Implicit and Explicit Face Recognition in Association with Autism Spectrum Disorder

Darren Hedley, BPsyc (Hons.), M.A.

School of Psychology
Faculty of Social and Behavioural Sciences

A thesis submitted to Flinders University for the degree of Doctor of Philosophy

February, 2012

TABLE OF CONTENTS

SUMMARY v

DECLARATION x

ACKNOWLEDGEMENTS xi

CHAPTER 1 1

- Introduction 1
    - Theoretical Framework 2
- Face Processing in ASD 13
    - Face Perception and Social Development in ASD 15
    - Atypical Face Perception in ASD 16
    - Face Specific Recognition Impairment in ASD 19
    - Atypical Face Processing and Eye Scanning in ASD 21
- Implicit and Explicit Memory 23
    - Implicit and Explicit Memory in ASD 24
    - Assessing the Influence of Memory on Implicit Face Processing 25
    - The Eye Movement-Based Memory Effect 26
    - Eye Movement-Based Memory Effect in ASD 28

CHAPTER 2 32

- Experiment 1 32
    - Method 35
        - Participants 35
        - Materials 37
        - Procedure 41
    - Results 42
        - Recognition Performance 42
        - Relationship between Face Recognition and Cognitive Function, Autistic Traits, and Negative Affect 44
    - Discussion 47

CHAPTER 3 50

- Experiment 2 50

    Method 52
        Participants 52
        Apparatus and Materials...54
        Procedure...54
        Eye Movement Parameters and Dependent Measures 56
    Results...61
        Eye Movement-Based Measures 61
        Viewer Defined Eye Movement-Based Measures 64
        Time Course Analysis for 1000 ms Time Bins 70
        Discrimination Performance and Bias......................................74
        Response Time 75
    Discussion 76
CHAPTER 4...80
  Experiment 3 80
    Method 80
        Apparatus and Materials...82
        Procedure...83
    Results...84
        Eye Movement-Based Measures 84
        Discrimination Performance, Bias and Error Rates 93
        RT..96
    Discussion 99
CHAPTER 5...107
  Experiment 4 107
    Method 111
        Participants 111
        Apparatus and Materials...112
        Procedure...112
    Results...116
        Eye Movement-Based Measures 116
        Discrimination Performance, Bias and Error Rates 117

Size of the RT advantage for Upright and Inverted Faces 122

Discussion 124

CHAPTER 6...133

Attention to the Eye and Mouth Region...133

Method 138

Participants 138

Materials...138

Procedure...138

Results...140

Percentage of Correct Responses for the Emotion Test..........................140

Proportion of Fixations to the Eye and Mouth Regions..........................140

Relationship between Fixations to the Eyes and Mouth and Discrimination Performance...146

Discussion 149

CHAPTER 7...152

General Discussion...152

Analysis of Eye Movement Data...155

Theoretical Perspective 158

Heterogeneity in Face Recognition Skills in ASD.................................165

Fixations to the Eye and Mouth Regions 167

Future Directions..169

REFERENCES 171

SUMMARY

Deficits in face processing have been regarded as central to the cognitive profile of individuals with an Autism Spectrum Disorder (ASD; e.g., Dawson et al., 2002; Dawson, Webb, Carver, Panagiotides, & McPartland, 2004; Schultz et al., 2000; Wilkinson, Best, Minshew, & Strauss, 2010). Given (a) face processing skills play an important role in recognising and interpreting social signals (Calder & Young, 2005; Herzmann, Danthiir, Wilhelm, Sommer, & Schacht, 2007), and (b) social disability in ASD is profound and central to the diagnostic criteria of the disorder (APA, 2000), it is not surprising that a considerable amount of research has been invested in investigating face processing in ASD (Klin et al., 1999). The present thesis examined face recognition, a central component of the face processing system which is thought to be affected in individuals ASD. More specifically, the contribution of memory associated with early implicit visual processing to the face recognition deficits that are often reported in the literature (Klin et al., 1999; Wolf et al., 2008) was assessed.

Despite the fact that face recognition skills have been widely studied in ASD, empirical evidence of a specific deficit has been mixed (Klin et al., 1999). Given these mixed results, some suggest deficits in face recognition in ASD may be the result of a general cognitive or perceptual impairment (Behrmann, Thomas, & Humphreys, 2006; Davies, Bishop, Manstead, & Tantam, 1994). Others argue that impairment in face recognition in ASD is a specific deficit resulting from atypical development of the face processing system (Dawson, Webb, & McPartland, 2005; Wolf et al., 2008).

Thus, two main theoretical perspectives on the face recognition deficit in

ASD have been proposed. The social motivation or expertise hypothesis posits that face recognition deficits arise from a failure to orient to faces during development. Consequently, the development of specialised brain regions associated with face processing is disrupted (Dawson et al., 2005). An alternative perspective suggests impairment in face recognition in ASD may result from difficulties with complex information processing (Minshew, Williams, & McFadden, 2008; D. L. Williams, Goldstein, & Minshew, 2006). To gather further evidence relevant to the evaluation of these perspectives I conducted four experiments to examine face recognition in individuals with ASD. Specifically, I examined whether there was evidence of dissociation between the early, automatic processing of face information and late, effortful face recognition. This should assist evaluation of whether the face recognition impairment in ASD is isolated to (a) late stage, complex information processing, or (b) affects multiple levels of the face processing system, including early stage processing, with the latter being more consistent with the social motivation/expertise hypothesis.

Experiment 1 confirmed previous studies reporting presence of a face recognition deficit in ASD. Participants were assessed with a standardised face recognition test, the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006a). Participants with ASD performed worse than matched controls and test norms overall. Nonetheless, many individuals with ASD performed at, or even better than, the typical level for their age. Thus, it is apparent face recognition in ASD is characterised by a large degree of heterogeneity between individuals. However, given the poorer performance in ASD participants when group means were examined, the next two experiments

were designed to determine whether the deficit in face recognition in some individuals with ASD is confined to late, high-level processes associated with explicit recognition, or whether it extends to early, implicit processing of visual information. If the former position is true, then this would be more consistent with the complex information processing hypothesis. If, however, the latter position is found to be true then this would suggest that both early and late levels of processing are affected, which would be more consistent with the expertise, or social motivation hypothesis.

The next studies used eye movement fixations to assess the influence of memory on implicit processing of studied faces. Previous studies have shown that eye movement behaviour differs for viewed compared to novel faces, a difference assumed to reflect the presence of a memory trace for old, but not to new faces (Althoff & Cohen, 1999). Specifically, Experiments 2 and 3 compared (a) the influence of memory on implicit visual processing for unfamiliar faces using eye movements and reaction time (RT), and (b) explicit face memory using an old-new discrimination task. Experiment 3 differed from Experiment 2 in that the degree of similarity between study and test stimuli was manipulated: previously unseen images of target faces were presented at test, and some of the images were degraded with visual noise. Experiment 3 therefore increased the level of difficulty for the recognition task. Both experiments were supportive of a deficit in explicit face recognition in ASD, with explicit face recognition in ASD being particularly affected by task difficulty (i.e., the stimulus manipulation in Experiment 3). Eye movement-based measures, however, indicated that at least some areas of implicit visual processing associated with face recognition are intact in ASD. Specifically, the influence of memory on visual scanning of viewed faces compared to novel faces was similar for participants with and without an ASD. Given the apparent dissociation between implicit face processing and explicit face recognition, these results are consistent with the complex information processing hypothesis.

Consistent with the complex information processing hypothesis, face processing in ASD may be affected by a deficit in holistic or configural processing, and a bias for part or feature based encoding. Some studies have reported an advantage for inverted face recognition in individuals with an ASD compared to non-ASD persons. More specifically, individuals with an ASD may not be affected to the same extent as non-ASD persons by face inversion, which disrupts configural processing. This is referred to as the Face Inversion Effect (FIE). If persons with ASD are reliant on feature based recognition then this will be advantageous for inverted face recognition, but disadvantageous for upright recognition. Experiment 4 examined the FIE in participants with an ASD. Again, eye movement measures were used to assess implicit visual processing of face stimuli, RTs were examined, and an old-new recognition task assessed explicit face recognition. Eye movement measures did not reliably discriminate old and new faces. It is likely that either the stimuli or the task led to a high degree of homogeneity in eye movements between all stimuli. Nonetheless, and contrary to expectation, both participants with and without an ASD showed strong RT and accuracy based FIEs. This indicates that ASD participants demonstrated configural face processing and did not show an advantage for feature based recognition as predicted. Explicit face recognition was again found to be worse in

ASD participants compared to non-ASD participants.

Given that the influence of memory on implicit processing has not been well studied in persons with ASD, and there is little or no research with this group that has specifically examined the role of memory on implicit face processing, this research adds to the knowledge base in this area. The results reported here place the origin of the deficit in resource intensive processes associated with explicit, high-order recognition decisions. In contrast, early, automatic face processing may be spared. Contrary to some studies, no difference in regions viewed (e.g., reliance on the mouth compared to the eyes) was found between ASD and non-ASD participants, and there was no evidence of an ASD advantage for feature based recognition.

DECLARATION

I certify that this thesis does not contain any material which has been accepted for the award of any other degree or diploma; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text of the thesis or notes.

Darren Hedley, BPsyc (Hons.), M.A.

22nd February, 2012

ACKNOWLEDGEMENTS

First and foremost, thank you to my supervisors. Robyn, your support, encouragement, and confidence in my work pushed me both academically and personally. Your passion for your work provides a continual reminder of why we do what we do, and is truly inspirational. Neil, I have benefited greatly from your kindness, wisdom and encouragement. Despite your commitments you have always found time for me. Keep on riding that banzai pipeline!

Thank you to Ben Maddock for providing technical expertise and support, also to Sean Fitzgibbon, Nathan Weber, Alyssa Sawyer, Pawel Skuza, Nathan Leggett, Paul Williamson and everyone from the eyewitness lab at Flinders University.

Thank you to Yessica for hanging in there and for moving so far from home to support me, to my mum Robyn for many years of unconditional encouragement and support, to my brother David who also provides me with inspiration and of whom I am so proud, to Anusha, Micah and Zachary, and to my extended family; particularly Daryl and the rest of the wanderers and adventurers from the clan who feed my spirit. To my dad for advising me to accept the offer of the PhD position. To members of the Flinders University Underwater Club (FUUC), roomies Cath, Nicole and Fei, the Crazy Farmers, and to Billy T, Aussie Bob, Jason, and the rest of the unsavoury musicians, hangers on, and unsavoury hangers on who have kept me truly amused over the last few years. Un fuerte abrazo a Jerrilou, Jane y Jason, a mis compadres de Alliant, y a todos mis amigos de Mexico.

Thank you to Brad Duchaine for supplying the Cambridge Face Memory Test (CFMT), and for valuable feedback and comments regarding Experiment 1.

Above all, thank you to all of the participants who so freely gave their time, and to Jon Martin and Autism SA for their assistance with recruitment.

This research was supported by (a) Australian Research Council (ARC) LE0882562 to Neil Brewer, Robyn Young et al., and ARC DP1093210 to Neil Brewer et al., (b) a Flinders University Research Grant to Robyn Young and Neil Brewer, and (c) a Flinders University Research Scholarship (FURS).

Portions of the research in this paper use the FERET database of facial images collected under the FERET program, sponsored by the DOD Counterdrug Technology Development Program Office (Phillips, Moon, Rizvi, & Rauss, 2000; Phillips, Wechsler, Huang, & Rauss, 1998), the Productive Aging Laboratory (PAL) Face Database (Minear & Park, 2004), and the Computer Vision Laboratory (CVL) Face Database, University of Ljubljana, Slovenia (Peer, 2011; Solina, Peer, Batagelj, Juvan, & Kovač, 2003).

CHAPTER 1

Introduction

Autism Spectrum Disorders (ASD) are characterised by impairment in social perception and cognition, communication, and idiosyncratic interests and repetitive behaviours (APA, 2000). Of these, social deficits are possibly the most debilitating and profound (Rutherford, Clements, & Sekuler, 2007). Because face processing is thought to be highly integrated with social development (Dawson et al., 2002; Pelphrey et al., 2002), much research in the ASD field has involved the study of faces, and the way in which they are perceived and processed by persons with ASD. Specifically, there is some evidence that faces may be processed or perceived differently by persons with ASD compared to individuals who are typically developing, or who have non-ASD conditions (Baron-Cohen et al., 1999; Dawson et al., 2002; Dawson, Webb, & McPartland, 2005; Hubl et al., 2003; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pelphrey et al., 2002; Pierce, Muller, Ambrose, Allen, & Courchesne, 2001; Rutherford et al., 2007; Schultz et al., 2000). Difference or impairment in face processing is thought to contribute to the development of social impairment that characterises the disorder (Dawson, Webb, & McPartland, 2005; Schultz, 2005). The present program of research investigated face perception, specifically face recognition, in individuals with an ASD diagnosis.

