defined as a "superiority in performance when visual stimuli are horizontal or vertical, as opposed to oblique" (Appelle, 1972, p. 266) and occurs in human adults and children and in other animals, such as goldfish, rats, and chimpanzees (for a review see Appelle, 1972). Jastrow (1893 in Appelle, 1972; and in Latto & Russell-Duff, 2002) was likely the first to describe this phenomenon when he asked participants to copy or place visually presented lines in a specified orientation. He found that task performance was superior for lines presented in a horizontal or vertical orientation.

With the Necker cube the top view was preferred to the bottom view. When viewing the Necker cube, the top view is what one would perceive if one were looking down on a cube that was sitting on a solid surface, such as a table. It may have been relatively easy for participants in the present study to adopt this perspective because the computer monitor displaying the cube was at eye level and supported by a table. Switching to the bottom view interpretation may have been much more difficult because the viewer would need to imagine that the cube was floating in mid air or hanging from an obscured rope. If it really is easier to perceive the top view interpretation of the Necker cube, we should find that the preference for the top view remains even after inversion of the stimulus about the planar axis, even though in this case the front face of the cube now lies on the right (rather than the left) side of the display. This could be tested in a future study.

Depth cues may also be involved in creating the preference we observed. For example, in the monocular depth cue of relative height or elevation, an object located below the horizon is perceived as being closer to viewer than if it is located above the horizon. For the top view of the Necker cube, the front face of the cube is mostly perceived below eye level which may make the cube appear closer to the viewer. In the alternative (bottom) view, more of the front face of the cube is above eye level, possibly making the cube appear further away. The preference for the top view in the present research may be the result of a combination of a lower-region preference (Vecera et al., 2002) and pictorial depth perception cues that reflect environmental regularity. It would be interesting to determine if interpretation preferences for the Necker cube could be manipulated by changing the physical location of the computer monitor or the fixation point, or by manipulating pictorial depth cues in the display.

Informed Reversals Experiment: Effect of Instruction

Consistent with previous research (Strüber & Stadler, 1999; Meng & Tong, 2004), participants in the present study were able to decrease and increase the speed of their reversals when instructed to do so. These results suggest that viewers have strong selective attentional control over their reversals, regardless of the type of ambiguous figure that is being viewed. As noted above, our results also showed significant differences in perceptual reversal rates for the different types of ambiguous figures in the alternate quickly instruction condition. Specifically, perceptual reversal rates were comparable for Rubin's vase-face and Boring's young girl-old woman, and rates for these figures were significantly faster than those seen with either the Necker cube or the Maltese cross. The difference seen between the figures may be because the latter two figures are line drawings whereas the former two are not. We argue against this idea. As noted above, in the case of figure-ground displays, whether the interpretations differ in luminance or are separated by a visible or illusory contour (e.g., a line) does not change which interpretation can be held longer (Peterson et al., 1991). While it is possible that this difference might influence the ability to switch quickly between interpretations, we think this is unlikely.

A more parsimonious explanation for the differences we observed for figures involving faces and those involving only objects is that top-down selective attentional control can be influenced by the content of the stimuli. These results are consistent with Strüber and Stadler's (1999) suggestion that meaningful figures show different switching patterns than less meaningful figures. However, we suggest that rather than defining the ambiguous figures along a continuum of meaningfulness, it might be more important to consider whether or not they contain faces or, more generally, whether or not people in the general population would be strongly predisposed to try to process the figure globally.

Interestingly, perceptual reversal rates were similar for Boring's young girl-old woman and Rubin's vase-face in the alternate quickly instruction condition. Why might this be the case? Is it that participants used a set processing mode (either global or local) when perceiving both interpretations of Rubin's vase-face in the alternate quickly instruction condition? We suggest that it might be easier to switch quickly between the faces and the vase when one adopts a particular processing strategy as opposed to switching between two different strategies. Examination of other variables for the alternate quickly instruction condition might help to answer the questions raised above.

Informed Reversals Experiment: Effect of Inversion

Because faces are preferred over nonface objects and draw our attention (Johnson et al., 1991; Valenza et al., 1996; Farroni et al., 2002; Cavanagh et al., 2001; Nummenmaa et al., 2006; Goren et al., 1975; Easterbrook et al., 1999a; Johnson et al., 1991), and because inverting faces typically results in a decrement in performance on recognition and matching tasks (e.g., Farah et al., 1995a), we hypothesized that the inversion of an ambiguous figure containing a face should cause a change in reversal behaviour (i.e., an “inversion effect”). We were particularly interested in inverting Rubin’s vase-face as it was the only figure in the set of figures used in our first analysis that contained both face and object interpretations. Studying the effects of inverting this figure, then, may allow us to determine if inverted faces compete for attention to the same degree that upright faces do.

The results of our experimental manipulation supported our predictions. When viewing upright stimuli participants showed a preference and a fixation bias for the face interpretation. These biases, however, were eliminated after stimulus inversion. This result cannot be attributed to a difference in luminance between the vase and faces interpretation, or indeed to a variety of other factors known to affect phenomenal figural assignment (c.f. Driver and Bayliss, 1996), as these were held constant in the upright and inverted displays. This result could, however, reflect the fact that, when the faces in Rubin’s vase-face were inverted, the faces became that much more challenging to perceive because inversion disrupted participants’ ability to process them holistically (Farah et al., 1995a; Bartlett & Searcy, 1993; Singer & Sheinberg, 2006; Yovel & Kanwisher, 2004; Peterson et al., 1991). If this interpretation is correct, then the results might suggest that the faces within the inverted ambiguous figure were perceived and processed more like objects than faces.

Some support for this conclusion comes from the data from the instruction manipulation. We were interested to see if participants' responses to the instruction manipulation would vary as a function of the orientation of the stimulus figure. This was, in fact, the case. Thus, we found that participants could not switch inverted displays as quickly as upright displays in the fast instruction condition. Interestingly, a comparison of Figures 2.8 and 2.11 reveals that, with inversion of the Rubin's face-vase figure, reversal rates in the alternate quickly condition actually dropped to those seen with object-object figures such as the Maltese cross and the Necker cube (verified through pairwise comparisons). This finding, together with the inversion effects described earlier, suggests that inversion of faces caused them to be perceived and processed more like objects than faces (cf. Aguirre et al., 1999; Epstein et al., 2006; Haxby et al., 1996). More detailed examination of participants scanpaths, comparison of brain activation patterns during viewing of upright and inverted versions of the figure (cf. Hasson et al., 2001), and a more detailed exploration of the impact of individual difference variables on performance (cf. Stoesz, Jakobson, Kilgour, & Lewycky, 2007; Stoesz & Jakobson, 2008) may shed additional light on this issue.

Conclusions

Our findings strongly indicate that both the type of figure and a top-down factor, namely, one's instructional set, strongly influence perceptual reversal behaviours. A key finding from the present research was that ambiguous figures containing faces are processed quite differently from those containing objects. Thus, rather than classifying figures based on some arbitrary level of “meaningfulness” it might be more useful to consider whether or not a face (or, more generally, an agent) is present that could capture attention. Furthermore, the present study showed that the inversion of an ambiguous figure containing faces (i.e., Rubin’s vase-face) results in an “inversion effect” analogous to that seen in tasks requiring matching of faces. This is an interesting finding; it highlights the importance of considering how inversion changes not only how we perceive and process faces, but how we *attend to* them as well. In this way, we have shown that reversible figures can be a very valuable tool for examining face processing mechanisms.

CHAPTER 3: Perceptual Reversal Patterns in Individuals with Asperger Syndrome

Autism spectrum disorders (ASD) are a heterogeneous collection of conditions that share common features, including social deficits (for review see Bauman, Bauman & Kemper, 1994; American Psychological Association, 1994; Wing & Gould, 1979; Sigman, Dijamco, Gratier, & Rozga, 2004). The most well-known of these conditions is autism. This condition, initially described by child psychiatrist Leo Kanner (1943), is characterized by impairments in social skills, verbal and nonverbal communication, and imaginative activities. In addition, children with autism display restrictive, stereotyped patterns of behaviour; they may engage in repetitive behaviours (e.g., hand flapping, spinning, or rocking), and/or focus on particular aspects of the environment (e.g., wheel on a toy car). Although Asperger Syndrome (AS) is situated on the same continuum as classical autism, it is recognized as a distinct disorder (American Psychological Association, 1994). Individuals with AS typically have average to superior intelligence, often demonstrate highly specialized skills, and do not have the typical language delays seen in autism. These strengths, however, fail to provide individuals with AS the skills necessary to understand their own emotions or the emotions of others (Wing, 1981). It is this impairment in reciprocal social interaction that places AS on the autism spectrum.

In this chapter, we will explore responses of individuals with AS to the ambiguous figures described in Chapter 2. For a variety of reasons (outlined below), one might well expect these individuals to process such figures in an atypical way. Before describing some of the relevant literature, however, we should point out that, despite increased interest in AS, much of the current research has reported results that collapse across individuals with a variety of diagnoses that place them at the high-functioning end of the autism spectrum, including pervasive developmental disorder - not otherwise specified (PDD-NOS), high-functioning autism, and AS. This tendency to group individuals with these diagnoses together reflects, in part, the fact that they often show similar behavioural patterns (Szatmari, 2005). Furthermore, recruiting and testing high-functioning individuals is often more convenient (Mottron, 2004) and avoids the possible interfering effects of low intellectual functioning (van der Geest, Kemner, Verbaten, & van Engeland, 2002). As such, the literature reviewed here, in Chapter 3, largely describes past results from research studies involving mixed groups of individuals on the high-functioning end of the autism spectrum. One of the goals of the present research, therefore, was to test a more homogenous group of individuals on the autism spectrum – those with the specific diagnosis of AS – to determine whether they would show atypical perceptual reversal patterns when viewing ambiguous figures (see Chapter 2, Figures 2.1 and 2.2).

Abnormalities in processing social stimuli

The social and communication deficits observed in individuals on the autism spectrum often become apparent in their inattentiveness and indifference towards other people (Langton et al., 2007; Palermo & Rhodes, 2007; Mack et al., 2002; Turati, Valenza, Leo, & Simion, 2005; Easterbrook et al., 1999a). Compared to neurotypical controls, individuals with ASD exhibit abnormal gaze when looking at people (Swettenham et al., 1998; Easterbrook, Kisilevsky, Muir, & Laplante, 1999b; Sterling et al., 2008) but not at objects (Mercadante et al., 2006; Trepagnier et al., 2002). Even as toddlers, they spend proportionately less time looking at people and proportionately more time looking at objects than typically developing children, and do not shift attention normally from one person to the another, or from a person to an object (Swettenham et al., 1998). It may be that their failure to attend to faces contributes to abnormal development of face “expertise” by altering the typical neural development of face processing mechanisms, including those supporting the processing of eye gaze (Kleinhans et al., 2008; Pelphrey et al., 2002).

In addition to deficits in processing the faces of people and other agents (Blake et al., 2003; Speer, Cook, McMahon, & Clark, 2007), broader abnormalities in identifying “agency” have been described in individuals with ASD, even when the “agents” are nonliving objects that simply appear to move with intention (Castelli et al., 2002; Trepagnier et al., 2002; Blair et al., 2002). For example, in a study involving individuals with AS, Castelli et al. (2002) found that when simple geometric shapes (such as triangles) are moved in certain ways, controls frequently describe these movements using mental state terms (e.g., coaxing, tricking). In contrast, the autism group made fewer and less appropriate mental state attributions for these stimuli. When the shapes moved randomly, however, individuals with AS and controls provided equally accurate descriptions of the objects’ movements. In the same study, the AS group showed less activation than controls in medial prefrontal cortex and superior temporal sulcus (regions also associated with the processing of biological motion; Allison, Puce, & McCarthy, 2000) while viewing the movements that elicited mentalizing in controls, compared to that seen when viewing randomly moving shapes (Castelli et al., 2002).

Researchers have speculated that the impairments associated with social stimuli seen in ASD are due to a lack of attentional control (Bird et al., 2006; Courchesne et al., 1994; Fletcher-Watson, Leekam, Turner, & Moxon, 2006; Landry & Bryson, 2004; Speer et al., 2007; Senju, Tojo, Dairoku, & Hasegawa, 2004). Landry and Bryson (2004) showed that children with autism had more difficulty than a group of typically developing children in shifting attention from a central to a peripheral target when the central display remained on the screen during presentation of the peripheral display. In fact, on 20 percent of these trials, the children with autism were “stuck” on the central display and failed to disengage at all.