While the term face recognition can be used to refer to both face matching studies where target and test faces are presented simultaneously and to studies where the subject is required to identify a face they are familiar with or have viewed on a previous occasion (i.e., a recognition memory task) to avoid confusion the term face recognition here exclusively refers to the latter type of test (face matching tasks or other tasks where faces are presented simultaneously were identified as such in the text).

Theoretical Framework

Kanner (1943, 1971) first described reduced attention to faces and poor eye contact as characteristics of infantile autism, and failure to attend to faces has been cited as a key indicator of ASD in very young children. Face perception involves an assessment of gender, emotion, attractiveness, recognition and locus of attention (Duchaine & Yovel, 2008; Kanwisher, McDermott, & Chun, 1997; A. W. Young, 1998). Of these skills, face recognition is one of the most studied, possibly because of its importance to our daily social functioning (Duchaine & Yovel, 2008). Given the likely role of face memory in recognising and interpreting social signals (Calder & Young, 2005; Herzmann et al., 2007), it is not surprising that face recognition studies have featured prominently in ASD research (Klin et al., 1999). Many studies have reported face recognition impairments in individuals with an ASD (Klin et al., 1999; O'Hearn, Schroer, Minshew, & Luna, 2010; Wolf et al., 2008). Yet, understanding of the origin of the face recognition deficit is lacking (Behrmann, Thomas, et al., 2006; Scherf, Behrmann, Minshew, & Luna, 2008).

Two prominent and contrasting frameworks have been proposed for understanding the face recognition impairment in ASD. The social motivation hypothesis, guided both by the observation that young children with ASD often avoid looking at faces, and by neurological studies that have found atypical brain activity in individuals with ASD whilst viewing faces, posits that impairment in face recognition in ASD is the consequence of a lack of interest in faces during critical periods of early development. This is thought to lead to disruption of the development of brain regions that are considered to be specialised for face processing (Dawson et al., 2002; Dawson, Webb, & McPartland, 2005; Dawson, Webb, Wijsman, et al., 2005; Grelotti et al., 2005; Klin et al., 1999; McPartland, Webb, Keehn, & Dawson, 2011; Sterling et al., 2008). Neurological studies have found that 3 to 4 year old children with ASD may show atypical neural responses to face stimuli compared to young typically developing children (Dawson et al., 2002; Dawson et al., 2004). Further, unlike typical infants, children as young as 12 months, who are later diagnosed with ASD, fail to look at others (Osterling & Dawson, 1994). Impaired face recognition, despite typical performance on recognition tasks involving buildings, chairs, leaves and some measures of pattern recognition, is also interpreted as supporting this hypothesis (Dawson, Webb, & McPartland, 2005; Dawson, Webb, Wijsman, et al., 2005; McPartland et al., 2011). Because neurological markers thought to be associated with face processing may be absent or delayed in individuals with an ASD it has been suggested face processing may be disrupted during the early stages of encoding (Dawson, Webb, Wijsman, et al., 2005). Thus, faces may be processed atypically from stimulus onset. Neuroimaging studies have not been without challenge, however, with some studies reporting more typical responses in individuals with ASD (Hadjikhani et al., 2004; Pierce, Haist, Sedaghat, & Courchesne, 2004). This latter finding suggests neurological systems dedicated to face processing may not be as severely affected as previously thought (Behrmann, Avidan, et al., 2006).

In contrast to the social motivation perspective, others have argued that deficits in memory for tasks requiring complex organisational strategies or for complex visual stimuli may result from a general deficit in complex, or higher-order, information processing (e.g., Behrmann, Avidan, et al., 2006; Behrmann, Thomas, et al., 2006; Minshew & Goldstein, 1998, 2001; Minshew, Goldstein, Muenz, & Payton, 1992; Minshew et al., 2008; Scherf, Luna, Minshew, & Behrmann, 2010; D. L. Williams, Goldstein, & Minshew, 2005; D. L. Williams et al., 2006). For example, Minshew et al. (2008) posit:

> "…at the cognitive-neurological level, autism is a disorder of complex information processing that disproportionately impacts complex or higher order processing with intact or enhanced simple information processing" (p.383).

Consistent with this model, the ASD cognitive profile is characterised as showing dissociation between simple and complex abilities (Minshew & Goldstein, 1998). This unique profile typically includes (a) deficits in complex processes including concept formation, complex memory and language, and skilled motor abilities, and (b) intact examples of simple processes including attention, sensory perception, simple memory and language, and rule learning (Minshew & Goldstein, 1998). In the visuospatial domain, face recognition provides the definitive neuropsychological test of complex information processing (Minshew et al., 2008). Under this model the face recognition deficit in ASD provides an example of a generalised integrative processing deficit that is not unique to faces nor results from the social nature of faces – as Minshew et al. argue, any class of complex stimuli that requires expertise and the integration of multi-dimensional information would prove problematic for individuals with ASD (2008).

Complexity may refer to the nature of the stimulus, the multiplicity of processes involved in task performance, and the integration of multiple features (Minshew & Goldstein, 1998; Minshew et al., 2008). The face recognition deficit in ASD is conceptualised as a higher order information processing problem rather than a specific face processing deficit with origins in social development. Unlike recognition of buildings or chairs, optimal performance on face recognition tasks is reliant on the discrimination of stimuli that are highly homogenous. More specifically, Minshew et al. (2008) argue that face recognition relies on “the brain’s automatic capacity for integrating multiple features and making comparisons to previously created prototypes” (p.392). This suggests that, for faces, information storage and retrieval is reliant on more complex strategies than those involved in the recognition of simple, less homogenous objects (Behrmann, Avidan, et al., 2006).

It is, nonetheless, important to acknowledge that all stages of visual processing (e.g., detection, encoding) may also be described as neurologically complex. While there is no doubt that early stages of visual processing are complex, consistent with Minshew et al. (2008), complexity here is conceptualised as reflecting late stage processing leading to conscious awareness. This point may be considered a weakness of the complexity hypothesis.

In support of the information processing hypothesis, both children (D. L. Williams et al., 2006) and adults (Minshew et al., 1992; D. L. Williams, Goldstein, & Minshew, 2005) with ASD were characterised by significantly worse performance compared to controls on complex visual memory and spatial working memory tasks, but no differences in memory ability were found for word lists or simple associative processes (the Wide Range Assessment of Memory and Learning, WRAML, and the Wechsler Memory Scale – Third Edition, WMS-III). Further support for a more general deficit in information processing in ASD can be found in studies reporting worse performance in individuals with ASD than controls on recognition tasks of homogenous, non-social stimuli (i.e., Greebles; Behrmann, Avidan, et al., 2006; Scherf et al., 2008).

While the findings of different neurophysiological responses in face responsive regions (e.g., the fusiform face area, N170) have been provided as evidence in support of the social motivation hypothesis – the failure of individuals to develop expertise for faces might be accounted for by a lack of interest in faces – these findings are not necessarily inconsistent with the complex information hypothesis. Failure to automatically develop prototypes that support the integration of multiple features (i.e., the underlying cognitive mechanism) might also affect the development of specialisation in the fusiform face area and its associated systems (i.e., the neural mechanism associated with face processing; Minshew et al., 2008; T. W. Wilson, Rojas, Reite, Teale, & Rogers, 2007).

In support of an alternative explanation to that posited by Dawson and colleagues (Dawson et al., 2002; Dawson, Webb, & McPartland, 2005; Dawson, Webb, Wijsman, et al., 2005; Grelotti et al., 2005; Klin et al., 1999; McPartland et al., 2011; Sterling et al., 2008), there is little evidence that face recognition is associated with level of social impairment (Barton et al., 2004) or self-reported autistic symptoms (see Experiment 1), which might be expected if the deficit was associated with social development. Consistent with Minshew and Goldstein

(1998), if the face recognition deficit in ASD results from abnormal late, high-order processing difficulties, there is no reason why some aspects of early visual processing of faces might not be spared. This was the focus of the current line of research.

There are several interpretations of the complexity account that may be relevant to face processing in ASD. First, faces are intrinsically complex stimuli and all tasks that involve stimuli of comparable complexity (e.g., Greebles) may be difficult for individuals with an ASD. A second interpretation of the complexity hypothesis is that individuals with an ASD may struggle with the more cognitive demands of face recognition and these difficulties may be more pervasive when assessed explicitly, compared to implicitly. It is this second account which is explored here.

To distinguish between the social and information processing accounts of the origin of the face deficit in ASD, a distinction between implicit and explicit face recognition was made. Specifically, if the complex information hypothesis is correct, only explicit recognition, that is reliant on effortful, resource intensive cognitive processes (Aloisi, McKone, & Heubeck, 2004), will be affected and implicit recognition will be spared. However, if a single face processing system is underdeveloped through lack of social contact, then both implicit and explicit face recognition should be affected.

The division of memory based recognition studies depends on the nature of the retrieval task: those that require explicit recollection, and those that assess memory either in the absence of (Aloisi et al., 2004) or prior to (Boehm, Klostermann, Sommer, & Paller, 2006; Jacques, d'Arripe, & Rossion, 2007) an explicit recognition decision, with the latter referred to as implicit memory tasks (Murphy, McKone, & Slee, 2003). Importantly, there is evidence that implicit and explicit memory processes may be dissociated (Maljkovic & Nakayama, 2000; Murphy et al., 2003). The most striking example of dissociation is found in cases of individuals with severe prosopagnosia who, despite absence of awareness of face recognition, show evidence of implicit face recognition (Avidan & Behrmann, 2008; also see A. W. Young, 1998, for a review).

Aloisi et al. (2004; see also Jacoby, 1991; Parkin & Russo, 1990) suggest deficits in explicit, but not implicit memory may result from deficient effortful or resource-intensive processing in conjunction with intact automatic processing. Their work with children with ADHD, who exhibit a range of neurologically based cognitive deficits that may affect performance on tasks with high resource and executive demands, provided evidence of dissociation between the two processes. Compared to controls, children with ADHD showed a deficit in explicit object recognition in conjunction with intact implicit recognition. If complex information processing is similarly affected in ASD then explicit, but not implicit, face processing may be affected. However, if the face recognition deficit in ASD originates from the social quality of faces and is evident early in visual processing, then both implicit and explicit processes should be affected.

To date, the majority of face recognition studies in ASD have used explicit recognition tasks. Thus, it is not clear whether the deficit in face recognition in ASD is confined to explicit recognition, or extends to implicit visual processing associated with faces. The answer to this question has important implications for the conceptualisation of the origin of the face recognition deficit in ASD.

Furthermore, ascertaining the origin of the face processing deficit in ASD has practical implications for intervention. If the origin is socially based then interventions aimed at increasing the reward value of attending to faces during early development may be important. If, however, the origin of the impairment is related to complex information processing, then interventions aimed at enhancing domain-general skills may be beneficial (Damiano, Churches, Ring, & Baron-Cohen, 2011).

While numerous studies have examined explicit face recognition in persons with ASD (e.g., Boucher & Lewis, 1992; Boucher, Lewis, & Collis, 1998; Hauck, Fein, Maltby, Waterhouse, & Feinstein, 1998; Klin et al., 1999; R. Wilson, Blades, Coleman, & Pascalis, 2009; R. Wilson, Pascalis, & Blades, 2007; Wolf et al., 2008), none have expressly examined implicit measures associated with face recognition tasks in this group (for a possible exception see Sterling et al., 2008; although the authors do not refer to implicit visual processing per se, and the assumption that implicit memory processes were involved is made here). It is therefore unclear whether reported impairments in face recognition that frequent the ASD literature involve the implicit memory system and early visual processing, the explicit memory system, or both.

Here, eye movement behaviour was used as one indicator of implicit memory for studied faces. Eye movements have been described as “a sensitive indicator of recognition” (Bate, Haslam, & Hodgson, 2009, p. 658) and are functional for face recognition. For example, restricting eye movement has been shown to reduce recognition performance (Henderson, Williams, & Falk, 2005). Eye movements are important indicators of visual memory and can be employed to indicate object or identity identification prior to explicit awareness (Holm, 2007; Holm, Eriksson, & Andersson, 2008). In terms of visual cognition, it is thought the eyes are directed toward regions of interest that confirm or disconfirm a perceptual hypothesis: recognition is based on the degree of confirmation between the incoming visual information and representation stored in memory (Di Lollo, 2010). Top-down cognitive processes which involve memory are therefore thought to influence eye movement behaviour during face processing (Barton, Radcliffe, Cherkasova, Edelman, & Intriligator, 2006). More specifically, it has been argued that information from memory is accessed automatically and has an obligatory effect on viewing behaviour prior to awareness of recognition (Ryan, Hannula, & Cohen, 2007). Furthermore, this early influence of memory on viewing behaviour may be evident from the first fixation, indicating that it occurs prior to conscious awareness of recognition (Ryan et al., 2007).

In the current thesis eye movement behaviour was used to provide a behavioural measure of the influence of memory on implicit visual processing of faces. This was distinguished from explicit face recognition, which was assessed using an old – new recognition task. While eye movements may provide an estimate of implicit face recognition or implicit memory (Hannula et al., 2010), because implicit recognition was not assessed directly (e.g., as per Aloisi et al., 2004) the term ‘implicit processing’ was operationalized here to mean ‘the influence of memory on visual processing occurring during the visual scanning of faces’. Implicit processing was assessed either during a recognition task, or during 5 s of free viewing.

An alternate way of framing the distinction between implicit eye movement-based measures of face processing and explicit face recognition performance is in terms of low- and high-level perceptual processing. This different theoretical approach distinguishes between two aspects of visual processing associated with eye movements. The first concerns the physical properties of the stimulus, such as the luminance or hue, which provide a primarily bottom-up influence on eye movement behaviour (Hannula et al., 2010). The second is related to episodic memory, or one’s previous experience with a stimulus (Hannula et al., 2010), which provides a top-down influence on eye movements. While the matter is one of theoretical importance, this thesis was primarily concerned with the latter aspect of visual processing, specifically the top-down influence of memory on eye movement behaviour. This was consistent with Cohen and colleagues (Althoff, 1999; Althoff & Cohen, 1999; Althoff et al., 1999; Althoff, Maciukenas, & Cohen, 1993; Ryan et al., 2007) who suggest that “eye movements can reveal memory for elements of previous experience without appealing to verbal reports and without requiring conscious recollection” (Hannula et al., 2010, p. 1). Of course, this is not to imply that low-level features are not likely to affect eye movement behaviour. Rather, low-level perceptual processing of face stimuli was not the primary focus of this thesis.

Specifically, Althoff and Cohen (1999) coined the term ‘eye movement-based memory effect’ to refer to the influence of memory on eye movement behaviour. Processing of known faces includes a memory component which is thought to supplement the processing of bottom-up visual information (Bate et al., 2009). As such, the influence of memory has been used to explain differences in viewing behaviour that emerge between faces that have been previously viewed or are known (i.e., a memory trace exists) and novel faces (Althoff & Cohen, 1999; Bate et al., 2009; Bate, Haslam, Tree, & Hodgson, 2008; Sterling et al., 2008). The eye movement-based memory effect has also been demonstrated in studied non-famous faces, with results suggesting it is related to visual, rather than semantic, information (Ryan et al., 2007). Eye movements therefore provide a behavioural measure of visual information processing that can be dissociated from explicit recognition decisions.

The eye movement-based memory effect has been reliably demonstrated in several face recognition studies (e.g., Althoff & Cohen, 1999; Bate et al., 2009; Bate et al., 2008; Ryan et al., 2007), although there has been only one attempt to study it in individuals with an ASD. Sterling et al. (2008) examined the eye movement-based memory effect in 17 individuals with an ASD (M_{age} = 23.50, *SD* = 7.19) and a control sample of 18 typically developing participants (M_{age} = 24.24, *SD* = 6.86). Unlike typical participants, participants with an ASD did not show differences in eye movement behaviour for either familiar or studied faces compared to novel faces. These results are consistent with the existence of a deficit in implicit face processing in ASD. However, participants with an ASD also showed no difference in accuracy and RT compared to controls, suggestive of typical levels of explicit recognition. Nonetheless, the absence of an indicator of typical memory influences on implicit face processing deserves further investigation as this would imply that early, automatic recognition is affected.

Thus, the current research deviated from the majority of face recognition studies in the ASD field in that a distinction was made between explicit and implicit processing. It was argued that, if the face recognition impairment evident in ASD is related to a lack of attention to faces during early development which affects specific face processing brain regions (i.e., the social motivation hypothesis) then both implicit and explicit processing should be affected. If, however, the deficit is associated with complex information processing, then the influence of memory on implicit face processing should be spared. Specifically, evidence of dissociation between explicit recognition and implicit face processing would be supportive of the complex information processing hypothesis. If both implicit processing and explicit recognition are affected, then this would suggest multiple levels of face processing are involved, providing evidence of a more extensive face processing deficit and consistent with the social motivation/expertise hypothesis. The next section provides a review of studies of face perception in ASD, including face recognition, and the role of implicit and explicit memory in relation to face recognition is examined. An overview of studies that have used eye movement behaviour in face recognition research is also provided.

Face Processing in ASD

Face recognition can best be understood as a specific perceptual skill or cognitive process that, along with several other processes (e.g., emotional expression and speech analysis; Bruce & Young, 1986; Duchaine & Yovel, 2008), is more often than not encompassed by the overarching term ‘face perception’[1]. Face perception is assumed to play an integral role in social

---

[1] An alternative theoretical model depicts ‘face memory’ (instead of face perception) as a general factor, with face perception, face learning and face recognition as narrower sub-factors (Herzmann et al., 2007). In this model, all sub-factors are considered necessary to remember a face, and face recognition is described as “the extraction of the invariant facial features from the perceived stimulus, the existence of representations stored in memory, and the successful comparison of

development (Duchaine & Yovel, 2008), and as such may be important to understanding the social difficulties faced by individuals with ASD diagnoses (Klin et al., 1999). As several studies have highlighted the difficulties with face perception in individuals with ASD and its implications, it is pertinent to begin with a brief review of face perception and its role in social development.

Kanwisher, McDermott, and Chun (1997) define face perception as broadly including:

> "…any higher-level visual processing of faces from the detection of a face as a face to the extraction from a face of any information about the individual's identity, gaze direction, mood, sex, etc." (p. 4302).

There is disagreement as to whether or not faces are visually 'special' and are processed by face specific cognitive mechanisms (e.g., Kanwisher et al., 1997; Kanwisher, Stanley, & Harris, 1999; Kanwisher & Yovel, 2006; Yin, 1969; Yovel & Kanwisher, 2004), or generalised mechanisms for stimuli for which one has expertise (e.g., Diamond & Carey, 1986; Gauthier, Behrmann, & Tarr, 1999), with the former position predominating current thinking on the matter (also see Duchaine & Yovel, 2008; Valentine, 1988). There is little contention, however, that faces provide a unique and incredibly rich source of social information (Duchaine & Yovel, 2008; Gepner, Deruelle, & Grynfeltt, 2001; Kanwisher & Moscovitch, 2000; A. W. Young, 1998). Faces play an important role in how people learn about each other (Boucher, Lewis, & Collis, 2000; Leopold & Rhodes, 2010). Furthermore, Leopold and Rhodes (2010) argue that elements of

---

stored facial structures with those currently seen" (p.309). This description is nonetheless consistent with the theoretical description of face recognition adopted here, and also with that of Bruce and Young (1986).

face perception may have evolved in social mammals to enable “complex social communication” and, at least in humans, these authors suggest “fluency” in face perception provides for “great social advantages” (p. 233). Individuals who have a severe impairment in face perception resulting from acquired injuries or developmental issues report greater social difficulties as a result (Duchaine & Nakayama, 2006b). The study of face perception thus provides an important research avenue for the investigation of social deficits in ASD (Klin et al., 1999).

Face Perception and Social Development in ASD

During infancy, faces are thought to provide an important early communication channel between child and caregiver, prior to the onset of language (Nelson, 2001). However, infants with ASD typically fail to attend to faces in the same way as their peers. Using retrospective video analysis of first year birthday parties, Osterling and Dawson (1994) and Clifford, Young, and Williamson (2007) found that a failure to look at others proved to be one of the most reliable measures for discriminating infants diagnosed with an ASD. Dawson et al. (2005) suggest that a failure to process facial information in a typical manner may provide one of the earliest measurable symptoms of ASD. Clifford et al. (2007) suggest that a failure to monitor eye gaze may underlie the poor development of joint attention skills, which in turn are thought to play a critical role in the social development of the disorder (Charman, 2003; Charman et al., 2000; Mundy & Crowson, 1997). Face recognition has been found to correlate with social development and adaptive skills in children with ASD (Hauck et al., 1998), thus providing initial support for a specific relationship between face recognition and social function in ASD. As noted above, however, not all studies have found a significant relationship between social function and face recognition.

The social developmental approach to understanding the face processing impairment in ASD is appealing and has been influential in guiding research and intervention. For example, training in face perception has provided an avenue for clinical intervention. A recent program aimed at improving social functioning and emotion recognition by directing children's attention to real faces imposed on animated objects has shown some initial success in young children with ASD (Golan et al., 2010; R. Young & Posselt, 2011). Although more research is needed into the efficacy of these types of interventions, it is thought that the development of face perception skills at an early age may positively influence the course of social development in these children.

Atypical Face Perception in ASD

Studies that have examined face perception in ASD have reported atypical functioning including: less adaptive face encoding compared to non-ASD controls on a face-identity discrimination task (Pellicano, Jeffery, Burr, & Rhodes, 2007); abnormal fixation of the lower region of the face and/or avoidance of the eyes (Corden, Chilvers, & Skuse, 2008; Rutherford et al., 2007; Spezio, Adolphs, Hurley, & Piven, 2007); significantly different visual scan paths compared to controls, including less viewing of non-core features (Pelphrey et al., 2002); poor recognition of simple and complex emotions (Ashwin, Wheelwright, & Baron-Cohen, 2006; Golan, Baron-Cohen, Hill, & Rutherford, 2007; Pelphrey et al., 2002; Spezio et al., 2007); and a preference for feature versus configural or holistic processing (Annaz, 2006; Behrmann, Thomas, et al., 2006; Joseph &

Tanaka, 2003; but see Wolf et al., 2008 for evidence of normal holistic face processing in individuals with ASD). These findings indicate that certain face perception skills may develop atypically in individuals with ASD.

For typical development the brain appears to become highly specialised for processing information from faces (Nelson, 2001). Neurological studies have found some evidence that people with ASD respond differently than expected to face stimuli. For example, Dawson et al. (2002) found that, unlike non-ASD children, young children with ASD failed to show an expected event-related potential (ERP) response to their mother's face, yet they responded typically to a familiar toy. There is a growing body of evidence of atypical neural activation in response to faces (e.g., Dalton et al., 2005; Pierce et al., 2001). Together with behavioural studies, these studies provide evidence that face perception may develop differently in persons with ASD compared to persons with typical development (Behrmann, Thomas, et al., 2006). These studies are interpreted as supportive of the social motivation/expertise hypothesis because evidence of atypical processing is confined to faces.

Nonetheless, not all studies report impaired or atypical face perception in ASD. For example, there is some evidence that degree of familiarity may moderate neural responses such that more familiar faces elicit more typical response patterns. Pierce, Haist, Sedaghat, and Courchesne (2004) found that neural activation in response to faces more closely resembled typical activation in participants with ASD when highly familiar faces (e.g., mother or co-worker) were used as stimuli. Similarly, Wilson, Pascalis, and Blades (2007) found face recognition strategies in participants with ASD more closely resembled those of non-ASD participants when faces were highly familiar to participants. Furthermore, participants with ASD in Wilson et al. did not show impaired face recognition relative to typical controls. Therefore, some aspects of task performance may approach typical levels, but this may be dependent on the stimulus used.

To examine the effect of face familiarity on face recognition, Sterling et al. (2008) examined gaze data for highly familiar (e.g., mother) and less familiar (a previously unfamiliar studied face identified as ‘new friend’) faces in children with ASD. In contrast to Pierce et al. (2004), and also Wilson et al. (2007), no differences in gaze patterns were identified between highly familiar and unfamiliar studied faces, and recognition performance was not found to be influenced by the degree of familiarity. Sterling et al. did, however, report atypical eye gaze patterns between the children with ASD and controls. Nonetheless, no differences between the groups in overall face recognition ability were found.

Others suggest that the face processing impairment in ASD may not be specific to autism. For example, Wilson et al. (2009) reported poorer performance on a face matching task that used unfamiliar faces in low functioning children with ASD compared to typical controls, but they found no differences between the children with ASD and non-ASD children with developmental delay. This raises the possibility that face processing skills may be related to more general cognitive skills rather than a specific impairment in face processing per se.