Slower switching of attention has also been found in adults with autism (Fletcher-Watson et al., 2006). In a classic change blindness task, participants were required to detect the difference between two photographs presented sequentially. In half of the images, the change in the photograph was on an item defined as being of central importance, and in the other half of the images the change was on an item of marginal importance. Although both ASD and control participants spotted the difference in the photographs more quickly in the central condition than in the marginal condition, a significant interaction between group and condition revealed that the participants with autism were slower to move their attentional focus to marginal objects (Fletcher-Watson et al., 2006). These attentional disturbances may reflect weaker connectivity between the frontoparietal attention network and visual processing areas in ASD (Castelli et al., 2002; Just, Cherkassky, Keller, & Minshew, 2004; Kleinhans et al., 2008).

A goal of the present study was to determine whether individuals with AS would respond differently than individuals without AS to the experimental manipulations described earlier in Chapter 2. Examining how individuals with AS examine and interpret ambiguous figures may help to explain why they focus on particular aspects of their natural environment at the expense of others. Given that ASDs are characterized by difficulties in switching attention (see above), we expected to find that perceptual reversal rates would be slower in the AS group. We also reasoned that, if participants with AS find it more difficult than controls to shift their gaze when moving between competing interpretations of an ambiguous figure, the number of fixations they make would also be lower, overall (i.e., their fixations may tend to be “sticky”). In addition, given the abnormalities in face processing that have been described in individuals with ASD (e.g., (Kleinhans et al., 2008; Pelphrey et al., 2002), we hypothesized that atypical reversal behaviours might be especially evident with ambiguous figures containing interpretations of faces compared to those containing interpretations of objects, both in the Spontaneous Reversals Task and in the Informed Reversals Experiment.

The effect of inversion on perceptual reversal rate

Past research has shown that individuals with ASD show a weaker face inversion effect than their neurotypical peers when sorting, identifying, and matching whole faces or facial features (Hobson et al., 1988; Joseph & Tanaka, 2003; Langdell, 1978). In one of these studies, participants with and without autism sorted photographs of full faces or faces that were missing either the mouth, or the mouth and forehead, according to identity or emotion (Hobson et al., 1988). The analyses revealed that the groups did not differ significantly in either sorting task when the stimuli were presented in the upright orientation. With inverted displays, however, the performance of individuals with autism was superior to that of matched controls.

Langdell (1978) found similar patterns of results using face parts and inverted stimuli. Regardless of stimulus orientation, younger children with autism (9 years of age) were better than controls at recognizing their peers from photographs showing only the lower half of the face (i.e., the mouth) than those showing the upper half; this pattern was reversed in control children, highlighting the importance of the eye region for this group. In addition, older children with autism (14 years of age) were much better at identifying peers in the inverted condition compared to control children. Although both studies showed that individuals with autism were affected by inversion (their performance with upright stimuli being better than their performance with inverted stimuli), they were able to focus in on particular aspects of inverted faces (i.e., the mouth) in order to make their matches – a strategy not utilized by the neurotypical participants.

Other findings lend support to the claim that superior ability to focus in on particular features of faces underlies the atypical (i.e., weaker) inversion effect that is typically observed in individuals with ASD. For example, abnormal gaze patterns have often been observed when individuals with ASD view upright faces. Thus, when viewing upright stimuli, individuals on the spectrum are less drawn to look at faces when viewing natural social scenes (Klin et al., 2002), and when they examine faces they fixate on different facial features (Dalton et al., 2005; Klin et al., 2002; Langdell, 1978; Pelphrey et al., 2002; Swettenham et al., 1998; Spezio et al., 2007) and exhibit more erratic, undirected, and disorganized scanpaths (Pelphrey et al., 2002) than controls.

In the first study of its kind, Klin et al. (2002) used eye-tracking technology to measure the visual fixations of adolescent males with and without autism while they viewed dynamic social scenes. Fixation information was superimposed on the visual scenes. Still images were then produced from these composite recordings and were subsequently coded using a detailed coding procedure. The locations of each participant’s fixations (e.g., whether they focused on the eyes, mouth, or body of a person, or on an object in the scene) and the percentage of total viewing time spent on fixations were analyzed. Individuals in the autism group spent half as much time focusing on the eye region, and twice as long focusing on the mouth, body, and object regions of the display, compared to age- and verbal IQ-matched controls. Further analyses revealed that fixation time on the eye region was the best predictor of group membership. Within the group with autism, longer mouth and shorter object fixation times were associated with higher levels of social competence. As noted by the authors, this result "…is as intriguing as it is counterintuitive…" (Klin et al., 2002, p.814). Given that higher levels of verbal skill are associated with better outcomes in autism (Klin et al., 2007; Saulnier & Klin, 2007), the authors suggested that participants in their study may have learned to focus in on the mouth in order to be more accurate in decoding the speech of others (Klin et al., 2002).

Others have found that abnormal gaze patterns for children with high-functioning autism are most evident when they look at photographs of inverted human faces (van der Geest et al., 2002). In one study, children with autism spent about the same amount of time looking at upright faces as upside-down faces, whereas typically developing children spent more time looking at the upright faces than the upside-down faces (van der Geest et al., 2002). The ASD group also made a smaller number of fixations directed at the eye region and to the face as a whole than controls, regardless of stimulus orientation.

On the basis of their findings, van der Geest and colleagues speculated that the absence of an inversion effect for faces in individuals with autism reflects a failure to engage in holistic processing of upright human faces. In fact, the way individuals on the spectrum process stimuli of *all* types (faces and objects) may reflect a processing style that is biased towards local rather than global information processing – termed 'weak central coherence' (Happé, 1999; Happé & Frith, 1996; Happé & Frith, 2006; Manjaly et al., 2003; Mottron & Belleville, 1993; Mottron et al., 2000; Mottron et al., 1999; Shah & Frith, 1993). The tendency to process details at the expense of the gist or global meaning can be disadvantageous in some cases; however, in some tasks having strong segmentation abilities provides an advantage. For example, individuals with ASD show superior abilities on several experimental and clinical tasks that tap into local processing skills, including: the standard Weschler Block Design test (Shah & Frith, 1993), copying "impossible" figures (Mottron et al., 1999), and the Embedded Figures Test (Manjaly et al., 2003; Pellicano et al., 2005; Ring et al., 1999). Individuals with autism also show a detail-by-detail drawing style (Mottron & Belleville, 1993).

Given the above, we were interested in whether or not inversion of an ambiguous figure would alter the perceptual reversal patterns of individuals with AS (i.e., lead to an "inversion effect") and, if so, whether this effect would vary in magnitude from the inversion effect seen in controls. Specifically, in contrast to controls (see Chapter 2), participants with AS were not expected to perceive the face interpretation for proportionally more time than the vase interpretation when viewing the upright Rubin's vase-face figure (see Figure 2.2), and to show a smaller "inversion effect" for this figure. As described in Chapter 2, the definition of the "inversion effect" differs here from the classical definition. In the classical definition of the face inversion effect, upside-down presentation of faces causes a significant decrement in performance. The definition used here refers to a change in which interpretation is *attended to* following stimulus inversion.

Summary

The perceptual reversal behaviour patterns of individuals with AS were compared to those of the control group described in Chapter 2. In the Spontaneous Reversals Task, we expected that individuals with AS would find it harder to generate both interpretations of content-reversible ambiguous figures (containing faces and agents) than perspective-reversible ambiguous figures (containing objects). In the Informed Reversals Experiment, individuals with AS were expected to have difficulty selectively controlling their attention and alternating between interpretations of ambiguous figures. As a result, the AS group was expected to make fewer reversals overall, and to experience difficulty controlling their switching speed when instructed to do so. Individuals on the autism spectrum were also expected to exhibit a more atypical response when they viewed ambiguous figures containing human faces, compared to that seen when viewing those containing objects only. Furthermore, relative to controls they were expected to show a weaker "face bias" for the upright Rubin's vase-face, and a weaker inversion effect for this same figure.

Method

Participants

Eight participants (5 males, 3 females; mean age = 20.13 years, *SD* = 1.64; range = 18-23 years) were recruited for the AS group. Individuals with AS were recruited by accessing a list of individuals with AS maintained by Dr. Janine Montgomery (Department of Psychology, University of Manitoba); all had previously participated in research in her laboratory (see below) and had given their consent to be contacted for future research. All of the participants had received a diagnosis of AS from a medical doctor, psychologist, or psychiatrist, and that diagnosis had been confirmed by Dr. Montgomery using the Krug Asperger Disorder Index (KADI, Krug & Arick, 2003), the most reliable and valid screen for identifying individuals with AS (Campbell & Fiske, 1959). Dr. Montgomery's research was approved by the University of Saskatchewan's Behavioural Sciences Research Ethics Board, the Conjoint Faculties Research Ethics Board at the University of Calgary, and the Human Research Ethics Board at the University of Manitoba. The testing protocol for the current research was approved by the Human Research Ethics Board at the University of Manitoba.

Participants recruited for the AS group in the present study were given twenty dollars to cover parking and other incidental expenses (e.g., fuel) incurred while participating in this research project.

Materials and Procedure

Participants were tested individually. During the experimental session, each participant read and signed a consent form, completed a General Information Questionnaire (see Appendix A), and had his/her visual acuity assessed before the experimental tasks were administered. Following these assessment measures, participants completed two ambiguous figures reversal experiments – the Spontaneous Reversals Task and the Informed Reversals Experiment (see Chapter 2 for a detailed description of the stimuli used and the administration procedures). Note that, unlike the control participants described in Chapter 2, individuals with AS were not administered the WASI because they had recently been assessed on this measure by Dr. Montgomery. Because it was not appropriate to re-administer the IQ test after such a short interval, we asked these participants to consent to permit Dr. Montgomery to share the results of this test with us.

The WASI was used for purposes of matching this group of individuals with AS to the group of control participants. Verbal-, Performance-, and Full-scale IQ scores are the dominant matching variables used in current cognitive research on pervasive developmental disorders (Mottron, 2004). In addition, Weschler instruments are recommended over other IQ measures for matching purposes (Mottron, 2004). Information about IQ was also collected because IQ has been shown to contribute to participants' performance on the measures of attention (Bradley, Mogg, Falla, & Hamilton, 1998; Cooper & Langton, 2006) and the rate of perceptual reversal (Leopold & Logothetis, 1999).

Results

The group of individuals with AS was comparable to the group of controls described in Chapter 2 in terms of mean age [$t(26) = -1.00$, $p > .30$] and mean Full-scale IQ (FSIQ) [$t(26) = -.60$, $p > .50$]. FSIQs ranged from 85-125 in the control group, and from 88-129 in the AS group.

Spontaneous reversals experiment

Given previous findings (Sobel et al., 2005), we predicted that, when presented with a set of ambiguous figures, the individuals with AS would be less likely than controls to report more than one interpretation per figure when uninformed about the ambiguity, particularly when viewing content-reversible figures depicting faces or agents.

Overall, individuals with AS reported perceiving 9.25 ($SD = 2.19$) out of 16 possible interpretations on this task. A one-sample *t*-test (comparing the scores to eight) confirmed that participants were, on average, unable to spontaneously generate more than one interpretation per figure, $t(19) = 1.62$, $p > .15$. Additional planned analyses comparing each of the two subscores to four (a score suggesting that viewers can only perceive one interpretation per figure) indicated that the AS group was, on average, only able to generate one interpretation per figure for both content-reversible, $t(7) = .80$, $p > .40$, and perspective-reversible figures, $t(7) = .10$, $p > .10$. This pattern was different from that shown by controls. Thus, as noted in Chapter 2, controls were able to generate, on average, more than one interpretation per figure, regardless of category. In fact, 70% of controls scored above 4 per category (range: 5 to 8), but only 50% of AS scored above 4 per category (all obtaining a score of 5).

In order to determine if individuals with AS would show a difference in the number of spontaneously generated interpretations for content-reversible and perspective-reversible ambiguous figures, we entered the subscores into a paired-samples *t*-test. We found no differences between these categories of figures (content-reversible figures: $M = 4.25$, $SD = .89$; perspective-reversible figures: $M = 5.00$, $SD = 1.51$), $t(7) = -1.82$, $p = .11$. As predicted, however, there was a trend for individuals with AS to spontaneously generate fewer interpretations than controls for content-reversible figures (i.e., figures containing faces), $t(26) = 1.98$, $p < .06$, but not for the perspective-reversible figures in the Spontaneous Reversals Task.

Informed reversals experiment: Passive viewing

One of the goals of the present research was to determine whether individuals with AS would show a different pattern of perceptual reversals than individuals in the control group. Because the variances for all variables were wildly different between the two groups (as verified by tests of homogeneity), we opted to analyze the data from the AS group separately using a two-step approach. In step one, we entered the scores for each variable into separate ANOVAs. Although this first step revealed that the AS group as a whole presented with a different pattern of results than the control group (whose data were described in detail in Chapter 2), it did not reveal the unique perceptual reversal behaviours exhibited by each individual with AS. In order to examine the data more closely, in step two we compared each AS participant's score to the 95% confidence interval (CI) calculated from the control group's data for each variable. This approach makes sense in light of the fact that individuals with ASDs have been described as a heterogeneous group (Mottron, 2004; Klin, 2003; Szatmari, 2005). Jarrold and Brock (2004) recently argued that examining the individual differences exhibited by those with ASDs is necessary in order to map out the relative strengths and weaknesses of each individual on the autism spectrum. Furthermore, Jarrold and Brock suggest that examining individual differences provides an important complement to matched-group designs.