Face Specific Recognition Impairment in ASD

Numerous studies provide evidence of face recognition impairment in individuals with ASD (Blair, Frith, Smith, Abell, & Cipolotti, 2002; Boucher & Lewis, 1992; Boucher et al., 1998; Klin et al., 1999; Scherf et al., 2008; D. L. Williams, Goldstein, & Minshew, 2005; Wolf et al., 2008) including young children with the disorder (Chawarska & Shic, 2009). There are, however, several studies that have failed to identify specific deficits in face recognition in participants with ASD diagnoses when compared to matched controls (Celani, Battacchi, & Arcidiacono, 1999; Davies et al., 1994; Hobson, Ouston, & Lee, 1988; Langdell, 1978; Volkmar, Sparrow, Rende, & Cohen, 1989; R. Wilson et al., 2007). Thus, the issue of whether ASD is characterised by generalised face recognition impairment remains somewhat contentious (Klin et al., 1999).

For studies that have identified deficits in face recognition in participants with ASD, impairment may not extend to object memory (Hauck et al., 1998; Scherf et al., 2008; Wolf et al., 2008). In fact, individuals with ASD have been found to be superior on some object matching tasks relative to verbal IQ matched controls (Blair et al., 2002), indicating that memory impairment may be specific to faces (e.g., Hauck et al., 1998; Wolf et al., 2008). These findings are thus more consistent with the social motivation hypothesis than the complex information processing hypothesis. Nonetheless, there remains a general lack of consensus regarding the evidence for a face specific recognition deficit in ASD.

Two studies by Klin et al. (1999) and Wolf et al. (2008) involving large samples of individuals aged under 18 years with ASD (for participants with ASD n = 102, M_{age} = 7.37, SD = 2.93 years; n = 66, M_{age} = 11.9, SD = 3 years, respectively) provide the most convincing evidence to date of specific face recognition impairment in ASD. Using the standardised Face Recognition subtest of the Kaufman Assessment Battery for Children (K-ABC), Klin et al. found that children with ASD diagnoses demonstrated face specific recognition deficits independent of overall cognitive ability and visual memory when compared to matched controls. Similarly, Wolf et al. used an extensive face processing battery to assess ASD participants who were matched on chronological age, verbal IQ, performance IQ and full scale IQ to non-ASD controls. They reported specific face recognition impairment in the participants with an ASD. Yet, while face processing is now thought to be fully developed by 5 to 7 years, performance on face recognition tasks improves dramatically between childhood and adolescence, probably reflecting the development of general cognitive capacity (Crookes & McKone, 2009). Developmental delay may therefore exert a significant influence on performance in children with an ASD. In order to reliably assess face recognition performance in ASD, it is important to include the assessment of adults. Studies with older participants, however, have also shown poorer face recognition relative to individuals without an ASD (e.g., Blair et al., 2002; O'Hearn et al., 2010; Trepagnier, Sebrechts, & Peterson, 2002), although these studies had very small sample sizes (i.e., 12, 14, and 5 adult participants with an ASD, respectively).

While these studies provide evidence of face recognition impairment in the absence of other cognitive impairment in persons with an ASD, not all studies have demonstrated a clear dissociation between face recognition performance and other cognitive skills. For example, D. L. Williams, Goldstein, and Minshew

(2005) assessed several facets of memory using the Wechsler Memory Scale-III (WMS-III) in 29 adults (aged between 16 and 53 years) with diagnoses of high functioning ASD. Participants with ASD diagnoses were impaired at face recognition; however, they were also impaired in memory for family scenes (involving pictures of different scenes with four members from the same family, with participants assessed on what they can remember from the scene). Thus, poor performance on the face recognition component of the test was not unique and is suggestive of a general visual processing deficit.

Therefore, it is unclear whether or not general cognitive function contributes to the impairment evident in some studies. Although Wilson et al. (2009) report that developmentally delayed children exhibit similar poor performance on face matching tasks to low functioning children with ASD, the findings by Wolf et al. (2008) that higher functioning individuals with ASD also exhibit poor face recognition relative to peers cannot be accounted for by general cognitive ability, and is suggestive of an ASD specific impairment in face recognition. While it is important to acknowledge that the tasks used in these studies are not directly comparable, it does highlight the inconsistency of findings between studies in this area. To better understand face perception in ASD, some have turned to the investigation of viewing strategies believing that atypical or unusual viewing strategies by persons with ASD may result from underlying perceptual abnormalities.

Atypical Face Processing and Eye Scanning in ASD

Eye scanning studies may provide some insight into how people with an ASD perceive faces, and have been useful in highlighting differences in viewing strategies between persons with ASD and other disorders or typical development. An assumption is held that what is viewed externally reflects the information being processed internally. Viewing strategies may therefore shed some light as to the nature of the information being processed by individuals with ASDs. For example, some studies have found that, compared to typical controls, people with an ASD diagnosis tend to avoid the eyes (Klin et al., 2002; Pelphrey et al., 2002; Spezio et al., 2007) and fixate more on the mouth region (Joseph & Tanaka, 2003; Klin et al., 2002; Spezio et al., 2007). Atypical eye-scan patterns have recently been associated with impaired face recognition in children with ASD aged between 2 and 4 years, with older children showing comparative decrement in attention to key facial features (Chawarska & Shic, 2009). Some studies, however, have reported typical eye-scan patterns in participants with ASD. Rutherford and Towns (2008) found that, in contrast to previous studies (e.g., Pelphrey et al., 2002; Spezio et al., 2007), participants with an ASD did not avoid the eyes, and did not spend more time than controls looking at the mouth region when asked to identify simple emotions, although they did look less at the eyes for complex emotion identification tasks (see Sawyer et al., 2011 for evidence of typical scan patterns during a complex emotion recognition task). Van der Geest, Kemner, Verbaten, and van Engeland (2002) also found participants with an ASD demonstrated similar scan patterns to controls when viewing upright faces (the proportion of fixations to the eye and mouth regions were assessed in the current series of studies, as was the relationship between region viewed and face recognition).

In sum, while there is an extensive collection of studies that have examined face perception and face recognition in individuals with ASD, results are inconsistent. Not all studies are supportive of the hypothesis that faces are perceived or processed differently, or that there is a face recognition deficit, leading some to question whether face perception is atypical in persons with ASD (e.g., Jemel, Mottron, & Dawson, 2006). Others have suggested that if a deficit is present, it may not be ASD specific (e.g., R. Wilson et al., 2009) or unique to faces (Scherf et al., 2008). Thus, many questions remain to be answered in this area.

The current research specifically examines memory associated with face recognition: a specific cognitive process that comprises part of the face processing system (Duchaine & Yovel, 2008). Impaired face recognition in individuals with ASD would likely compromise other related processes (Bruce & Young, 1986), with potential negative social consequences.

Implicit and Explicit Memory

Memory is intricately involved in face recognition decisions (Althoff & Cohen, 1999; Bruce & Young, 1986; A. W. Young, 1998). As implicit and explicit memory can be isolated and thus treated as separate entities (Buckner et al., 1995; Gordon & Stark, 2007; Light, Singh, & Capps, 1986; Parkin & Streete, 1988), it is possible to independently assess the influence of implicit and explicit memory on face recognition[2]. Because implicit and explicit memory are thought to be dissociated (Maljkovic & Nakayama, 2000; Murphy et al., 2003), it does not necessarily follow that memory will function equally at both implicit and explicit

---

[2] Some authors (e.g., A. W. Young, 1998) have invariably referred to this distinction as the difference between overt and covert recognition, and also direct and indirect recognition. For the sake of consistency, the terms explicit and implicit recognition will be used here.

levels. Moreover, Young (1998) argued that impaired implicit face recognition might indicate a deficit at a basic level of visual processing, whereas intact implicit recognition coupled with an explicit impairment indicates a deficit at a higher level of visual processing. As such, explicit recognition may rely on complex processes that may not be involved in early, implicit visual processing (Murphy et al., 2003). Because of its reliance on multiple systems, explicit memory may therefore be more susceptible to neurological damage (Aloisi et al., 2004).

Implicit and Explicit Memory in ASD

Most memory studies from the ASD literature have reported explicit memory performance, with few examining the role of the implicit memory system. Implicit memory may, however, be assessed by evaluating performance improvements on implicit learning tasks. There have been a few studies that have examined implicit learning in ASD. Of these, some have reported unimpaired implicit learning using repetition priming (Bowler, Matthews, & Gardiner, 1997) and pictorial priming (Renner, Klinger, & Klinger, 2000) tasks, while others (Gordon & Stark, 2007; Mostofsky, Goldberg, Landa, & Denckla, 2000) have found participants with ASD either show deficits or are delayed in their rate of acquisition. It is not clear, however, that reaction time (RT) paradigms truly address implicit skills given that they necessarily assume participants are sufficiently motivated and interested in the task at hand to perform at their peak consistently. Müller, Cauich, Rubio, Mizuno, and Courchesne (2004) did, however, report atypical neural activation in participants with ASD compared to controls during an implicit learning task. As these studies did not directly assess implicit memory performance or the influence of memory on implicit visual processing, it is difficult to draw any real conclusions as to whether implicit face memory may be affected in persons with ASD.

The uncertainty regarding the influence of memory on implicit visual processing and how it may contribute to the reported face recognition impairment in people with ASD provides a direction for future research. While some studies have investigated implicit learning in ASD, they are somewhat limited as the stimuli have typically been non-social in nature. The study of memory associated with implicit face processing is highly relevant, particularly given that explicit memory for faces has been shown to be poor compared to memory for non-social stimuli, such as objects or words, within this population (Hauck et al., 1998; D. L. Williams, Goldstein, Carpenter, & Minshew, 2005; D. L. Williams, Goldstein, & Minshew, 2005; D. L. Williams et al., 2006).

Assessing the Influence of Memory on Implicit Face Processing

Face recognition tasks have traditionally assessed performance by examining discrimination accuracy and RT. This was based on the assumption that a stronger memory trace should facilitate quicker and more accurate decisions (Vickers, 1979). The influence of memory on implicit face processing, however, can be assessed by using indirect or covert recognition tasks that do not require the involvement of an explicit response. Different indirect measures that have been used in face recognition tasks include skin conductance (Bauer, 1984; Ellis, Young, & Koenken, 1993), evoked potentials (Renault, Signoret, Debruille, Breton, & Bolgert, 1989), and eye-movements (Althoff & Cohen, 1999; Althoff et al., 1993; Bate et al., 2009; Rizzo, Hurtig, & Damasio, 1987; Ryan et al., 2007).

Based on a series of experiments examining explicit and implicit priming effects in a visual search task, Maljkovic and Nakayama (2000) provided evidence for a distinct short term implicit memory system that they suggest may be specialised for the direction of visual attention and eye movement behaviour. The next section provides support for the use of eye movement behaviour in examining the influence of memory on implicit face processing, and cites specific examples of the application of this approach as evidence of the link between eye movements and implicit memory.

The Eye Movement-Based Memory Effect

Differences in eye movement behaviour between familiar and novel faces may provide an example of the influence of memory on implicit face processing (Althoff & Cohen, 1999). In non-ASD persons, eye movement behaviour has been found to differ between faces for which one has had some prior exposure and those that have not been viewed previously (Althoff & Cohen, 1999; Bate et al., 2009; Sterling et al., 2008). A study by Rizzo et al. (1987) neatly demonstrates the use of eye movements in detecting the influence of implicit face memory. These authors found that visual scanpaths (i.e., the scanning of salient features) differed for highly familiar faces (compared to non-familiar faces) in one participant with prosopagnosia who was unable to consciously (i.e., explicitly) recognise the same faces. These differences in visual scanning patterns suggest the existence of an internal schema for familiar faces. Bate, Haslam, Tree, and Hodgson (2008) also found the same effect in one participant with prosopagnosia (see also Barton, Radcliffe, Cherkasova, & Edelman, 2007).

Eye movements have also been shown to be important in the learning and recognition of new faces. For example, Henderson et al. (2005) showed that the restriction of eye movement behaviour (fixations were restricted to the centre of a face image between the eyes, fixations outside this area caused a mask to cover the image) during the learning of new faces led to impairment in the subsequent recognition of those faces compared to unrestricted viewing during learning (recognition accuracy improved by 28% when eye-movement behaviour was unrestricted during learning). This indicates that eye movements are likely to play a functional role in face learning, possibly by facilitating improved encoding of information.

Prior experience with a stimulus (e.g., the viewing of familiar or known faces) is thought to affect the “ease and rapidity” with which visual information is processed (Barton et al., 2006, p. 1090). Moreover, it has been shown that more fixations and different scanning patterns are involved in the processing of novel faces than familiar faces (Althoff & Cohen, 1999). Althoff and Cohen argued that differences in fixation patterns between novel and familiar faces reflect the influence of memory on scanning behaviour. These authors coined the term the ‘eye movement-based memory effect’ to describe these differences. More recently Bate et al. (2009) replicated Althoff and Cohen’s (1999) methodology and main findings of an eye-movement effect for famous and novel faces in older (45 to 64 years) and younger (18 to 19 years) adults.

While Althoff and Cohen (1999) studied the eye movement-based memory effect for famous faces, the effect has also been demonstrated using non-famous faces. Ryan et al. (2007) exposed participants to unfamiliar faces three times. On the fourth exposure participants were randomly shown a set containing a viewed face and either one or two new (novel) faces, or a set of entirely novel faces. They found that the viewing duration of the first fixation differed significantly for previously viewed compared to novel faces during the recognition task.

Critically, given first fixations usually occur within the first 200 to 300 ms of stimulus onset (Hannula et al., 2010), the first fixation may provide valuable information regarding the very early processing of visual information, prior to conscious awareness. Behavioural studies have shown that individual face recognition may occur simultaneously with face detection (Tanaka, 2001), and event related potential (ERP) studies show electrophysiological responses to face stimuli occur around 130-160 ms after stimulus presentation (Jacques et al., 2007; Jacques & Rossion, 2006). It is therefore likely that top-down influences on eye movement behaviour should similarly be evident early after stimuli presentation, possibly within the first fixation. In further support of the importance of the first fixation in face recognition, Hsiao and Cottrell (2007, 2008) restricted the number of fixations participants could use during a face recognition task. These authors found that one fixation was sufficient for face recognition, although slightly better results were reported for two fixations. Interestingly, allowing participants to use three or unrestricted fixations did not improve performance. Nonetheless, first fixation data may provide an important indicator of the influence of implicit memory on face processing.

Eye Movement-Based Memory Effect in ASD

Earlier in this introduction section I provided an overview of a study by Sterling et al. (2008) who used eye-tracking to investigate attention toward familiar (mother, new friend) and unfamiliar faces in participants with ASD. The study did not find evidence of differences in eye movements between familiar and novel faces in participants with ASD. Nonetheless, accuracy rates for ASD participants ranged from 84.87% (*SD* = 22.29%) to 91.60% (*SD* = 16.02%) for viewed and novel faces, respectively. These compared favourably with those of non-ASD participants, reported as 87.40% (*SD* = 12.25%) for viewed faces and 84.15% (*SD* = 20.77%) for novel faces, and is suggestive of good overall face recognition. However, the use of familiar faces such as famous people, family members or friends in recognition studies has been criticised due to the influence of factors (e.g., the availability of additional information) that can cause "substantial construct-irrelevant variance in test performance" (Herzmann, Danthiir, Schacht, Sommer, & Wilhelm, 2008). Thus, the task may not have been difficult enough to reveal the expected (explicit) face recognition impairment in the ASD participants. By adopting a paradigm using multiple unfamiliar faces that are learned within an experimentally controlled setting, the drawbacks associated with the use of previously familiar faces in recognition studies can be overcome (Herzmann et al., 2008). Furthermore, given that Sterling et al. failed to identify an eye movement-based memory effect in participants with ASD, an investigation of their findings is important in understanding the influence of memory on implicit face processing in ASD.

The next chapters document a series of experiments that investigate face recognition and face processing in participants with ASD and in comparison samples of non-ASD participants (who were assessed and assumed to be typically developing). Experiment 1 assessed explicit face recognition with the Cambridge

Face Memory Test (CFMT; Duchaine & Nakayama, 2006a). Experiment 2 examined whether individuals with an ASD show evidence of an eye movement-based memory effect when viewing unfamiliar, studied faces. More specifically, it was predicted that indices of eye movement behaviour would differ for studied compared to novel faces. Experiment 3 extended Experiment 2 by manipulating the degree of similarity of the stimuli between study and test. As cognitive load increases or the level of the complexity of the material increases, deficits may become more pronounced (D. L. Williams et al., 2006). It was expected that face recognition performance would deteriorate with changes to images such as changing the pose, lighting and adding visual noise to degrade the image (see Duchaine & Nakayama, 2006a), but it was not known whether eye movement-based differences between studied and novel faces would also be evident for previously unseen, altered images of studied faces. In addition to the eye movement measures, an old-new discrimination task was used in both experiments to provide a measure of participants' explicit face recognition performance. Because different fixation patterns may emerge under different test conditions (Ryan et al., 2007), it was also considered important to examine viewing behaviour while participants freely viewed faces. Thus, Experiment 2 and Experiment 3 included a free viewing and a recognition test condition. In Experiment 3 RT was measured on the discrimination task. In Experiment 4 implicit processing and explicit face recognition was assessed for inverted and upright faces. Because configural processing is disrupted in inverted tests of face recognition, the use of inverted and upright faces provided an opportunity to distinguish featural (i.e., parts based) from configural (i.e., holistic) processing.

This is of interest because individuals with ASD are thought to have a bias for featural processing. Furthermore, this provided an opportunity to examine implicit face processing in ASD more closely.

Last, although not the primary focus of this thesis, data from these experiments provided an opportunity to examine differences between persons with and without ASD in the facial regions used during face processing tasks. Specifically, individuals with ASD are thought to be more reliant on the mouth than the eyes for face processing tasks including face recognition and expression analysis. To address this question fixation data from Experiments 2 and 4 were analysed to determine whether participants with ASD showed atypical fixation patterns to these regions during the free viewing and face recognition tests. Fixation patterns were also analysed for a simple emotion identification test. Finally, the relationship between face recognition performance and the proportion of fixations to the eye and mouth regions was also explored in this chapter.

CHAPTER 2

Experiment 1

Given studies contrasting face recognition performance in persons with an ASD and typically developing individuals have been mixed (Klin et al., 1999), with some demonstrating face recognition impairment (Blair et al., 2002; Boucher & Lewis, 1992; Campbell et al., 2006; Ellis, Ellis, Fraser, & Deb, 1994; Hauck et al., 1998; White, Hill, Winston, & Frith, 2006; D. L. Williams, Goldstein, & Minshew, 2005) and others no impairment (Celani et al., 1999; Davies et al., 1994; Langdell, 1978), Experiment 1[3] aimed to determine the extent of explicit face recognition impairment in individuals with an ASD. To address several methodological limitations related to the use of non-standard assessments or unreliable tests, assessment involved the use of a recently standardised assessment tool: the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006a), which provides norms based on a large Australian sample. Thus, Experiment 1 examined explicit face recognition for unfamiliar faces in persons with a diagnosis of an Autism Spectrum Disorder (ASD) and in a comparison sample of non-ASD participants.

Several problems have characterised face recognition studies in persons with ASD. First, many studies have been criticised for using non-standardised face recognition tests (Klin et al., 1999). Second, the validity of some of the commonly used standardised face recognition tests – such as the Benton Facial Recognition Test (BFRT; Benton, Sivan, Hamsher, Varney, & Spreen, 1994) and

---

[3] Experiment 1 appeared in the journal Autism Research as ‘Face Recognition Performance of Individuals with Asperger Syndrome on the Cambridge Face Memory Test’ (Hedley et al., 2011).

the Recognition Memory Test for Faces (RMF; Warrington, 1984), both widely reported in ASD research (Annaz, Karmiloff-Smith, Johnson, & Thomas, 2009; Blair et al., 2002; Campbell et al., 2006; Ellis et al., 1994; Minshew, Bodner, & Williams, 2009; White et al., 2006) – has been challenged (Duchaine & Nakayama, 2006a). For example, images used in the RMF contain hair, clothing, posture, expressions, and imperfections which allow for the use of non-face information in recognition decisions (Duchaine & Weidenfeld, 2003). The BFRT has been criticised because (a) it allows for feature-based matching, and (b) target and probe images are simultaneously presented for an unlimited duration (Bowles et al., 2009; Duchaine & Nakayama, 2006a). Finally, both the BFRT and the RMF have failed to detect impairment in individuals with prosopagnosia (Duchaine & Nakayama, 2006a). It is therefore possible that the extent of impairment in ASD may have been underestimated by those tests.

The CFMT is a recently standardised face recognition test that was designed to overcome the aforementioned problems, but it has received little attention in the ASD literature (but see O'Hearn et al., 2010 for a recent exception). Psychometric properties for the CFMT indicate that it is a reliable and valid test of face recognition. Reliability statistics reported by Wilmer et al. (2010) indicate a Cronbach’s α of 0.90 (*N* = 3,004), test-retest reliability with a mean delay of 6 months of 0.70 (*N* = 389), and alternate-forms reliability with a mean delay of 2 months of 0.76 (*N* = 42). The CFMT effectively discriminated individuals with prosopagnosia (*n* = 8) from those with no impairment (*n* = 50), returning rates for specificity (i.e., proportion of correct classifications of individuals without a face recognition impairment) and sensitivity (i.e., proportion of individuals with prosopagnosia who were correctly classified with a face recognition impairment) of 100% and 75% respectively (Duchaine & Nakayama, 2006a). Low correlations between the CFMT and the verbal paired-associates memory test ($r = 0.17$, $N = 1{,}532$), and the abstract art memory test ($r = 0.26$, $N = 3{,}004$) suggest the CFMT assesses face specific memory (Wilmer et al., 2010). In unimpaired individuals, the CFMT demonstrates a large inversion effect, considered indicative of specific face processing mechanisms (Duchaine & Nakayama, 2006a), and correlates well with other tests of face perception and face recognition (Bowles et al., 2009; Richler, Cheung, & Gauthier, 2011; Russell, Duchaine, & Nakayama, 2009; Wilmer et al., 2010). Because the CFMT is effective in detecting face recognition impairment where other tests have failed (Duchaine & Nakayama, 2006a), it has been widely used in face recognition studies with both typical and clinical populations (Herzmann et al., 2008; Russell et al., 2009; Wilmer et al., 2010; C. E. Wilson, Freeman, Brock, Burton, & Palermo, 2010; C. E. Wilson, Palermo, Schmalzl, & Brock, 2010; Yardley, McDermott, Pisarski, Duchaine, & Nakayama, 2008). Thus, the CFMT may also be effective in clarifying the presence of face recognition impairment in persons with an ASD.

Experiment 1 contrasted age-standardised CFMT scores for adult individuals with ASD with those for (a) a control group of participants without an ASD and (b) a published standardised Australian sample (Bowles et al., 2009). To explore individual differences that might be associated with face recognition performance in ASD, relationships between standardised face recognition performance and IQ, autistic traits, and negative affect were also examined. The assessment of autistic traits was included because, while individuals with ASD show impairment on face recognition tasks, it is not clear that the degree of symptom severity is related to task performance. An assessment of negative affect was included because of the possible relationship between depression and performance on face recognition tasks (Drakeford et al., 2007), and the predominance of depressive symptoms in individuals with ASD (Ghaziuddin, Ghaziuddin, & Greden, 2002).

Method

Participants

Participants were thirty-four individuals (24 male) with a diagnosis of an ASD who were paid for their participation and 43 (14 male) first year university students who were screened (see below) and assumed to be typically developing (non-ASD). Non-ASD individuals participated for course credit. All participants were at least 18 years of age and participation was voluntary. Participants with ASD were recruited with the assistance of the local state body for ASD assessment and service delivery. To be registered with the state body individuals must have received a multi-disciplinary diagnosis from at least two qualified and recognised diagnosticians and have met DSM-IV-TR (APA, 2000) criteria. In addition to DSM-IV criteria, all participants met clinical cut-off scores for ASD using at least one of the following tools: Autism Diagnostic Interview – Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994); Gillberg and Gillberg’s criteria (Gillberg & Gillberg, 1989); Childhood Asperger Syndrome Test (CAST; Scott, Baron-Cohen, Bolton, & Brayne, 2002; J. Williams et al., 2005), although specific information regarding which tests were used for each participant was not available (A. Harris, state body diagnostic services, personal communication, December 21, 2010).

Because Autistic Disorder, High Functioning Autism and Asperger Syndrome do not necessarily constitute the neat diagnostic categories as suggested by the DSM-IV (APA, 2000; Sanders, 2009), the term ASD was used here in place of other diagnostic labels. This is consistent with the proposed diagnostic revision of the term in DSM-5 (APA, 2011). All participants with ASD that participated in the studies contained in this thesis, however, had received formal diagnoses of Asperger Syndrome and no participants with different formal diagnoses were assessed.

Participants were excluded if they reported a history of significant psychiatric or neurological disorders and non-ASD participants were asked and excluded if they reported a diagnosis of a developmental disorder or a close family member with an ASD, or presented with an elevated Autism Spectrum Quotient (AQ) of ≥ 32 (based on the recommended cut-off for non-clinical samples; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). Data from one female participant in the non-ASD group who fell within the autistic range on the AQ (score = 33) were removed, leaving 42 non-ASD participants.