Perceptual reversal rate. As a group, participants in the AS sample (like controls, see Chapter 2, Figure 2.8) showed similar reversal rates for all four figures in the passive viewing condition, $F(3, 21) = 1.58$, $p > .20$, $\eta_p^2 = .18$. Within the AS group, however, there was considerable individual variation in performance and all of the AS participants, in fact, showed switching rates that were outside the 95% CI of the controls for at least some of the ambiguous figures (see Figure 3.1). In order to compare performance across figures, *z*-scores for each individual with AS were computed by subtracting the reversal rate of the individual from the mean reversal rate of the control group divided by the standard deviation of the control group. These scores were then plotted. As can be seen in Figure 3.1, in two cases (1 and 7), switching rates for all four figures were consistently higher than those seen with controls. These two participants (both women) showed extremely fast switching rates, particularly for the Rubin's face-vase and the Maltese cross (*z*-scores ranging from 3.69 to 9.78 for these two figures). The remaining participants (like controls) showed a similar pattern of responding for all four figures, although their switching rates were abnormally slow. Two of these participants (cases 2 and 6) exhibited switching rates that were consistently slower than controls.' Two participants (cases 3 and 5) performed within normal limits for the object figures, but showed slower reversal rates for figures containing faces. Finally, two participants (cases 4 and 8) demonstrated slow reversal rates for Boring's young girl-old woman only.

Overall, atypical reversal rates were observed 77.8% of the time for figures including faces (14 atypical scores), but only 50% of the time for those containing only nonface objects (8 atypical scores). Interestingly, the only figure that AS participants consistently showed atypical reversal behaviour on was Boring's young girl-old woman figure, which alternates between two face interpretations; here, two participants showed unusually fast switching rates, and the remaining six showed unusually slow switching rates.

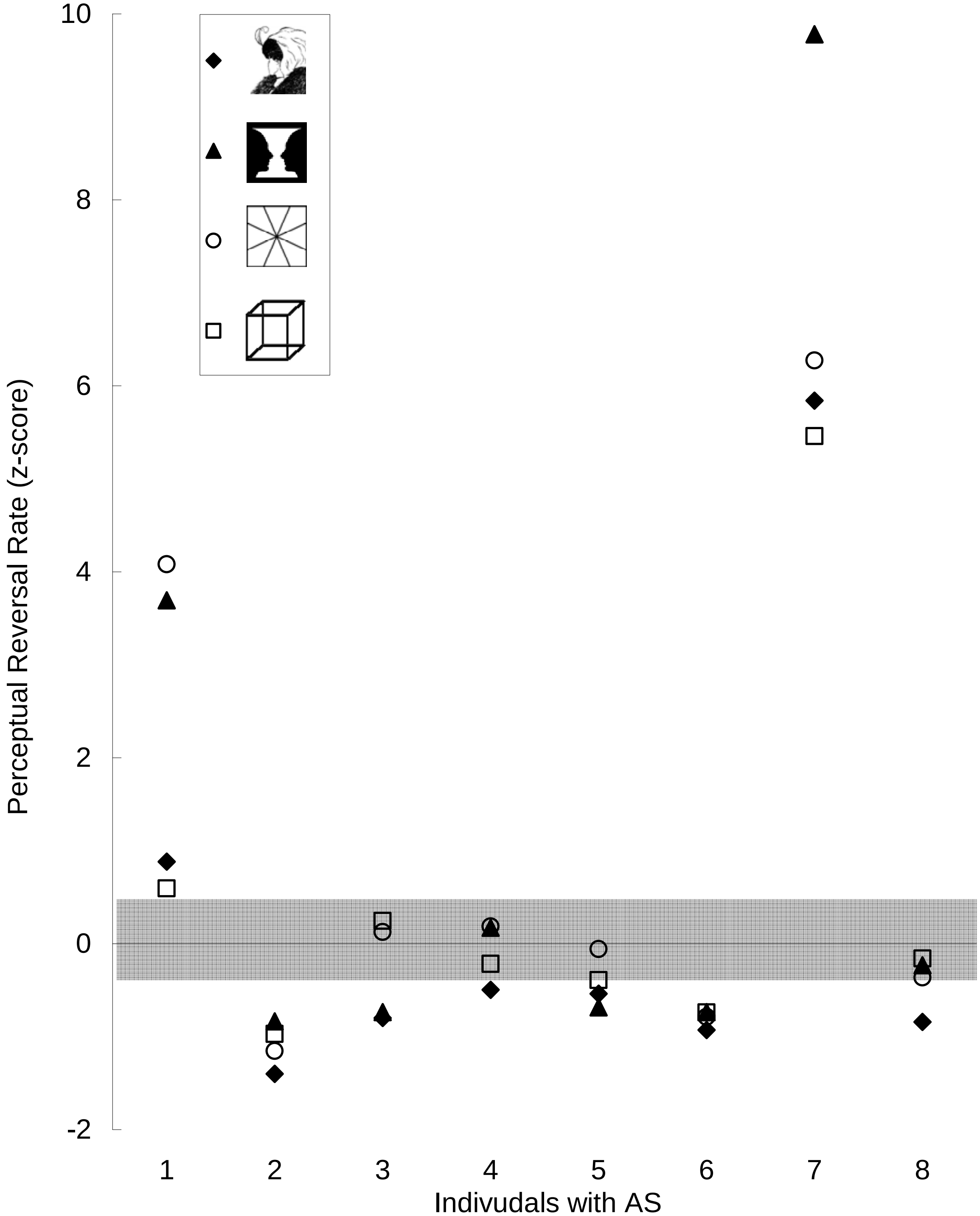

Figure 3.1. **Perceptual reversal rates for each ambiguous figure, expressed as z-scores, in the passive viewing condition. The 95% CI for the perceptual reversal rates are indicated with a shaded box for the control group. The scores for each individual with AS are indicated with points.**

Time spent reporting each interpretation. Unlike the pattern seen with controls (see Chapter 2), the participants with AS, as a group, showed no overall biases for any of the four figures (as verified through planned comparisons). Once again, however, these group means did not convey the whole story. Examination of individual participants' data revealed both a tremendous amount of variability, and a high incidence of atypical responses to the figures. This is best illustrated by examining preference scores computed (as in Chapter 2) by subtracting the time spent perceiving Interpretation 2 from the time spent perceiving Interpretation 1. For each figure, these preference scores were plotted relative to the 95% CI of these preference scores for controls (see Figure 3.2). Here: (a) scores above the CI indicate an abnormally strong preference for the same figure preferred by controls; (b) scores falling within the CI indicate a preference comparable to that exhibited by controls; and (c) scores below the CI indicate a weaker preference, no preference, or (in some cases) a preference for the interpretation that was not preferred by controls.

Examination of Figure 3.2 reveals that 3 of the 8 AS participants (cases 5, 6, and 7) had difference scores falling outside of the 95% CI of the controls for three of the four figures, and the four AS participants (cases 1, 2, 4 and 8) had atypical scores for all of the figures. None of the participants with AS showed the same pattern as the control sample (i.e., a preference that was in the same direction and equal to, or stronger than, that of controls for Rubin's vase-face, the Maltese cross, and the Necker cube, and no preference for Boring's young girl-old woman). Approximately half of the participants with AS showed an equivalent or stronger preference than that exhibited by the controls for the vertical cross of the Maltese cross and the top view of the Necker cube, but the other half showed either a weaker or opposite preference. Interestingly, the majority of individuals with AS (75%) showed a preference that was weaker than controls or, indeed, in the opposite direction (i.e., a vase preference) for Rubin's vase-face. Recall that controls showed no overall preference for one interpretation of the Boring figure. In contrast, all individuals with AS scored outside the CI, suggesting that they did show a preference. In three cases (2, 5, and 7), however, it was a preference for the old woman, while in the remaining five cases (1, 3, 4, 6, and 8) it was for the young woman. These data reinforce the point that the mean scores for the group are really not informative.

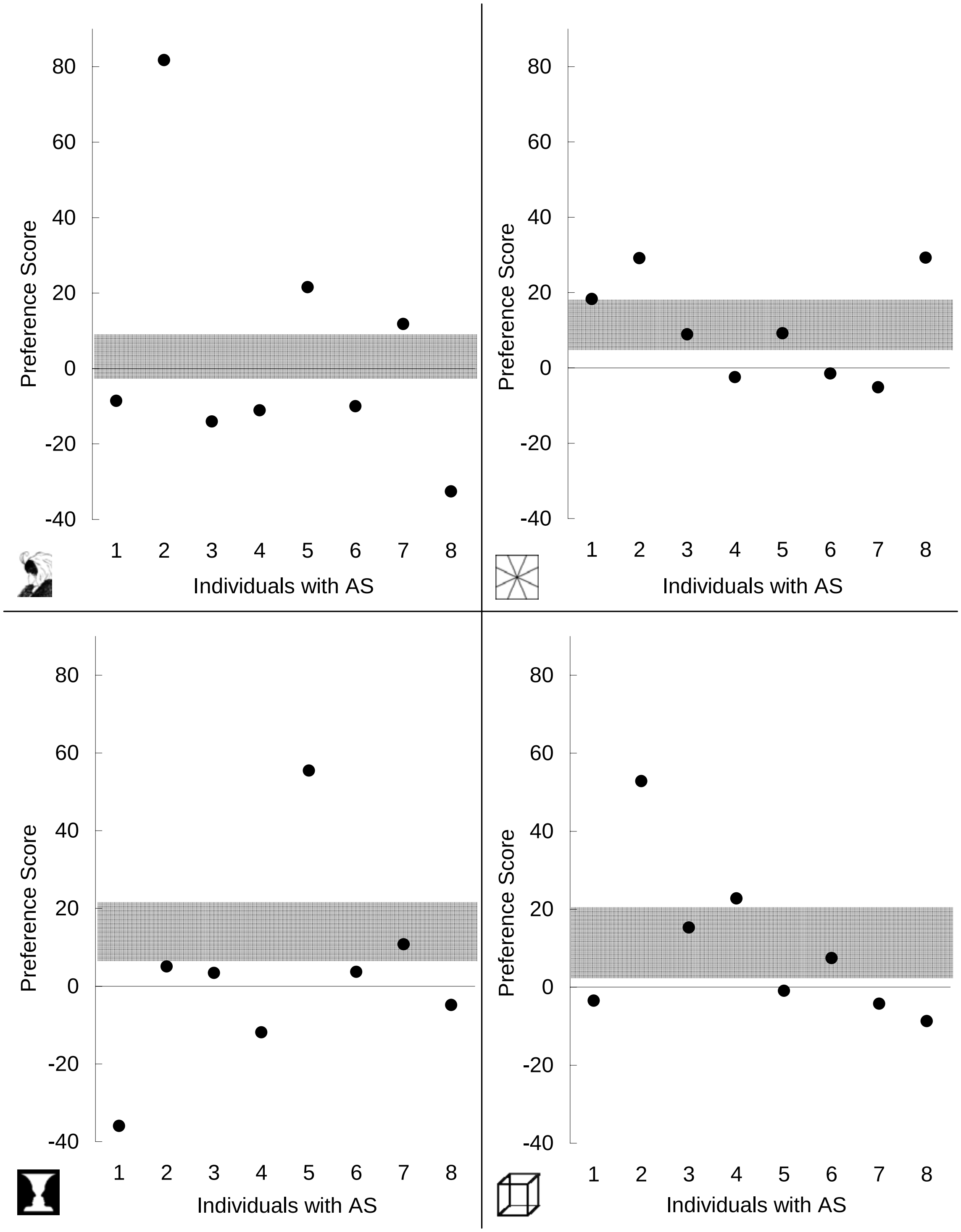

Figure 3.2. Preference scores for Boring's young girl-old woman, Rubin's vase-face, the Maltese cross, and the Necker cube. Positive scores indicate a preference to perceive Interpretation 1 and negative scores indicate a preference to perceive Interpretation 2. The 95% confidence interval for these preference scores are indicated with a shaded box for the control group. The scores for each individual with AS are indicated with points.

Number of fixations. Controls made fewer fixations when viewing the Maltese cross than when viewing any of the other figures (see Chapter 2, Figure 2.5). In the AS group, a trend for a main effect of Figure was observed [$F(3, 21) = 2.91$, $p = .08$, $\eta_p^2 = .29$]; examination of mean scores suggested that AS participants also made fewer fixations (in total) when viewing the Maltese cross than any of the other figures. Thus, the pattern in the group data is similar to that seen with controls. What is clear from Figure 3.3., however, is that, in virtually every instance, participants with AS made many more fixations than controls overall (i.e., most of the scores fell above the 95% CI for all four figures).