Table 1 summarises participant characteristics including age, Full Scale IQ (FSIQ), Verbal IQ (VIQ), Performance IQ (PIQ), autistic traits (AQ), and negative affect (DASS21: stress, depression, anxiety, total *z*-score). Participants with ASD were significantly older[4] and scored significantly higher on stress,

---

[4] Germaine, Duchaine, and Nakayama (2011) have shown that performance on an alternative form of the CFMT improves until around 30 years of age. This study, however, used age-standardised

depression, and anxiety than non-ASD participants. Participants with ASD and non-ASD participants did not differ significantly on any of the IQ scales, but participants with ASD scored significantly higher on the AQ than non-ASD participants.

Materials

Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006a). There are two versions of the CFMT which either presents faces in upright or inverted format. For the present study only the upright version of the test was used. The CFMT requires participants to recognise six learned male faces (targets) presented during three test phases. Each target face was presented with two similar distractor faces. Faces were presented with neutral expressions, no visible hair and with facial blemishes removed, across three test sections: recognition of the same image (same images); recognition of the same face in different viewpoints (novel images); and recognition of the same face in different images with Gaussian noise (novel images with noise). Scores represent the number of times the learned face is correctly identified; maximum possible scores for each test section are 18, 30 and 24, respectively. Test sections are summed to provide a total score (maximum = 72).

Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). The WASI is an individually administered, pen and paper assessment of intelligence for persons aged from 6 to 89 years that yields Verbal (VIQ), Performance (PIQ), and Full Scale (FSIQ) IQ scores. The WASI is based

---

scores. Furthermore, the slightly older age of participants with ASD might be expected to reduce the difference between ASD and non-ASD participants in the present sample.

Table 1

Participant Characteristics for Age, IQ, AQ, DASS21 Subscales, DASS21 Standardised Total Score and Between Group Comparison Statistics

	ASD (*n* = 34)		non-ASD (*n* = 42)		
	M (SD)[1]	Range	*M (SD)*	Range	Between Group Comparisons [2]
Age	29.9 (11.6) [a]	18.0-60.8	24.63 (7.38) [a]	18.3-47.7	*t*(53.50) = 2.22, *p* = .03, *d* = .54
FSIQ	105.59 (14.86)	83-139	109.57(9.06)	87-131	*t*(52) = -1.37, *p* = .18, *d* = .33
VIQ	106.62 (14.13)	86-134	108.21 (9.35)	90-140	*t*(55) = -.57, *p* = .57, *d* = .14
PIQ	103.06 (15.95)	67-134	108.43 (10.46)	79-132	*t*(55) = -1.69, *p* = .10, *d* = .41
AQ	29.65 (8.98) [b]	11-43	15.74 (5.25) [b]	4-29	*t*(51) = 8.00, *p* < .001, *d* = 1.94
DASS21 stress	20.06 (8.53) [c]	0-36	12.76 (8.82) [c]	0-30	*t*(74) = 3.64, *p* = .001, *d* = .84
DASS21 depression	16.18 (10.61) [d]	0-40	9.52 (9.06) [d]	0-34	*t*(74) = 2.95, *p* = .004, *d* = .68
DASS21 anxiety	12.29 (7.88) [e]	0-28	7.57 (7.93) [e]	0-30	*t*(74) = 2.59, *p* = .01, *d* = .59
DASS21 standardised total score	.37 (.81) [f]	-0.14-2.35	-0.30 (.81) [f]	-0.14-1.48	*t*(74) = 3.58, *p* = .001, *d* = .85

Note. [1] Means with the same letters as superscripts reflect significant differences, *p* < .05. [2] Where Levene's test indicated significantly different variance between groups the adjusted statistics are reported.

on the Wechsler Intelligence Scale for Children – 4th Edition (WISC-IV) and the Wechsler Adult Intelligence Scale – 3rd Edition (WAIS-III). The WASI consists of four subtests (Vocabulary, Similarities, Block Design, and Matrix Reasoning) and takes around 30 minutes to complete. The WASI was selected over the WAIS-III as it is quicker to administer. Nonetheless, the WASI is highly correlated with other assessments of IQ, including the WAIS-III, with coefficients ranging from .66 to .88 for the subtests and .92 for FSIQ. Norms for the WASI are based on a sample of 1,145 adults and 1,100 children. Internal consistency for the subtests are reported as .90 to .98 (Vocabulary), .84 to .96 (Similarities), .90 to .94 (Block Design) and .88 to .96 (Matrix Reasoning). Coefficients for the scale scores are reported to range from .92 to .98 for VIQ and .94 to .97 for PIQ, and for FSIQ the score ranged from .96 to .98. Average test-retest coefficients ranged from .87 to .92, and inter-rater reliability is reported to range from .98 to .99.

Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001). The AQ is a 50 item self-administered questionnaire designed to assess the degree to which the individual exhibits features of "the core autistic phenotype", or autistic traits. The AQ has been assessed as a screening tool for Asperger Syndrome (AS) and High Functioning Autism (HFA) (Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005, p. 332). The areas of social skill, attention switching, attention to detail, communication and imagination are each assessed by 10 questions consisting of four forced choice response options including: 'definitely agree', 'slightly agree', 'slightly disagree' and 'definitely disagree'. Responses characteristic of an ASD are scored as a 1, and non-ASD characteristic responses are scored as 0. Total scores can range from 0 to 50. The authors recommend a ‘useful’ cut-off of 32 points (Baron-Cohen et al., 2001), but the AQ has also been shown to have good discriminant validity and screening properties for AS and HFA at a threshold score of 26 (Woodbury-Smith et al., 2005). In the current study the AQ provided a continuous measure of ASD traits. However, the AQ was employed as a screening measure to identify at risk (i.e., AQ > 32) non-ASD individuals following the guidelines of the authors.

Test-retest reliability (2 week interval) for the AQ is $r = .70$, $p = .002$ (Baron-Cohen et al., 2001). As the AQ is self-report, a parent-report form was developed by the authors consisting of 40 items of the AQ (10 items were removed as these items could only be answered subjectively). The self-report and parent-report forms were compared for adults with AS or HFA. A resulting difference of 2.8 points ($SD = -0.6$) revealed that parents scored their child more highly than the individual, suggesting the self-report form is slightly more conservative than others estimates (Baron-Cohen et al., 2001). Internal consistency (Cronbach’s alpha) for each of the five domains of the AQ was reported as: Communication = .65; Social = .77; Imagination = .65; Local Details = .63; Attention Switching = .67 (Baron-Cohen et al., 2001). The AQ discriminates referred individuals suspected of having an ASD who received a diagnosis of ASD from those who did not, with significant group differences between AQ scores ($p < .001$) and area under the ROC curve of 0.78 ($n = 100$; Woodbury-Smith et al., 2005). Using a cut-off of 26 points, Woodbury-Smith et al. reported sensitivity estimates of .95, specificity of .52, positive predictive value of .84 and negative predictive value of .78 for their clinical sample. Further support for the ability of the AQ to discriminate individuals with ASD diagnoses from individuals with other diagnoses can be found in a Dutch validation study (Hoekstra, Bartels, Cath, & Boomsma, 2008). Participants with an ASD scored significantly higher on the AQ than participants with a diagnosis of Obsessive Compulsive Disorder (OCD, $p < .001$) and generalised social anxiety disorder (SAD, $p < .001$).

Depression Anxiety and Stress Scales Short Form (DASS21; Lovibond & Lovibond, 1995). The DASS21 provides three individual scales; depression, anxiety and stress. Each scale contains 7 items. Participants use 4-point severity/frequency scales to rate the extent that they have experienced symptoms over the last week. Scores for each scale are summed and then multiplied by two to provide an overall score for each of Depression, Anxiety and Stress (maximum score of 42 for each scale). In addition to the individual scales, a total score was calculated by summing the scales and converting the result to a *z*-score. Norms, reliability and validity data can be found in Henry and Crawford ($N = 1794$; 2005) and also in Crawford, Cayley, Lovibond, Wilson, and Hartley ($n = 497$; 2011). Both studies reported reasonable internal consistency with Cronbach's alpha for the scales reported as .79 to .82 (Anxiety), .89 to .90 (Stress) and .88 to .90 (Depression), and a total score for the combined scales returned rates of .93 to .94. The DASS-21 exhibited a three-factor structure consistent with the scales, and showed high convergent and discriminant validity with independent measures of anxiety and depression (Henry & Crawford, 2005).

Procedure

Consent to participate was obtained. The CFMT was presented on a 17 inch monitor, participants were seated approximately 60 to 65 cm from the screen. The CFMT is fully automated and includes a practice section and all instructions. For the practice section participants are shown an image of a cartoon character (Bart Simpson) and are then required to select the character from a display including two other characters. Failure to select the correct character prevents the test from continuing. All participants passed the practice section (i.e., were able to identify Bart from other characters) thereby demonstrating adequate comprehension of the test instructions. The WASI, AQ and DASS21 were administered either immediately following the CFMT or on a separate day.

Results

An alpha level of $p < .05$ was set for all analyses.

Recognition Performance

Means and standard deviations of raw scores for each of the three test sections, and the total score of the CFMT are provided in Table 2. Given the large age range of participants, the significant difference in age between participants with ASD and non-ASD participants, and the known relationship between age and performance on the CFMT (Bowles et al., 2009), age-standardised *z*-scores for the total score were calculated using a formula reported by Bowles et al. (2009; also see C. E. Wilson, Freeman, et al., 2010) and are provided in Table 2. For comparison purposes, CFMT data from an Australian study (Bowles et al., 2009) also appear in Table 2.

Table 2

CMFT Scores for Participants with ASD, Non-ASD Participants, and a Comparison Standardised Control Group [a]

		ASD (n = 34)	non-ASD (n = 42)	Controls [a] (n = 124)
		M *(SD)*	*M* *(SD)*	*M* *(SD)*
CFMT Raw score	Same images	16.26 (2.63)	17.81 (.55)	17.7 (0.7)
	Novel images	18.44 (5.05)	22.26 (4.61)	22.5 (4.9)
	Novel images + noise	13.06 (4.17)	14.81 (3.92)	15.2 (4.0)
	Total	47.76 (9.69)	54.88 (8.21)	55.4 (8.5)
Age-standardised *z*-scores		-0.86 (1.15)	-0.04 (.97)	n/a

Note. [a] CFMT raw scores for controls are taken from Bowles et al. (2009; Table 2: Young adult 18-35). Note also that raw scores for young adults reported by Bowles et al. were almost the same for early middle age adults aged 36-49 years (Total Score M = 55.6, SD = 9.3).

Figure 1 provides the distribution of standardised CFMT scores for participants with ASD and non-ASD. Scores for both participant groups were normally distributed as indicated by *z*-score values for skewness and kurtosis (*z*-scores: ASD skewness = 0.44, kurtosis = -0.61; non-ASD skewness = 0.13, kurtosis = -1.60). The standardised scores for the ASD group were significantly below zero, $t(33) = -4.34$, $p < .001$, indicating overall performance significantly below typical levels. Scores for the non-ASD group were not significantly different from zero, $t(41) = -0.27$, $p = .79$, indicating typical performance. Scores more than 2 SDs below the mean on the CFMT are considered to reflect severe face recognition impairment (Bowles et al., 2009; Duchaine & Nakayama, 2006a): eight participants (24%) with ASD (range -1.95 to -3.15 SDs below the mean) fell into this category. In contrast, 53% of participants with ASD scored within +/-1 SD of the mean, with three participants with ASD (9%) scoring at least 1 SD above the mean, suggesting good, if not superior, face recognition performance.

Relationship between Face Recognition and Cognitive Function, Autistic Traits, and Negative Affect

A series of Pearson correlations (Table 3) explored the relationship between face recognition (CFMT) and (a) cognitive function (FSIQ), (b) autistic traits (AQ), and (c) negative affect (DASS21 standardised total score). All correlations between the CFMT age-standardised scores and the AQ, IQ, and the DASS21 standardised total score were found to be non-significant for participants with and without an ASD.