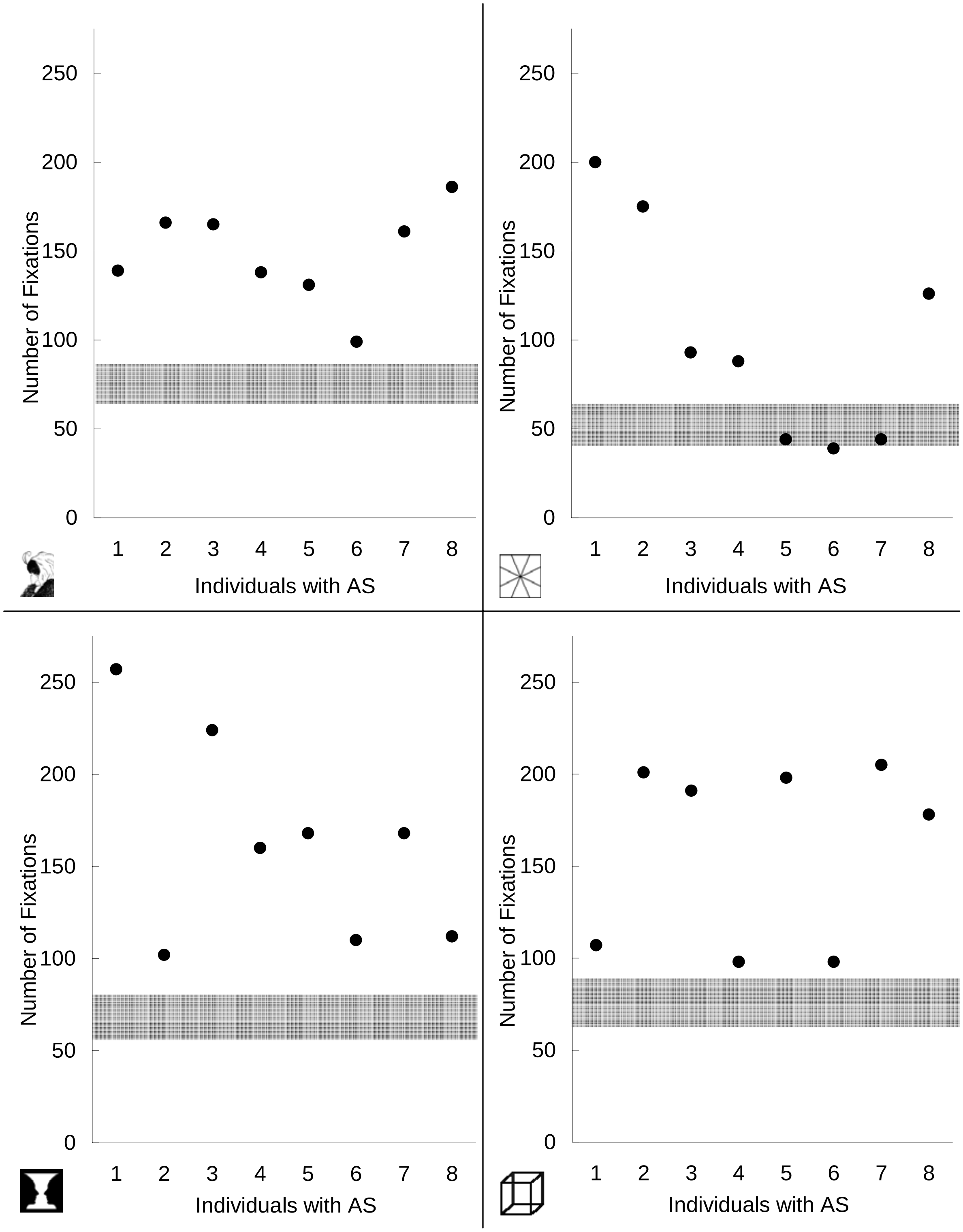

Figure 3.3. **Boring's young girl-old woman, Rubin's vase-face, the Maltese cross, and the Necker cube. This graph shows the number of fixations made when participants reported perceiving the interpretations. The 95% CI for the number of fixations are indicated with a shaded box for the control group. The scores for each individual with AS are indicated with points.**

In Chapter 2, we also reported that controls generated significantly more fixations when perceiving the face than the vase interpretation of the Rubin's vase-face, and when perceiving the top as opposed to the bottom view of the Necker cube (see Chapter 2, Figure 2.6). In the AS group, planned comparisons between the two interpretations for each figure revealed that there were no fixation biases for any of the figures. Once again, however, there was a large degree of individual variability, and a high incidence of atypical responding. To illustrate this, in Figures 3.4 we present fixation bias scores (again, computed as in Chapter 2), along with the 95% CI of controls for these scores. Only with the Maltese cross figure did most of the AS participants score within the 95% CI of the control group. In other words, AS participants did not generally show the same biases that were evident in the control group. For both the Rubin's face-vase figure and the Necker cube, AS participants' bias scores tended to fall at or below the lower limit of the CI. In other words, their "bias" was either nonexistent or opposite in sign to that exhibited by controls.

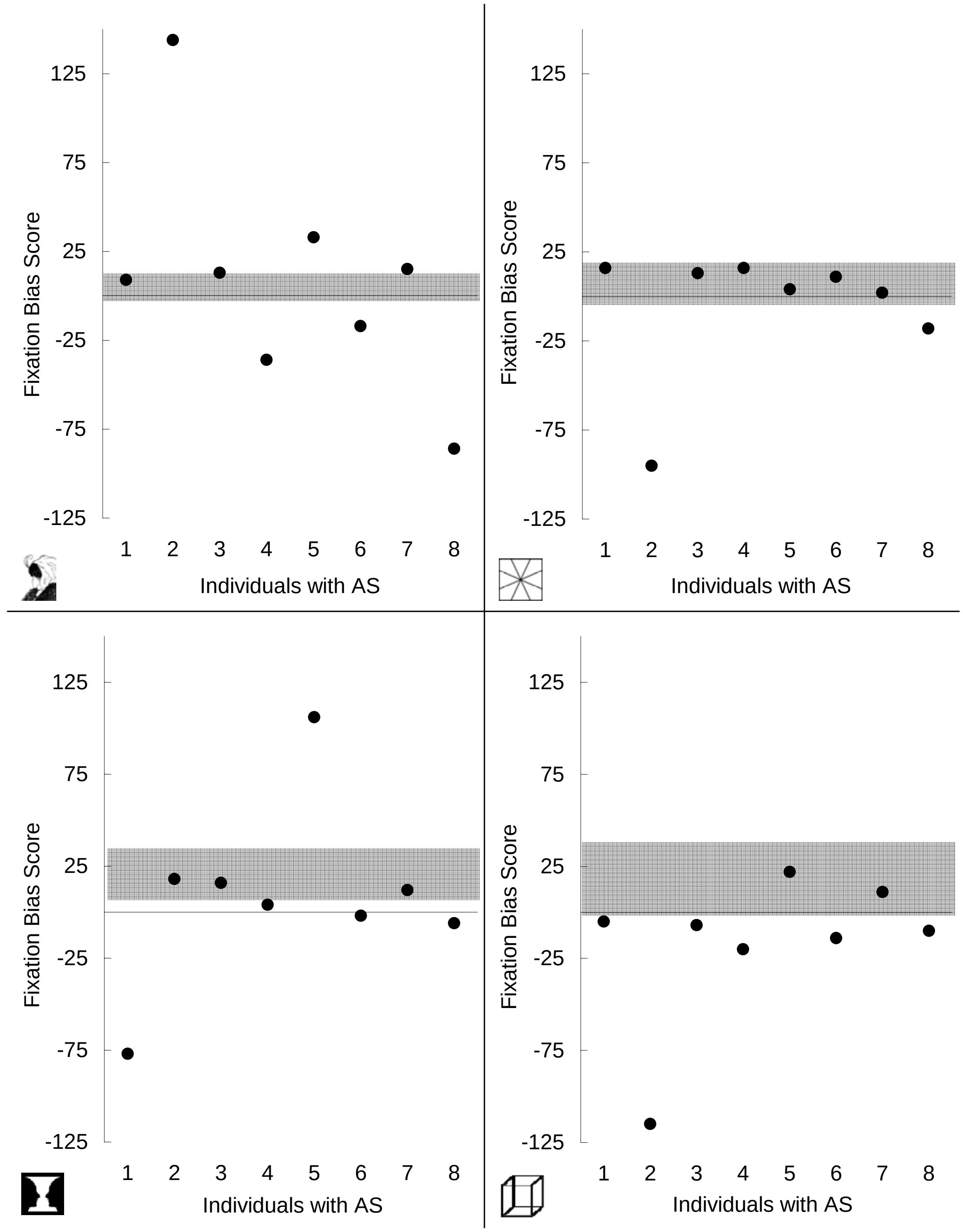

Figure 3.4. **Fixation bias scores for Boring's young girl-old woman, Rubin's vase-face, the Maltese cross, and the Necker cube. Positive scores indicate that more fixations were made when participants reported perceiving Interpretation 1. Negative scores indicate that more fixations were made when participants reported perceiving Interpretation 2. The 95% CI for these bias scores are indicated with a shaded box for the control group. The scores for each individual with AS are indicated with points.**

Another way to look at this is to examine the association between perceptual preferences and fixation bias scores, as we had done in Chapter 2. These associations were somewhat different for AS participants than controls. Thus, controls made relatively more fixations when perceiving their own "preferred" view of each figure (see Chapter 2, Figure 2.7), while AS participants showed this pattern only for the figures involving faces: Boring's young girl-old woman, $r(8) = .95$, $p < .001$; Rubin's vase-face, $r(8) = .97$, $p < .001$. [Recall, however, that their preferences differed from controls' for these two figures (see above).] For the other two ambiguous figures, they showed the opposite relationship. For these figures, then, AS participants made relatively more fixations when perceiving their own "nonpreferred" view: Necker $r(8) = -.89$, $p < .004$; Maltese Cross $r(8) = -.66$, $p < .08$.

Summary. The first goal for Chapter 3 was to determine whether individuals with AS would show a different pattern of perceptual reversal behaviours than controls within the content-reversible ambiguous figures, and between the content-reversible figures and the perspective-reversible Necker cube. Like controls, six members of the clinical group showed similar rates of reversal on all four figures; however, they were slower than controls. On the other hand, two women with AS exhibited extremely fast switching rates, which varied according to the figure being viewed. Their switches were particularly fast for Rubin's vase-face and the Maltese cross; indeed, their reversal rates for Rubin's vase-face were consistently much higher than those seen with either the content-reversible Boring's young girl-old woman or the perspective-reversible Necker cube. It is important to highlight that we observed that 77.8% of the reversal rates were atypical for figures involving faces but only 50% of the scores were atypical for the figures not involving faces. Additionally, all participants with AS showed atypical reversal rates for Boring's young girl-old woman.

Although the group means suggested that individuals with AS did not show clear preferences for certain interpretations of any of the figures (in terms of time), inspection of individual scores showed that many participants with AS had preferences that were either weaker or in the opposite direction to those of controls for Rubin's vase-face. In addition, all participants with AS showed a preference for one interpretation of Boring's young girl-old woman (a figure that was not biased in controls).

Controls made fewer fixations when inspecting the Maltese cross than any other figure. A similar pattern was seen in individuals with AS, although they made more fixations overall (for all figures). In addition, unlike controls, they made more fixations when perceiving their own "nonpreferred" view of the two figures involving objects (the Necker cube and the Maltese cross). In this respect, then, individuals with AS responded in a similar way to the content-reversible Maltese cross and the perspective-reversible Necker cube – both figures that include two objects.

Informed Reversals Experiment: Effect of Instruction

Perceptual reversal rates for the AS group were entered into a 3 (Instruction: slow alternating, passive viewing, fast alternating) x 4 (Figure: Boring's young girl-old woman, Rubin's vase-face, Maltese cross, Necker cube) ANOVA, with repeated measures on both factors. In the AS group, a trend for a main effect of Instruction was observed [$F(2, 14) = 4.56$, $p = .07$, $\eta_p^2 = .39$]; examination of mean scores suggested that participants tended to show a different number of switches between the alternate slowly instruction condition and passive viewing, the alternate slowly and alternate quickly instruction conditions, and the passive viewing and alternate quickly instruction condition ($p < .10$ for all three comparisons). Again, these group results do not reveal the remarkable individual variation within the AS group. As can be seen in Figures 3.5 to 3.8, reversal rates for each instruction condition fall outside of the control group's 95% CI for Boring's young girl-old woman. Of the remaining three figures, 70% of scores fall outside the control group's 95% CI. It is important to note that 7 out of 8 individuals with AS showed atypical perceptual reversal rates on all four ambiguous figures.

Examination of the differences in perceptual reversal rate between the slow and fast instruction conditions highlight the fact that individuals with AS show an effect of instruction that is clearly distinct from controls. Three individuals with AS (cases 3, 5, and 6) showed differences in the reversal rates between the alternate slowly and alternate quickly instruction conditions that were smaller than the controls (i.e., they showed little or no effect of instruction). In another three cases (1, 7, and 8) these difference were much larger than those seen in controls (i.e., they showed an abnormally large effect of instruction). In only two cases (2 and 4) were the differences between reversal rates seen in the alternate slowly and alternate quickly instruction conditions similar to controls' (i.e., they showed a comparable effect of instruction). This pattern is generally similar across the four ambiguous figures. Only one participant with AS (case 1) showed the same *pattern* exhibited controls (i.e., higher switching rates for Boring's young girl-old woman and Rubin's vase-face than for either the Maltese cross or the Necker cube in alternate quickly condition).

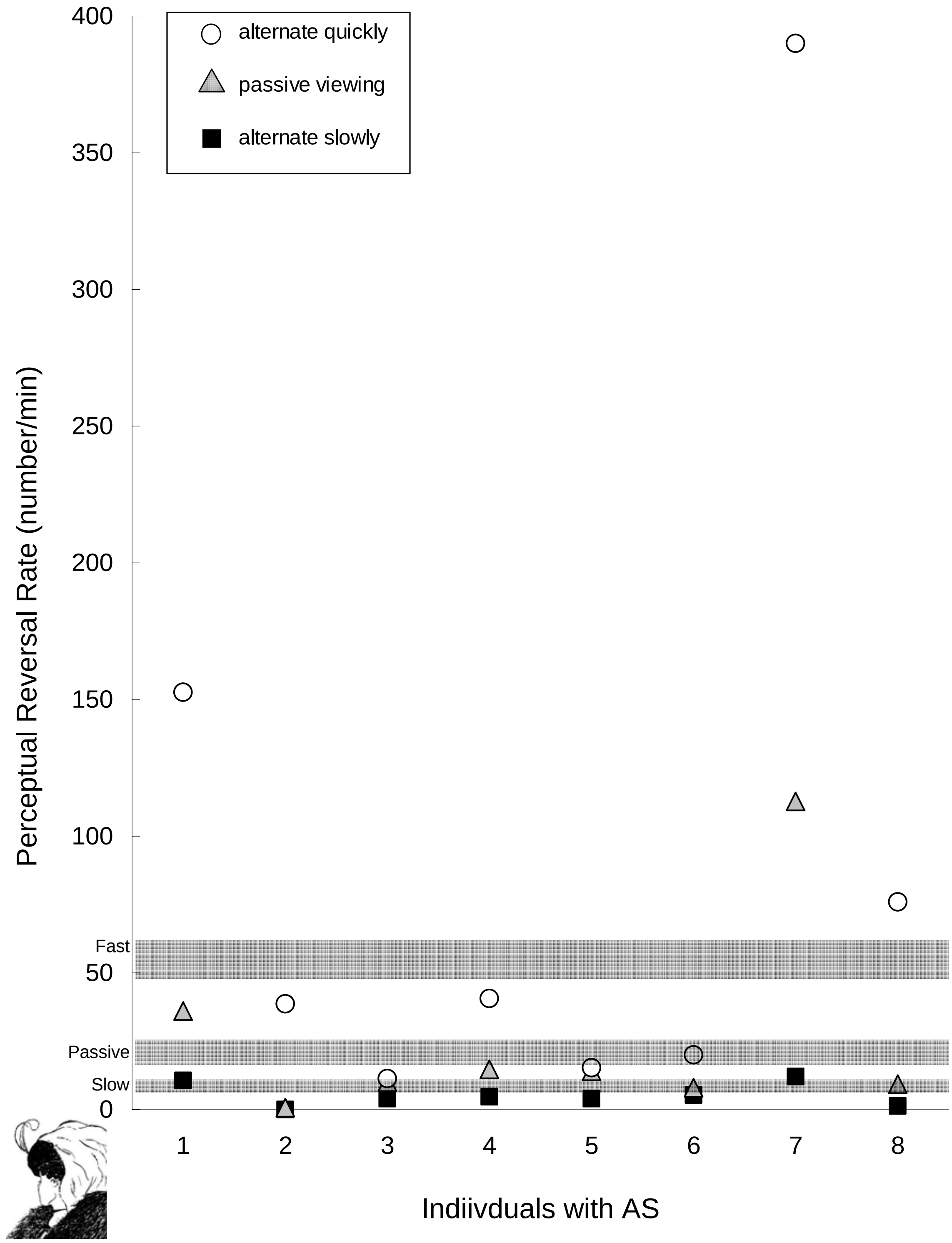

Figure 3.5. **Perceptual reversal rates for Boring's young girl-old woman. The 95% CI for the control group for each of the three instruction conditions (alternate slowly, passive viewing, and alternate quickly) are shown with shaded boxes. The perceptual reversal rates for each individual with AS are indicated with points.**

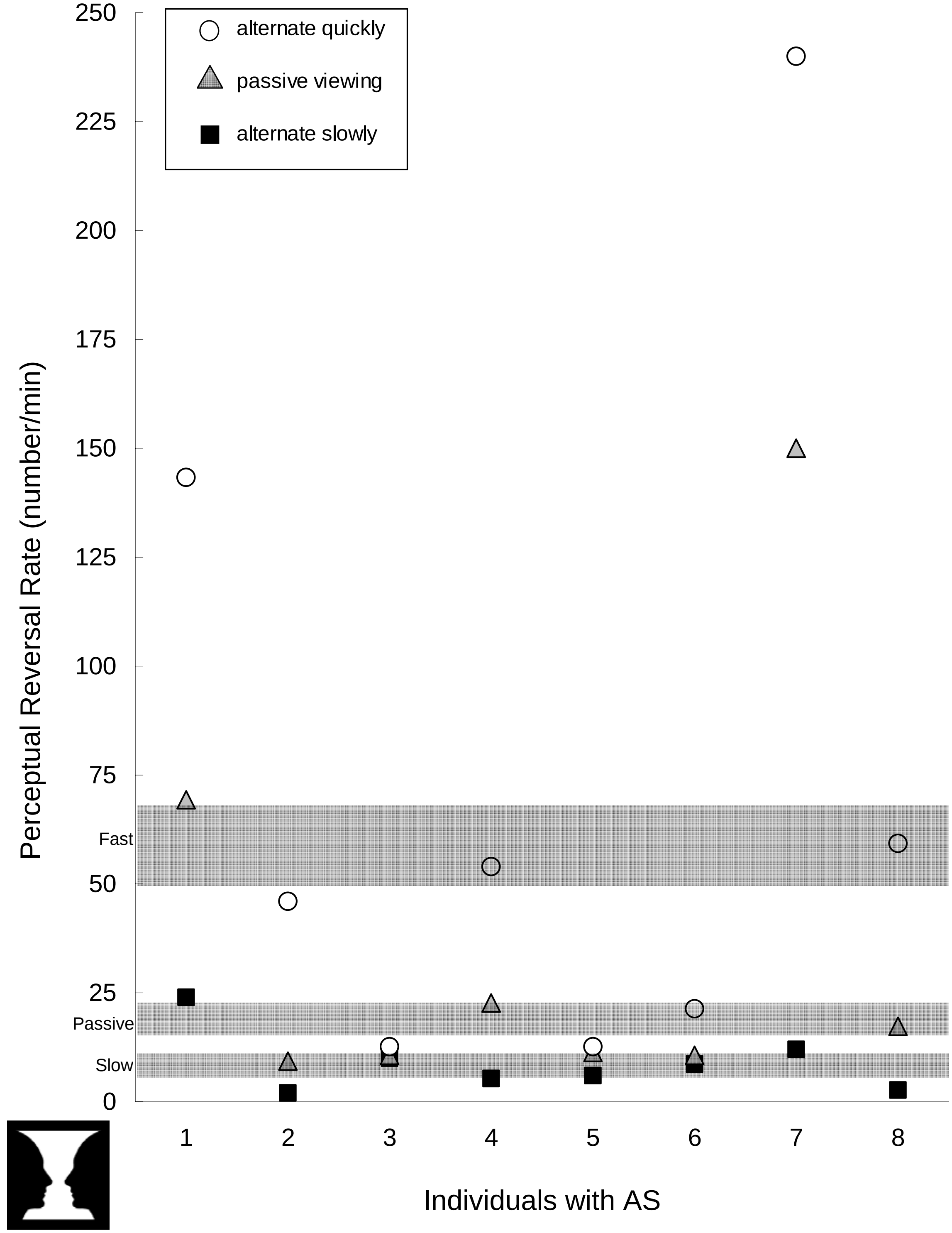

Figure 3.6. **Perceptual reversal rates for Rubin's vase-face. The 95% CI for the control group for each of the three instruction conditions (alternate slowly, passive viewing, and alternate quickly) are shown with shaded boxes. The perceptual reversal rates for each individual with AS are indicated with points.**

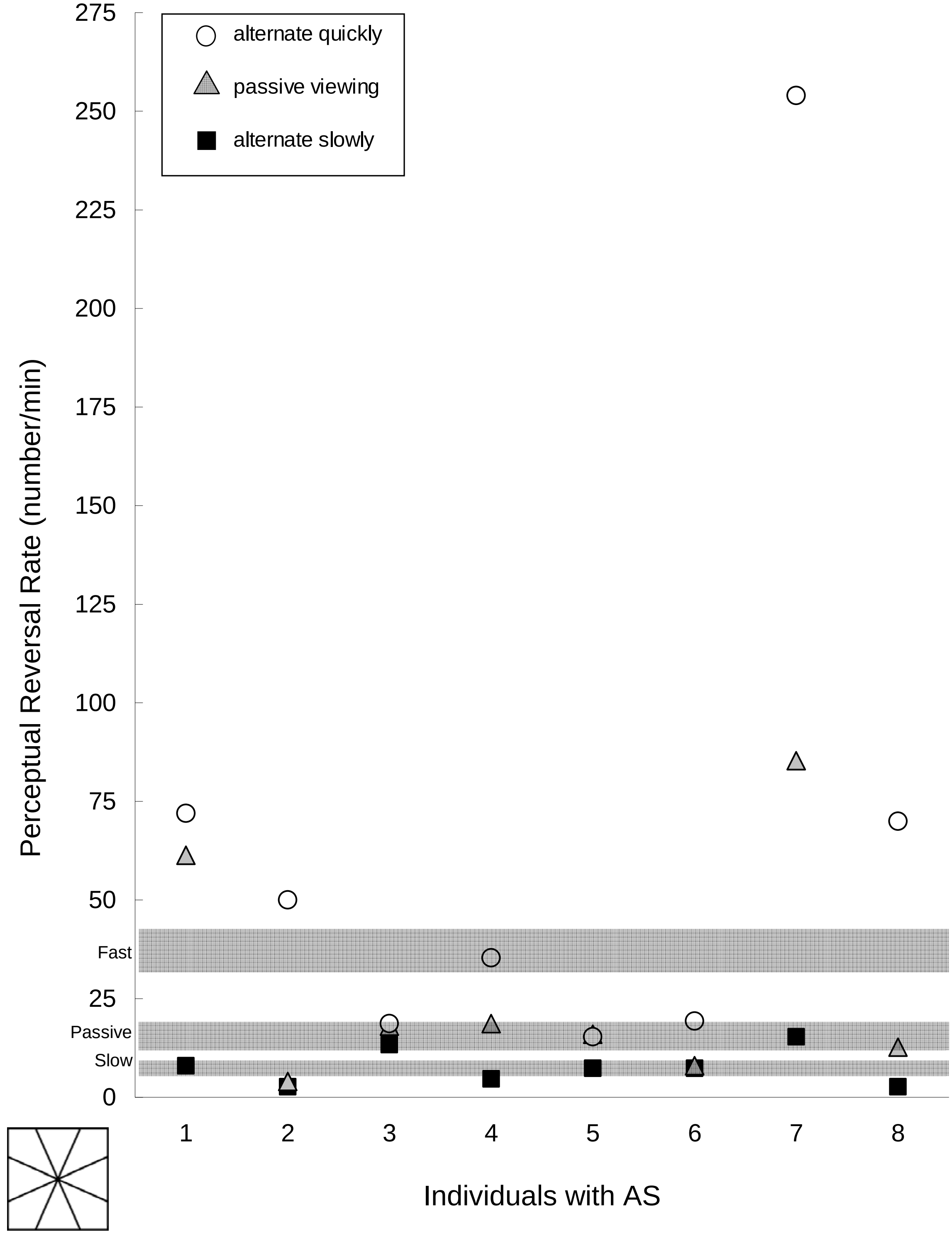

Figure 3.7. **Perceptual reversal rates for the Maltese cross. The 95% CI for the control group for each of the three instruction conditions (alternate slowly, passive viewing, and alternate quickly) are shown with shaded boxes. The perceptual reversal rates for each individual with AS are indicated with points.**