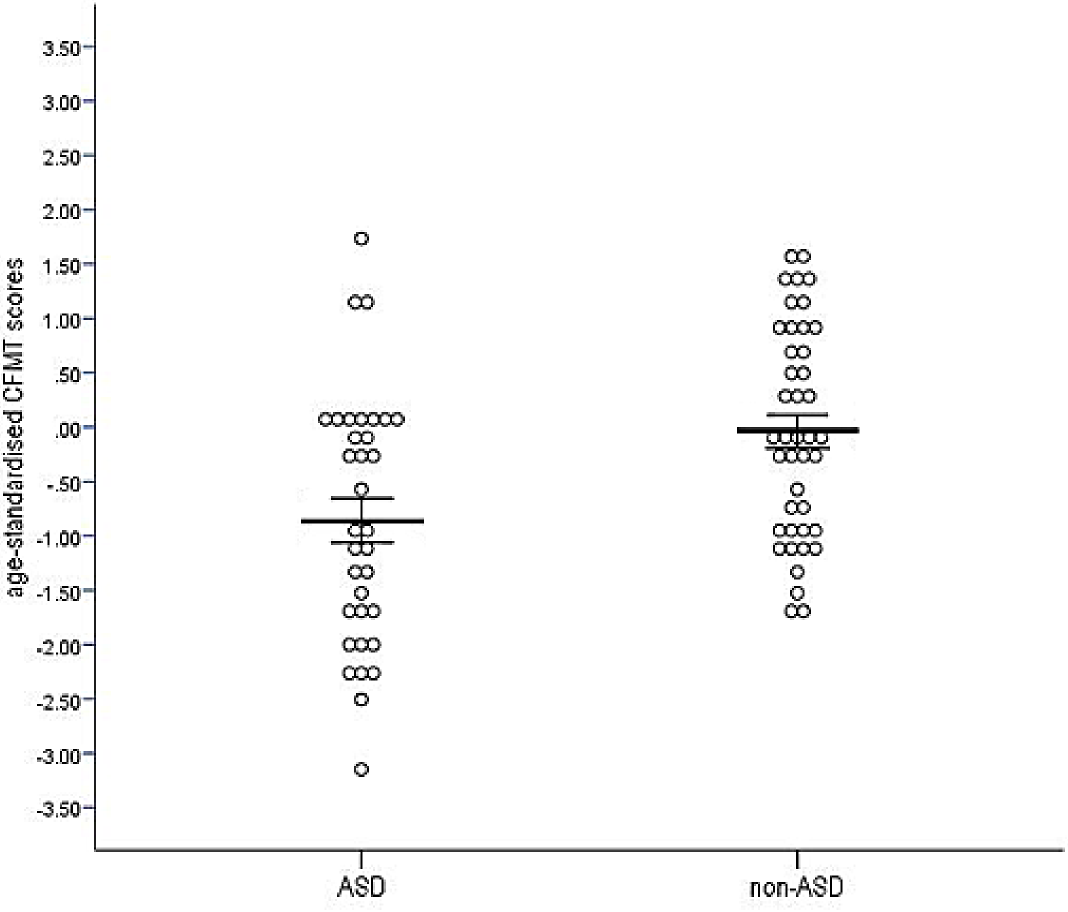


Figure 1. Distribution of age-standardised CFMT scores for participants with ASD and non-ASD. Bars represent Mean +/- SE.

To examine the influence of diagnostic category and the aforementioned factors on CFMT scores, a forced entry multiple regression was performed. CFMT standardised scores were entered as the dependent variable. For the predictor variables, diagnostic category (ASD, non-ASD) was entered at Step 1 and the AQ, FSIQ, and the DASS21 standardised total score were entered at Step

2[5]. At Step 1 the model accounted for 13.2% of the variance in CFMT scores, $F(1,74) = 11.25$, $p = .001$. At Step 2 the model accounted for 13.8% of the variance in CFMT scores, $F(4,71) = 2.83$, $p = .031$. Table 4 provides the statistics for each variable in the model. The addition of the other predictors at Step 2 only accounted for an additional 0.6% of variance in scores, and this change was not significant. At Step 2, only diagnostic category was a significant predictor of CFMT scores, $t(71) = 2.16$, $p = .03$. Overall, the model indicated that CFMT scores were independent of general cognitive ability, reported autistic traits, and negative affect.

Table 3

Correlations between the CFMT (age-standardised z-score) and FSIQ, AQ, and DASS21 Standardised Total Score for Participants with ASD (n = 34) and non-ASD Participants (n = 42)

	ASD	Non-ASD
FSIQ	.04	-0.10
AQ	.04	-0.12
DASS21 *z* score	-0.01	-0.14

---

[5] Although we matched groups on IQ, the effect size measure (see Table 1) for the non-significant between-groups comparison of FSIQ led us to include FSIQ as a predictor variable in the regression analysis. This analysis was also run using the Verbal and Performance IQ scales and the subscales of the DASS21, but the pattern of findings was unchanged.

Table 4

Forced Entry Multiple Regression with CFMT Scores Entered as the Dependent Variable and (Step 1) Diagnostic Category (ASD, Non-ASD), (Step 2) FSIQ, AQ, and DASS21 Standardised Total Score Entered as Predictor Variables

	B	*SE B*	*β*
Step 1			
Constant	-1.26	.28	
Diagnostic Category	.41	.12	.36**
Step 2			
Constant	-1.02	1.17	
Diagnostic Category	.40	.18	.35*
FSIQ	-0.003	.01	-0.03
AQ	.003	.02	.03
DASS21 standardised total score	-0.11	.17	-0.09

Note. $R^2 = .13$ for Step 1 ($p = .001$), $\Delta R^2 = .01$ for Step 2 ($p = .93$). * $p = .03$, ** $p = .001$.

Discussion

Experiment 1 used a recently standardised test to examine face recognition performance in a sample of adults with ASD. Overall, CFMT scores indicated that participants with ASD were significantly impaired at face recognition compared with a control sample and the standardised test norms. This is consistent with previous studies that have found face recognition deficits in participants with an ASD (e.g., Blair et al., 2002; Boucher & Lewis, 1992; Hauck et al., 1998; Klin et al., 1999; D. L. Williams, Goldstein, & Minshew, 2005; Wolf et al., 2008). However, consistent with other research that failed to identify face recognition deficits in ASD (e.g., Davies et al., 1994; Langdell, 1978), some participants with an ASD diagnosis performed at or above the typical level for their age.

This latter finding is consistent with Baron-Cohen and colleagues who argue that ASD symptoms fall on a continuum between social disability and normality (Baron-Cohen, 1995; Baron-Cohen et al., 2001). Rather than all persons with ASD being impaired at face recognition, a broad range of face recognition performance that includes typical levels of performance should be expected among this group. These results are also compatible with studies suggesting that face recognition skills are not strongly related to general cognitive functioning in persons with an ASD (Campbell et al., 2006; Klin et al., 1999; Langdell, 1978; Volkmar et al., 1989) or in persons who are typically developing (Herlitz & Yonker, 2002; Zhu et al., 2010). Furthermore, neither the degree of reported autistic traits (measured by the AQ) nor negative affect significantly influenced face recognition performance when controlling for diagnosis – diagnostic category was the only reliable predictor of performance on the CFMT.

One potential criticism of Experiment 1 is that recognition of a control set of non-face objects was not examined; hence, it is possible that the relative impairment in face recognition in participants with ASD may not be face specific. However, other studies have shown that individuals with ASD are not impaired in basic visual perception (Klin et al., 1999), and show preserved or superior recognition of non-face objects (e.g., cars, houses) while also demonstrating face recognition impairment (Wolf et al., 2008). These studies indicate face recognition deficits in ASD are not due to general impairment in perception or object recognition.

CHAPTER 3

Experiment 2

Experiment 1 provided evidence of impairment in explicit face recognition in persons with ASD. Experiment 2 was designed to determine whether the face recognition deficit evident in explicit recognition decisions is also associated with implicit memory. More specifically, Experiment 2 examined the eye movement-based memory effect (Althoff & Cohen, 1999) in participants with an ASD and in a control sample of IQ matched non-ASD participants. Eye movements were recorded while participants viewed studied and novel unfamiliar faces. Faces were viewed under two conditions: a free viewing condition where participants freely viewed the face for 5 s, and an old-new recognition test condition where participants were required to indicate if they recognised the face from the study phase. The free viewing condition was included because it provided an opportunity to examine (a) the eye movement-based memory effect under similar conditions to Althoff and Cohen who also examined data for a 5 s period, and (b) to compare eye movement behaviour between ASD and non-ASD participants for an equivalent viewing period. The recognition test provided the opportunity to examine eye movement behaviour prior to a recognition decision (i.e., pre-decisional).

Specifically, eye movements were examined to determine if eye movement behaviour differed based on viewing condition (studied, novel). Fixation patterns of unfamiliar faces were used to ensure all participants had the same amount of exposure to studied faces, and to reduce the influence of variance resulting from differences in semantic knowledge that might be associated with the use of well-known or famous faces (Herzmann et al., 2008; Russell et al., 2009). The following provides an overview of the eye movement-based measures used. A more detailed account can be found in the method section.

The primary eye movement-based measures were the average number of fixations during the viewing period, the average length of the fixations, and the length of the first fixation. Data were examined for the full 5 s viewing period in the free viewing condition, and prior to the recognition decision in the recognition test. The number of fixations was examined because this measure provided information regarding information acquisition or, in the case of the recognition test, the amount of information that is accumulated prior to explicit recognition (Holm et al., 2008). Due to the number of fixations in the recognition test being tied to response time, however, average fixation length was also included because it provided a measure that was independent of the length of time the face was displayed. The last measure was first fixation length. It was expected that the first fixation length, which was also independent from response time, would provide information regarding (a) early, pre-decisional processing in the recognition test, and (b) early processing in the absence of overt task requirements in the free viewing test. Significantly, the length of the first fixation has been found to provide a sensitive measure of recognition memory strength. Kafkas and Montaldi (2011) found that the duration of the first fixation during encoding was associated with a significant linear decrease as memory strength increased. These authors also found that the duration of the first fixation was significantly longer for later familiar than recollected items.

Several other eye movement-based measures which related to viewer-determined regions of interest (Althoff & Cohen, 1999) were also examined. These measures provided information regarding the different strategies employed by each participant when viewing the faces. More specifically, viewer-determined regions of interest were calculated by clustering the fixation data for each face, for each participant. The eye movement measures that were based on these regions included the number of regions viewed, the number of fixations and the number of fixations made before returning to a previous region (return fixation).

Finally, to investigate the time course of the eye movement-based memory effect and changes in viewing behaviour over the 5 s presentation, fixation data for the 5 s free viewing period were divided into 1000 ms time bins.

Method

Participants

Participants were 24 individuals (17 male) with a diagnosis of an ASD who were paid for their participation and 36 (17 male) university students who participated for course credit. General recruitment and exclusion criteria were the same as those reported for Experiment 1. No non-ASD participants presented with an elevated AQ for the current Experiment. To ensure participant groups were matched for cognitive ability, and to ensure that performance was not affected by intellectual disability, only participants with an estimated minimum FSIQ score of at least 85 were included. Descriptive information for the ASD and non-ASD participants in provided in Table 5. Participant groups were matched on age and IQ and only differed significantly on the AQ. All participants reported normal or corrected-to-normal vision.

Table 5

Participant Characteristics for Age, IQ, AQ, and Between Group Comparison Statistics

	ASD (n = 24)		non-ASD (n = 36)		
	M (SD)[1]	Range	*M (SD)*	Range	Between Group Comparisons [2]
Age	26.88 (9.87)	17.08-48.17	22.85 (6.92)	17.08-41.08	$t(37.87) = 1.74$, $p = .09$, $d = .49$
FSIQ	109.00 (14.43)	86-139	112.17 (10.81)	90-135	$t(58) = -0.97$, $p = .34$, $d = .26$
VIQ	109.00 (14.65)	86-134	110.58 (11.33)	88-133	$t(58) = -0.47$, $p = .64$, $d = .12$
PIQ	107.04 (14.49)	79-134	110.81 (10.41)	86-129	$t(38.55) = -1.10$, $p = .25$, $d = .31$
AQ	29.83 (8.38) [a]	12-45	14.58 (4.13) [a]	7-23	$t(30.53) = 8.28$, $p < .001$, $d = 2.47$

Note. [1] Means with the same letters as superscripts reflect significant differences, $p < .05$. [2] Where Levene's test indicated significantly different variances between groups the adjusted statistics are reported.

Apparatus and Materials

Stimuli were front-view coloured photos of the faces of 32 male and 32 female non-famous Caucasian persons aged 18-28 years that were selected from the Productive Aging Laboratory Face Database (Minear & Park, 2004). Faces were set on a black background (960 × 1280 pixels) and edited with Microsoft Paint.NET v3.10 to remove prominent marks or other features. Luminescence was equated between images, and the faces were cropped around the jaw line. Ears and hairline were included in the final image, but hair was cropped closely around the face to ensure consistency between stimuli. Consistent with Althoff (1998) and Ryan et al. (2007) faces with happy and neutral expression were used. Faces were matched and paired based on age, gender, emotional expression (i.e., half of the expressions were happy and half were neutral) and hair colour before being randomly divided into two main data sets (Set A, Set B). The use of two parallel image sets allowed for the counterbalancing of target and foil images between participants.