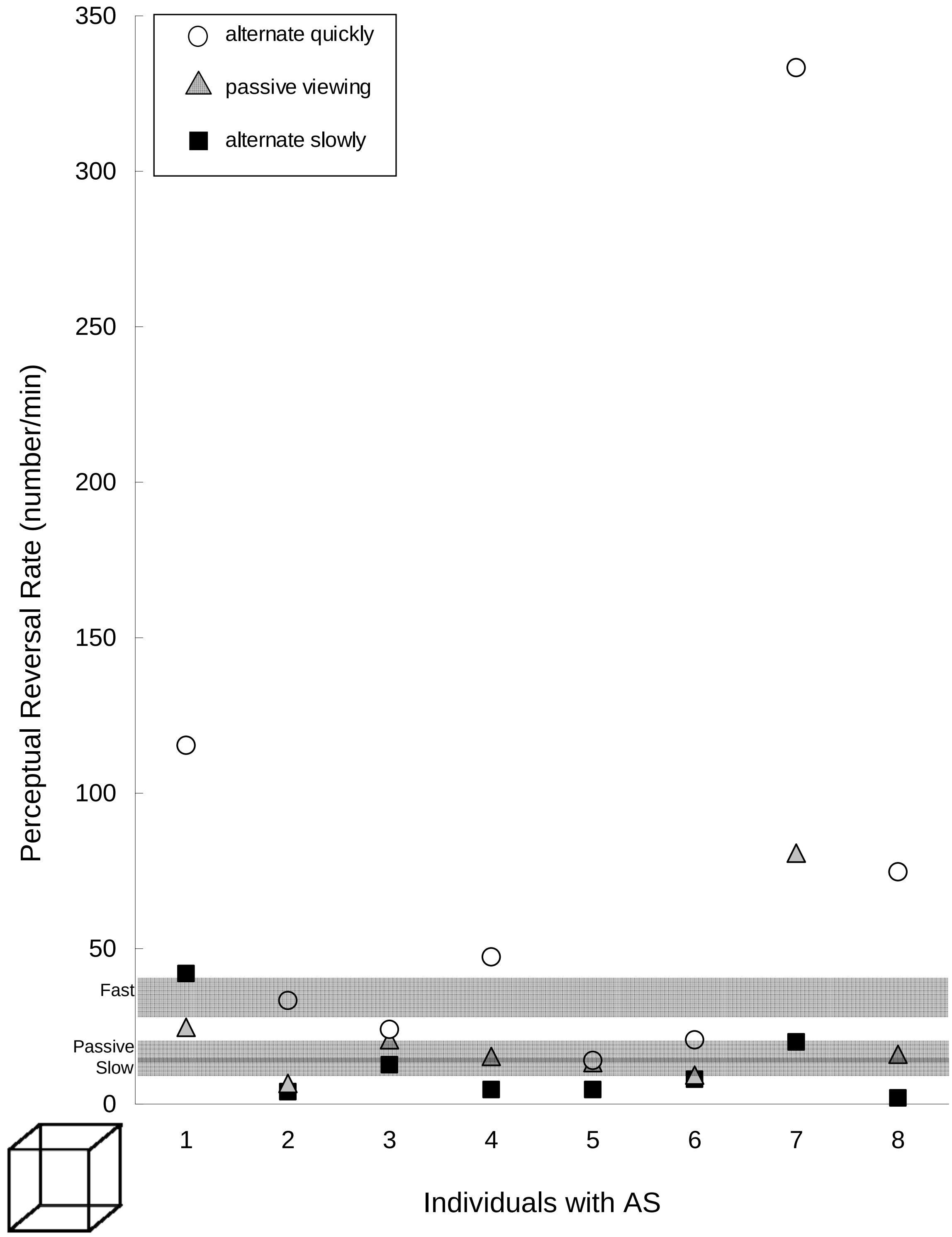

Figure 3.8. **Perceptual reversal rates for the Necker cube. The 95% CI for the control group for each of the three instruction conditions (alternate slowly, passive viewing, and alternate quickly) are shown with shaded boxes. The perceptual reversal rates for each individual with AS are indicated with points.**

Summary. Although the group means indicated that there was no effect of instruction in the AS group, some participants showed a smaller effect and some a much larger effect than controls. Only one participant with AS showed the same *pattern* exhibited controls (i.e., higher switching rates in the alternate quickly condition for the figures involving faces than for those involving objects).

Informed Reversals Experiment: Effect of Inversion

The final set of analyses conducted on data collected in the Informed Reversals Experiment was designed to compare the perceptual reversals patterns seen with upright and inverted Rubin's vase-face figures for the AS participants.

Passive viewing condition. As with controls (see Chapter 2), preference scores were computed by taking the difference between the length of time that participants reported perceiving the face and the vase interpretations. Fixation bias scores were computed by taking the difference between the number of fixations made while perceiving the face and the vase interpretations. Positive values of either variable indicate a face preference/bias.

For each variable, difference scores for upright and inverted stimuli were first compared using a repeated measures ANOVA. Unlike the pattern seen with controls (see Chapter 2), there was no significant main effect of Orientation for the preference scores [$F(1, 7) = 1.61$, $p > .24$, $\eta_p^2 = .19$] or for the number of fixations made [$F(1, 7) = 1.77$, $p > .23$, $\eta_p^2 = .20$]. Next, difference scores for upright and inverted stimuli were each compared to zero using one sample *t*-tests. Unlike controls (see Figures 2.7 and 2.8), in the AS group the mean preference scores and fixation bias scores were not significantly different from zero, regardless of stimulus orientation. Based on the group means, then, it appears that there is no evidence of perceptual bias with upright stimuli, and no evidence of an inversion effect, in the AS group.

As above, looking at individual differences on both of these measures was deemed necessary as the variation in the AS group was substantial. A closer inspection of Figure 3.9a revealed that, for upright figures, the preference scores for 7 of the 8 individuals' scores fell outside of the 95% CI of the controls. Interestingly, 6 of these individuals showed a weaker face bias, no bias, or a vase bias for the upright figure in the passive viewing condition. When viewing the inverted figure, only 4 of the 8 participants had preference scores that fell outside the 95% CI. More importantly than this, however, is the question of whether or not individuals showed an "inversion effect" – defined here as a *difference in performance* between responses to upright and inverted stimuli (note, here, that this use of the term differs from the classic usage). As can be seen from Figure 3.9a, two individuals (cases 2 and 5) showed an unusually large effect of inversion. This inversion effect was in the same direction as that seen in controls; thus, they both became relatively more "vase-biased" with stimulus inversion. Three participants (4, 6, and 8) showed an effect of inversion that was comparable in magnitude and direction to that shown by controls (despite differences in their "baseline" performance with upright displays). One participant (case 3) showed essentially no effect of inversion. Finally, two participants (cases 1 and 7) showed an "inversion effect" that was large, but *opposite in direction* to that exhibited by controls. These two individuals, then, became relatively more "face-biased" with stimulus inversion.

A similar pattern emerged in the fixation bias scores. Again, many of the individual scores were atypical but, more importantly, clear individual differences were apparent in the magnitude and direction of the “inversion effect” (see Figure 3.9b). Cases 2 and 5 showed an exaggeration of the inversion effect exhibited by controls on this measure, as they had with the preference scores described above. Cases 3, 4 and 6 showed an inversion effect that was comparable in magnitude and direction to that of controls. Case 8 showed little effect of inversion. Finally, cases 1 and 7 showed a large inversion effect, but one that was in the opposite direction to that exhibited by controls.

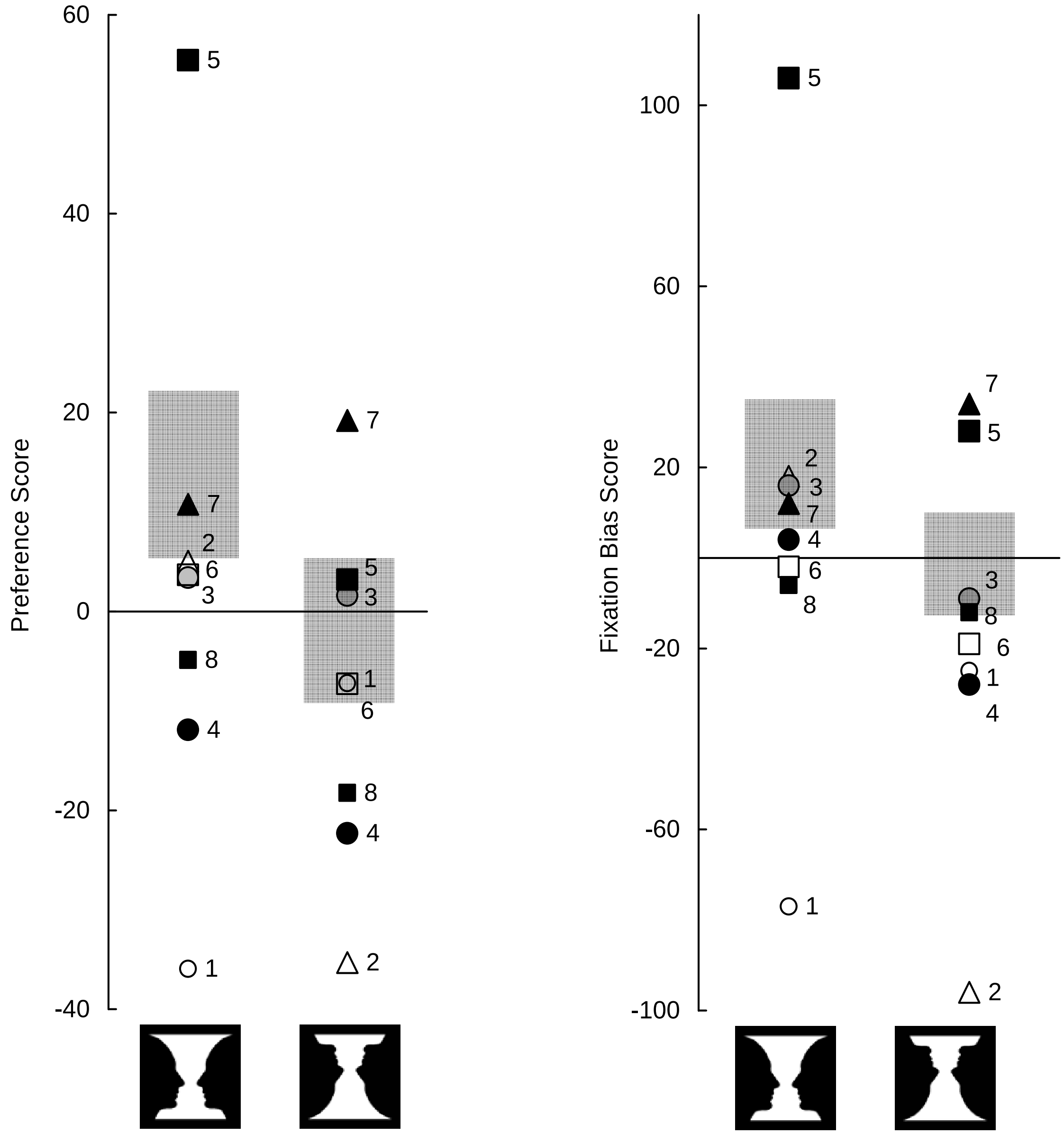

Figure 3.9. **Preference and fixation bias scores for upright and inverted Rubin's vase-face. These scores reveal the direction and magnitude of bias: (a) positive scores indicate a preference to perceive the faces, and negative scores indicate a preference to perceive the vase and (b) positive scores indicate that more fixations were made when participants reported perceiving the faces, and negative scores indicate that more fixations were made when participants reported perceiving the vase. The 95% CI for these scores are indicated with a shaded box for the control group. The scores for each individual with AS are indicated with points.**

Effect of instruction. The perceptual reversal rates from the individuals with AS were entered into a 3 (Instruction: passive, slow, fast) x 2 (Orientation: upright, inverted)

ANOVA with repeated measures on both factors. A main effect of Instruction was revealed, $F(2, 14) = 7.06$, $p < .03$, $\eta_p^2 = .50$, with significant differences observed between alternate quickly instructions and both passive viewing ($p < .02$) and alternate slowly instructions ($p < .03$). No significant differences were found between the passive viewing and alternate slowly instruction ($p > .08$). Unlike with controls, stimulus inversion had no effect on the group means. Unlike controls, there was no main effect of Orientation, and no significant Instruction x Orientation interaction; thus the group means would appear to indicate that participants with AS found it equally easy to switch between interpretations of the figure, regardless of its orientation or task instructions.

Examination of individual participant's data was revealing. In Figure 3.10 we present differences between reversal rates for upright and inverted stimuli; here, positive scores indicate that the participant makes more switches with upright than inverted stimuli, and negative scores indicate that s/he found it easier to switch inverted than upright stimuli. The shaded CIs reflect the fact that controls found it easier to switch upright than inverted figures in the alternate quickly instruction condition (as indicated in Chapter 2, Figure 2.11). In two cases (1 and 7), switching rates were consistently higher than those seen with the controls at all levels of instruction and for both upright and inverted figures, but while case 7 found it easier to switch with upright figures, case 1 found it easier to switch with inverted figures. In the remaining cases (2, 3, 5, 6, and 8), switching rates were consistently slower than those seen with the control group, and (unlike controls) they did not find it easier to switch upright than inverted figures during the alternate quickly instruction condition. Only participant 4 performed in a manner that was very comparable to controls; the key difference was that, unlike controls, this participant found it somewhat easier to switch upright than inverted figures even during passive viewing.

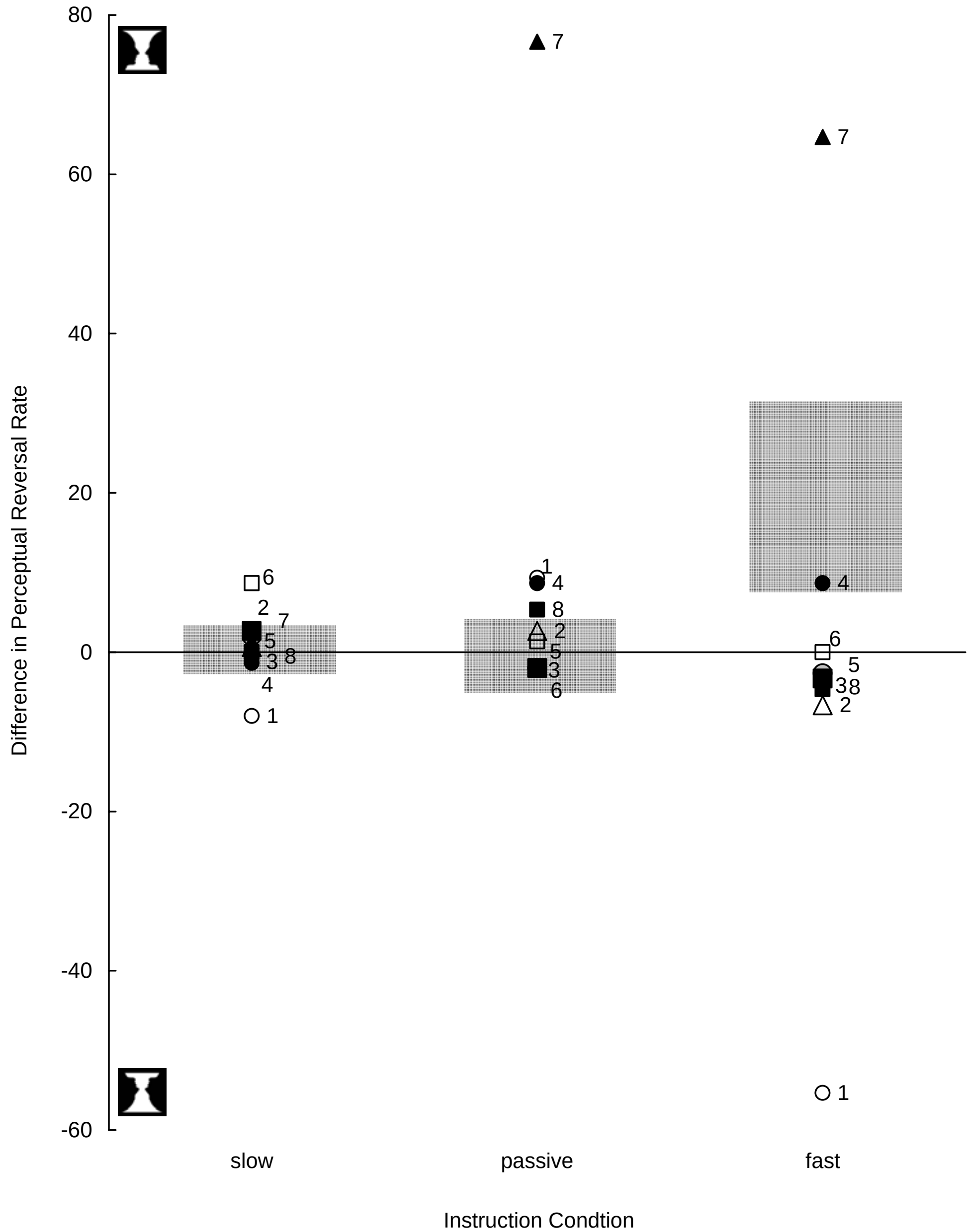

Figure 3.10. **Differences in perceptual reversal rates for upright and inverted Rubin's vase-face in each of the three instruction conditions: (a) alternate slowly, (b) passive viewing, and (c) alternate quickly. Difference scores reveal the direction and magnitude of the bias - positive scores indicate that faster reversal rates occurred for the upright Rubin's vase-face, and negative scores indicate that faster reversal rates occurred for the inverted Rubin's vase-face. The 95% CIs for each of the instruction conditions are indicated with a shaded box for the control group. The scores for each individual with AS are indicated with points.**

Summary. The final goal of the present study was to determine whether inversion of an ambiguous figure would lead to an "inversion effect" in individuals with AS, with either preference or fixation bias scores. We also wanted to determine whether the magnitude of the inversion effect (if present) would vary in response to changing task instructions. The group means suggested that, unlike controls, individuals with AS showed no preference for either interpretation of the upright Rubin's vase-face, and no inversion effect. Examination of the individual preference scores, however, provided more information. The majority of participants showed a weaker face bias, no bias, or a vase bias for the upright Rubin's vase-face. Five participants showed an "inversion effect" that was in the same direction as controls', and of equal or larger magnitude, although their baseline scores with upright displays varied (i.e., their responses became more "vase-biased" with inversion). One individual with AS showed no effect of inversion. Finally, two individuals showed an inversion effect that was in the *opposite* direction than that shown by controls (i.e., becoming relatively more face-biased with stimulus inversion). The analysis of the fixation bias scores mirrored the preference scores summarized above.

Finally, *only one* participant with AS performed in a way that was comparable to controls in response to the instruction manipulation (i.e., switching more slowly for the inverted than upright displays in the fast condition). The remaining participants either had faster switching rates than controls and/or found it easier to switch inverted than upright displays, or had slower switching rates than controls and showed no effect of inversion in the alternate quickly condition.

Discussion

To date, no one has examined face processing mechanisms in individuals with AS using the paradigm we have described in the current research. We predicted that individuals with AS would show perceptual reversal patterns for content-reversible and perspective-reversible ambiguous figures that would be distinct from controls in the both the Spontaneous Reversals Task and Informed Reversals Experiment. Specifically, individuals with AS were expected to have difficulty selectively controlling their attention and alternating between interpretations; as a result, they were expected to make fewer reversals overall in both tasks. Moreover, we expected this clinical group to experience difficulty controlling their switching speed when instructed to do so. In addition, we predicted that AS participants' abnormal reversal patterns would be more pronounced with ambiguous figures containing human faces than those not containing faces. Our final prediction was that individuals with AS would show a weaker face inversion effect with Rubin's vase-face.

As discussed below, many of the predictions described above were supported by the group data. Researchers have traditionally focused on such group comparisons to determine whether deficits exist in ASD. Atypical responding is only declared when significant differences are found between the performance of the clinical and control groups. However, Hill and Bird suggest that "this approach alone is problematic since individual differences tend to be large" (2006, p. 2823). Given this, focusing on group means alone may mask the abnormal performance of individuals with ASD. Indeed, when we examined individual scores within the AS group (an approach endorsed by many researchers, e.g. (Marshall & Newcombe, 1984; Jarrold & Brock, 2004; Crawford, Garthwaite, Howell, & Venneri, 2003) we found that these told a much more complex and compelling story than the group data. In the following paragraphs, we will discuss key results pertaining to each task, in turn – first presenting group results, and then focusing on individual differences in performance.

Spontaneous Reversals Task

The ability to perceive both interpretations of an ambiguous figure has been shown to be impaired in children with autism (Sobel et al., 2005). For example, Sobel et al. (2005) presented three ambiguous figures (i.e., man-mouse, duck-rabbit, and vase-faces) to children with ASD and controls. Whether or not they were informed about the figures' ambiguity, the ASD group generated fewer reversals and more single interpretations than age- and verbal-IQ-matched control children (Sobel et al., 2005).

Our results extend Sobel and colleagues' findings. Firstly, we showed a similar pattern of results for adults with AS. Secondly, we used a larger number of ambiguous figures than Sobel et al. (i.e., 8 compared to 3) and different types of figures -- content-reversible and perspective reversible. Regardless of the type of figure displayed, the adults in the current study reported perceiving, on average, only one interpretation per figure when uninformed about the ambiguity, whereas controls reported significantly more than one interpretation, on average. When we compared the groups directly, we found that individuals with AS tended to perceive fewer interpretations for content-reversible figures than the control group, but not for the perspective-reversible figures.

At an individual level, 70% of controls were able to generate more than one interpretation per figure in each category, with some participants perceiving all 8 possible interpretations. In contrast, only 50% of individuals with AS were able to generate more than one interpretation per figure in each category. Interestingly, in the AS group a maximum of 5 interpretations were offered for the content-reversible figures involving faces or agents, whereas up to 7 interpretations were offered for the perspective-reversible figures. In this case, our predictions were confirmed as the group and individual data are consistent in suggesting that individuals with AS have particular difficulty spontaneously generating alternate interpretations of figures containing faces or agents.

Informed Reversals Experiment: Passive Viewing Condition

In the passive viewing condition of the Informed Reversals Experiment, participants were asked to allow switches in perception to occur naturally. The reversal rates, preference scores, and fixation bias scores of participants with AS generally fell outside the normal range. Like controls, the AS group showed no effect of type of figure on perceptual reversal rates, and tended to make fewer fixations when viewing the Maltese cross than any other figure. Unlike controls, however, the AS group exhibited no overall preferences for particular interpretations for any of the figures, and no overall fixation biases.

The group results confirm the original prediction that individuals with AS would show atypical reversal behaviours. The individual data, however, are much richer. For the majority of individuals in the clinical group, perceptual reversal rates were abnormally slow for all figures (a finding we had expected; cf. Fletcher-Watson et al., 2006). On the other hand, two female participants showed extremely fast reversal rates compared to controls. One of these individuals commented on the fact that she felt that she could not keep her attention on either one of the interpretations and that her switching was “out of control". Although we did not expect to see unusually fast reversal rates in any individuals with AS, this pattern of responding is nevertheless consistent with the finding that individuals with ASD have difficulty controlling their attention (Bird et al., 2006; Courchesne et al., 1994; Kawakubo et al., 2007; Landry & Bryson, 2004; Renner, Grofer, & Klinger, 2006; Speer et al., 2007; Townsend, Harris, & Courchesne, 1996), and experience problems with executive function, particularly in terms of response initiation and intentionality (Hill & Bird, 2006).

Generally speaking, individuals with AS made more fixations than controls when viewing any of the ambiguous figures. This is interesting considering that more fixations are generally associated with a more distributed scanning area (Noton & Stark, 1971b). A question that arises, then, is whether the participants with AS in the present study would show a sequence of fixations that appears less planned and deliberate. In other words, would individuals with AS also show a less strategic scanning sequence when viewing all types of stimuli, or would differences between faces and objects emerge on this variable? We intend to address this interesting question in future research.

Interesting, all individuals with AS exhibited atypical reversal rates and, unlike controls, showed preferences for particular interpretations of the Boring's young girl-old woman figure. In addition, three-quarters of the participants with AS showed a weaker "face" preference, no preference, or a "vase" preference when viewing the upright Rubin's face-vase. In contrast, approximately half of the participants with AS showed an equivalent or stronger preference than that exhibited by the controls for the vertical cross of the Maltese cross and the top view of the Necker cube. Consistent with the results of the Spontaneous Reversals Task, then, these data indicate that individuals with AS have difficulty engaging and/or disengaging their attention (Landry & Bryson, 2004; Wainwright & Bryson, 1996; Casey, Gordon, Mannheim, & Rumsey, 1993), particularly with stimuli involving faces (Swettenham et al., 1998). These abnormal attention shifting patterns could be interpreted in two ways. First, our results are consistent with theories predicting that individuals with ASD have a specific deficit in attending to social stimuli, which may be related to impairment in direction of gaze (Senju et al., 2004) and joint attention (Baron-Cohen, 1995; Courchesne, Press, & Yeung-Courchesne, 1993). Alternatively, because some atypical responding was also observed for ambiguous figures containing objects (e.g., larger number of fixations), it may be that a general deficit in processing all types of complex configural stimuli contributes to (or exacerbates) problems in processing social stimuli (Davies, Bishop, Manstead, & Tantam, 1994; Behrmann et al., 2006).

Informed Reversals Experiment: Effect of Inversion

As noted above, unlike controls, the AS group as a whole showed no evidence of a perceptual preference for the faces in the upright version of the Rubin's face-vase figure under passive viewing conditions. Examination of individual performance revealed that this pattern was evident for half of the participants. Two individuals (cases 5 and 7) showed a face bias equal to or greater than that exhibited by controls but, interestingly, two individuals (cases 1 and 4) actually showed a rather striking vase preference when viewing the upright figure.

While the results described above are interesting in their own right, the main question we sought to address here was whether or not individuals with AS would show an "inversion effect" – defined here as a change in the focus of attention (rather than a decrement in performance) between upright and inverted stimuli. The group data suggested that the AS group was not affected by stimulus inversion (i.e., showed no *change* in their overall perceptual preferences). Examination of individual's data, however, revealed that this result only accurately described the performance of one participant (case 3). The remaining participants *all* showed an inversion effect, of sorts. However, this did not necessarily mean that, like controls, they changed from showing a face preference to no preference with stimulus inversion. In fact, this particular pattern was only seen occasionally. Many participants went from showing no preference (or a weak vase preference) to showing a stronger vase preference after stimulus inversion. More strikingly, two participants showed an "inversion effect" that was large, but *opposite in direction* to that exhibited by controls. These two individuals, then, became relatively more "face-biased" with stimulus inversion.

A similar pattern emerged in the bias scores based on the number of fixations made during each interpretation. Again, many of the individual scores were atypical but, more importantly, clear individual differences were apparent in the magnitude and direction of the "inversion effect". Two individuals showed an exaggeration of the inversion effect exhibited by controls on this measure, as they had with the time difference scores described above. Three individuals with AS exhibited an inversion effect that was comparable in magnitude and direction to that of controls (despite being more weakly face-biased with the upright displays), one individual showed little effect of inversion, and two individuals showed a large inversion effect that was in the opposite direction to that exhibited by controls. The performance of these two individuals might suggest that they are more drawn to inverted than to upright faces, perhaps because these stimuli can readily be processed using a strategy that they excel in, namely application of a piecemeal approach.

Interpretation of the findings for the inverted Rubin's vase-face is by no means a straightforward matter. In some previous work, individuals with ASD have been shown to exhibit smaller inversion effects and/or superiority with inverted faces when matching faces or face parts, and identifying identities and emotions (Hobson et al., 1988; Langdell, 1978). It has been suggested that these results might reflect an underlying bias to engage in local processing in this group, even with upright displays (Happé & Frith, 2006; Mottron et al., 2006). If they are already using such a strategy with upright faces, then inversion would be expected to have little effect on performance (unlike in neurotypical viewers, where inversion would disrupt the global processing of faces, triggering adoption of a local processing strategy (Farah et al., 1995a)). Other researchers, however, have found that individuals with ASD *are* affected by face inversion, suggesting they are sensitive to the global cues present in upright displays (Lahaie et al., 2006).

It would be very interesting to examine brain activation patterns in individuals with AS as they process upright and inverted ambiguous figures. Even if many of them are affected by stimulus inversion in a similar manner to controls on behavioural measures, they may be showing different patterns of neural activation that would provide insight into the underlying processing strategies that they are applying (cf. Hasson et al., 2001; O'Connor, Hamm, & Kirk, 2007).

Top-down Control of Attention in Individuals with AS

Although the group means indicated that participants could control their switching rates in a top-down fashion when instructed to do so, this was not invariably the case. Thus, some participants showed a little or no effect, and some a much larger effect of instruction than controls. *Only one* participant with AS (case 1) showed the same *pattern* exhibited controls (i.e., higher switching rates in the alternate quickly condition for the figures involving faces than for those involving objects). In addition, only one participants with AS (case 4) switched more slowly for the inverted than upright displays in the fast condition. The remaining participants either had faster switching rates than controls and/or found it easier to switch inverted than upright displays, or had slower switching rates than controls and showed no effect of inversion in the alternate quickly condition.

The atypical responses seen for the effect of instruction adds evidence that individuals on the autism spectrum demonstrate particular difficulties with executive functioning (Hill, 2004; Hill & Bird, 2006; Frith, 2004). Although less research has been conducted on the executive functions in individuals with AS, observations of particular behaviours suggest that impairments in top-down control are evident (Frith, 2004). Our research here provides compelling evidence that this may in fact be the case.

Conclusion

The current study makes an important contribution to our understanding of face processing and attentional control/social cognition in individuals with AS. An important take-home message from this work is that even within a diagnostically homogeneous group of individuals on the autism spectrum, heterogeneous responding should be expected (Szatmari, 1999). These individual differences are of great interest and should not be ignored, or masked by focusing on group means only.

CHAPTER 4: Conclusions and Future Directions

In the Informed Reversals Experiment, we demonstrated that perceptual reversal behaviours are influenced by the category of ambiguous figures in typically developing individuals. Specifically, the preferences reported, the fixation bias scores, and the perceptual reversal rates varied as a function of the particular content-reversible figure being viewed (face-face, face-object, or object-object). Differences were also observed between responses to particular content-reversible figures and the perspective-reversible Necker cube.

One of the key findings presented in Chapter 2 was the fact that individuals showed a preference to perceive the face interpretation over the vase interpretation of Rubin's figure, however, a preference was not observed for Boring's young girl-old woman. Thus, our results are consistent with previous research demonstrating that faces draw and demand more attention when paired with objects (Langton et al., 2007). Moreover, we found that presenting an inverted Rubin's vase-face resulted in an inversion effect analogous to that seen in studies of face processing (Farah et al., 1995a; Bartlett & Searcy, 1993; Singer & Sheinberg, 2006; Yovel & Kanwisher, 2004) and figure-ground discrimination (Gibson & Peterson, 1994; Peterson & Gibson, 1994; Peterson et al., 1991).

Describing the perceptual reversal behaviour patterns of typically developing individuals in response to the manipulations described in Chapter 2 allowed us to draw comparisons to behaviours exhibited by a particular clinical group - individuals diagnosed with AS. In Chapter 3, we described that in general, individuals with ASD have been shown to have abnormalities in face processing, atypical object processing, and general attentional deficits. We predicted, therefore, that individuals with AS would show atypical attention shifting when viewing figures containing competing interpretations. Our predictions were supported, both at a group level and by examining individuals' performance. Atypical patterns of perceptual reversals were especially evident with ambiguous figures containing faces or agents compared to those that involved only object interpretations. It is important to highlight that the current study also suggests that even within a diagnostically homogeneous group of individuals on the autism spectrum, heterogeneous responding may be expected (Szatmari, 1999).

Future Directions

In the current study, we reported on the time participants spent viewing particular interpretations, and on their perceptual reversal rates. The data for these variables came from participants' reports (i.e., key presses). Furthermore, we examined one variable that was collected through the eye-tracker -- the number of fixations, which is a variable used often in studies of visual processing of faces in individuals with autism (Adolphs, 2002; Dalton et al., 2005; Klin et al., 2002; Pelphrey et al., 2002; Corden et al., 2008). Other variables in our data set have yet to be examined. For example, researchers using eye-tracking technology often report the cumulative duration of all fixations (Barton et al., 2006), mean fixation duration (Ellis & Stark, 1978), first fixations (Rutherford & Towns, 2008), and average eye position (Einhäuser et al., 2004).It will be interesting to see how these variables were affected by the experimental manipulations.

In addition to the variables listed above, we are greatly interested in analyzing the spatial distribution of scanning (i.e., the hot spots of attention), and the sequence of fixations between different regions. In future research we plan to divide the Rubin's vase-face figure into different feature regions. Fixations could then be localized to these particular areas, and scanning sequences could then be determined using different methods such as Markov first-order matrices (Gbadamosi & Zangemeister, 2001). Of particular interest here is whether we would see a differential pattern of scanning with upright and inverted versions of the Rubin's vase-face akin to that seen with upright and inverted photographs of faces (Barton et al., 2006). For example, Barton et al. have shown that participants make more fixations to the mouth and chin and fewer to the brow when viewing inverted faces than upright faces. Moreover, we might test whether individuals in the general population would show a preference for the left side of the upright Rubin's vase-face and, if so, whether this preference is weaker or reversed in those with AS (Casey et al., 1993; Wainwright & Bryson, 1996).

Another question that we are interested in examining is whether facial expressions would influence perceptual reversal patterns. The abilities to correctly interpret and produce appropriate facial expressions are important social skills. Our attention is quickly drawn to emotional content in natural scenes (Nummenmaa et al., 2006) or faces (Cooper & Langton, 2006; Eastwood, Smilek, & Merikle, 2003; Koster et al., 2007; Langton et al., 2007; Mack et al., 2002). Interestingly, the literature suggests that happy expressions can be processed accurately even following face inversion, but the processing of negative emotions (sadness, fear, anger, disgust) is impaired after face inversion (Dawson et al., 2002; McKelvie, 1995; Prkachin, 2003). The fact that happy expressions are not affected by inversion may suggest that viewers process upright, happy faces in a parts-based manner (i.e., by focusing on the mouth; McKelvie, 1995).

In future, we plan to explore viewers responses to a smiling Rubin's vase-face (see Figure 4.1). We expect to find that the smiling faces in this new version of Rubin's vase-face capture viewers' attention much more than the neutral faces, and that inverting the smiling figure will produce a smaller "inversion effect" in controls than that seen with the neutral figure. We also expect that individuals with AS will perform differently from controls with these stimuli. Several recent studies suggest that individuals with ASD process emotional expressions in an atypical fashion. Spezio, Adolphs, Hurly, and Piven (2007) for example, have shown that people with high functioning autism look more at the mouth and less at the eyes than typical controls, regardless of the valence of the expression. If this is the case, then individuals with ASD may show similar patterns of perceptual reversal behaviour when examining both the original (neutral) and the smiling version of Rubin's vase-face, and show little or no effect of inversion with either figure.

***Figure 4.1*. Rubin's vase-face figure created with mirror images of a smiling profile.**

The results from our study show that ambiguous figures can be a very valuable tool for examining face processing mechanisms in the general population and other distinct groups of individuals, particularly for those diagnosed with AS. Future work in our laboratory will continue to utilize ambiguous figures to investigate how the visual system selects a particular interpretation to attend to.

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Appendix A

GENERAL INFORMATION QUESTIONNAIRE

NOTE: This information will be kept strictly confidential and will be used for research purposes only.

Participant ID #: ____________

YOUR MOTHER

Please indicate the highest level of education that your mother has completed:

_____ Less than seventh grade

_____ Seventh through ninth grade

_____ Tenth through eleventh grade

_____ Completed high school

_____ At least one year of college/university or other, specialized training

_____ Completed a college or university degree

_____ Completed a graduate or professional degree (e.g. MA, PhD, MD, etc.)

What is your mother's present occupation? ____________________________________

YOUR FATHER

Please indicate the highest level of education that your father has completed:

_____ Less than seventh grade

_____ Seventh through ninth grade

_____ Tenth through eleventh grade

_____ Completed high school

_____ At least one year of college/university or other, specialized training

_____ Completed a college or university degree

_____ Completed a graduate or professional degree (e.g. MA, PhD, MD, etc.)

What is your father's present occupation? _____________________________________

YOU THE PARTICIPANT

Date of birth: ____________ Age: ____________ Gender: M / F

What hand do you use to write with? __________________

What language(s) do you speak or understand?____

Is English your first language, or the language that you use most frequently?

____

What language(s) were you educated in?

____

Have you ever lost consciousness, experienced seizures, or had other known neurological problems?

____

____

____

____

____

Have you been identified as having academic problems? If yes, what type?

____

____

____

____

Appendix B

Spontaneous Reversals Task

Participant ID: _______________ **Date:** ______________________

One point will be awarded for each correct percept reported.

Instructions:
Before showing the first picture say, **" I will show you a series of pictures. I would like you to tell me the first thing you see in each picture."** Show the first picture and wait for a response. Write down their response and say, **"Do you see anything else?"** Write down the response. If the participant's response is unclear, ask for clarification.

face/saxophone player ____
____ **/2**

2 cubes ____
____ **/2**

father/son (old man/young man) ____________________________________
____ **/2**

folded paper (modified staircase) __________________________________
____ **/2**

chef/dog ____
____ **/2**

Staircase ____
____ **/2**

Boring's young girl-old woman ____________________________________
____ **/2**

Necker cube ____
____ **/2**

Content-reversible subscore /8

Perspective-reversible subscore /8

Total Score /16