Eye movements were recorded using a Tobii T60 eye tracker, which is a non-intrusive eye tracker integrated into a 17 inch TFT monitor with a resolution of 1280 × 1024 pixels and a data sampling rate of 60 Hz. The eye tracker does not require fixing of the participant’s head, nor for any device to be fitted to the participant. It allows for head movement of 44 × 22 × 30cm with a tracking distance of 50-80 cm and a maximum gaze angle of 35 degrees. Typical accuracy for the Tobii T60 is reported as 0.5 degrees of visual angle.

Procedure

Participants were randomly assigned to either Set A or Set B. They were then seated in front of the eye tracker in a quiet room at a distance of approximately 60 cm from the screen, which resulted in a stimuli presentation size of approximately 12° horizontal × 18° vertical. The eye tracker was calibrated for each participant using the standard 9-point Tobii calibration protocol. The calibration was repeated at the beginning of each test phase.

The experiment consisted of two phases: study and test (see Figure 2). The test phase consisted of the free viewing condition followed by the recognition test condition. Participants first completed the study phase followed by a 5 min filler task, a 5 min break and then the test phase. For the study phase participants were exposed to the 32 images from either Set A or Set B, three times. Images were presented randomly for 5 s each, thus each image was viewed for a total period of 15 s. Between each image a blank screen was displayed for 1000 ms, followed by a screen with a cross randomly displayed in one of the four corners of the monitor. Participants were instructed to fixate on the cross, which was displayed for 1500 ms. Participants were instructed to “please look at the images in any way you want”; they were not informed that they would be participating in a recognition test. Depending on whether participants were assigned to Set A or Set B, one set was used as target faces and the other set was used as novel or distractor faces.

For the free viewing condition participants were exposed to 16 (8 × happy, 8 × neutral) novel and 16 (8 × happy, 8 × neutral) studied faces, presented individually and in randomised order. A blank screen (1000 ms) was presented first followed by a cross (1500 ms) prior to each image presentation. Each image was presented for 5 s. Participants were again instructed to “please look at the images in any way you want”. The recognition test used 16 new novel and the remainder 16 studied faces, presented randomly. Participants were instructed to view each face for as long as required to make a recognition decision. They were instructed to press the space bar when they had made a decision as to whether or not they recognised the face. Once the participant pressed the key a new screen was displayed with the response options: participants clicked either ‘YES’ (studied) or ‘NO’ (novel) depending on whether they recognised the face or not from the study phase. The time to the first key press was defined as the participant’s response time (because standard protocols for RT assessment, such as emphasising both speed and accuracy, were not applied, the term ‘response time’ was considered more appropriate here; RT was assessed in Experiment 3), and yes/no responses provided data for assessing discrimination performance. Four practice faces were presented first, and these data were discarded from further analysis.

Eye Movement Parameters and Dependent Measures

Eye movement data were analysed using the Tobii Studio™ software package supplied with the eye scanner. The default Tobii fixation filter was applied. This groups gaze data into fixations and applies sliding averaging to detect quick changes in the gaze point. A default threshold radius (h) of 35 pixels was used to separate fixations. The output from Tobii Studio™ provided data for the fixation analyses based on the fixation data, which were confined to fixations that fell on the image (i.e., fixations on the background were excluded from further analysis).

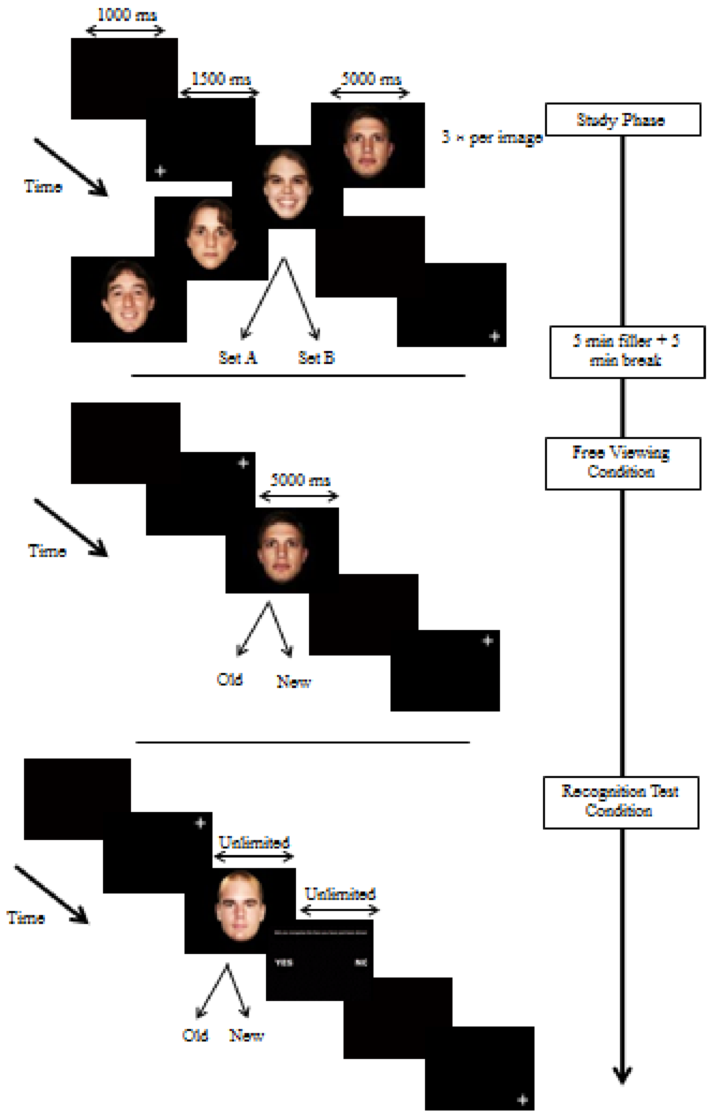


Figure 2. Experimental paradigm for Experiment 2. Images were presented in colour, different image sets were used for the free viewing and recognition test conditions. Participants completed the study phase, followed by the free viewing and recognition test conditions. During the study phase each face was presented three times. In the test conditions old and new faces were presented consecutively. Participants made a familiarity decision in the recognition test only.

The presentation of the fixation cross in one corner of the screen was designed to ensure the first fixation used in data analysis was a new fixation to the face. Because images were presented centrally, a saccade was required from the cross to the face, thus the first fixation was a new fixation rather than one left over from the previous screen (a similar design was adopted by Hsiao & Cottrell, 2008). Participants were reminded to fixate the cross prior to the new image presentation, and a review of the recordings confirmed this. Once the image was removed from the screen, the final fixation was usually one long fixation which carried over to the next (blank) screen (see Figure 2). The last fixations were therefore discarded from further analysis.

Eye movement-based measures. Consistent with previous studies (Althoff & Cohen, 1999; Bate et al., 2008; Sterling et al., 2008), the number of fixations for the full 5 s viewing period was analysed for viewed and novel faces for the free viewing phase. In addition, changes across 1000 ms time bins were examined for the 5 s free viewing phase. This allowed for a time course analysis of the emergence of differences in viewing behaviour between viewed and novel faces. For the recognition test the number of fixations that occurred within the timeframe required for the recognition decision (i.e., pre-decisional) was analysed. This was consistent with Bate et al. (2009; personal communication, September 8, 2009) and Barton et al. (2006), and reflects the accumulative amount of data required to reach a decision. However, because the average number of fixations in the recognition task is tied to response time, two other measures associated with fixation length that were thus independent from response time were analysed. Average fixation duration has been found to vary dependent on prior exposure or face familiarity, with longer fixations generally reported for studied or known faces compared to novel faces (Bate et al., 2008; Ryan et al., 2007). Hence, the average fixation length was examined. Furthermore, Ryan et al. (2007) found that, for a recognition task, the length of the first fixation was longer for studied than for novel faces. During free viewing, however, Kafkas and Montaldi (2011) found the length of the first fixation increased as the strength of recollection memory decreased. These studies highlight the relationship between memory and first fixation length. Finally, and possibly most significantly, one fixation has been shown to be sufficient for face recognition, with two fixations being optimal (Hsiao & Cottrell, 2007, 2008). Thus, the average length of the first fixation was also examined. Importantly, analysis of first fixation data, which on average reflected processing during the first 200 to 300 ms after stimulus onset, should reflect processing occurring before explicit awareness of identity.

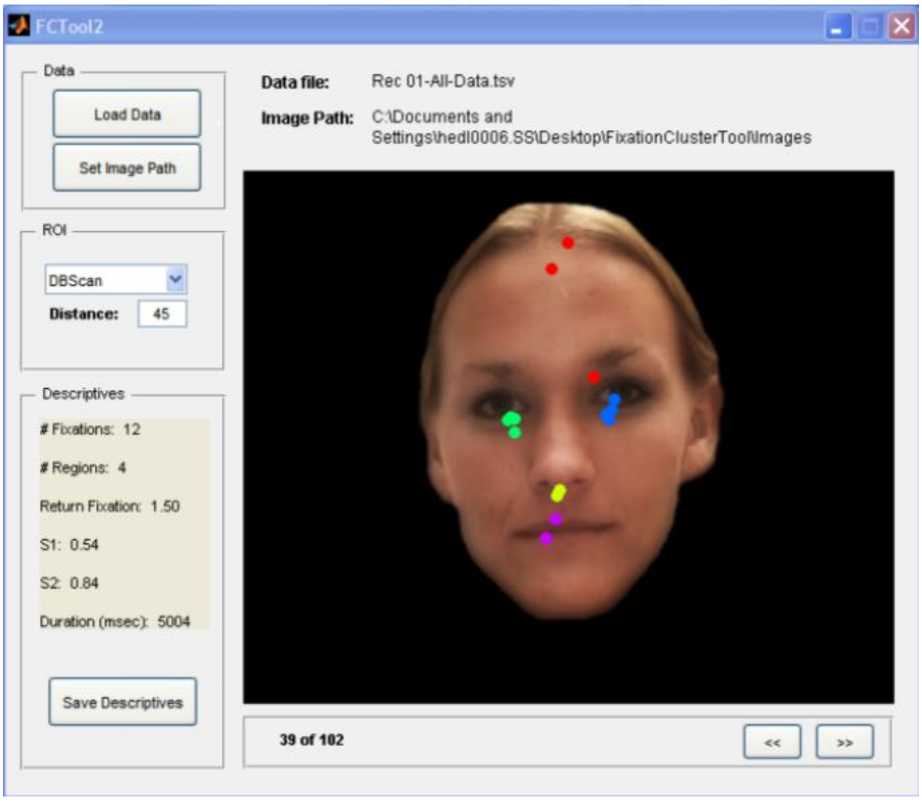
Viewer defined fixation patterns. Because the analysis described above was based on an a priori defined region (i.e., the whole face), a second set of data was derived from a cluster analysis of fixation data. These analyses were based on similar analyses described by Althoff and Cohen (1999). These measures were derived from viewer-defined regions of interest and thus provided a measure of the unique scanning strategies adopted by each participant. Specifically, fixation data for each participant were clustered using a simple threshold radius (h) algorithm (see Figure 3). The threshold radius was set at 45 pixels, which approximated 1 visual degree[6]. Single fixations outside of a 35 pixel radius from another fixation were treated as outliers and removed from further analysis. Inclusion of these data resulted in an overestimation of the predictability of the model. Inclusion or exclusion of these data, however, did not alter the overall results and, furthermore, these data were included in the overall analyses of fixation patterns. Data derived from the regions was subject to analysis. This technique had the advantage of providing a unique profile for the scanning behaviour of each participant. Three new eye movement-based measures were derived from the cluster analysis. These were the average number of fixations included in the clusters (number of fixations in cluster), the average number of clustered regions (regions), and the average number of fixations made prior to returning to a region (return fixation).

Discrimination performance and response time. For the recognition test condition discrimination performance and response bias were calculated using Signal Detection Theory (SDT; see Snodgrass & Corwin, 1988; Stanislaw & Todorov, 1999). Hit rate (correctly identifying a viewed face as viewed) and False Alarm rate (incorrectly identifying a novel face as viewed) were used to estimate A prime (*A′*), a nonparametric measure of sensitivity (Stanislaw & Todorov, 1999, p.140). A loglinear transformation was applied to avoid problems that might arise for Hit and False Alarm rates that equal 1 or 0 (Stanislaw & Todorov, 1999, p.143). Values typically range between .5 and 1; scores closer to 1 indicate better discrimination performance, with perfect performance equal to a

---

[6] Other pixel radii were examined; however the use of different threshold values did not change the overall pattern of results.

score of 1. Response bias (*C*) is interpreted as neutral for values of 0, conservative (i.e., tendency to respond 'no') if *C* is positive, and liberal (i.e., tendency to respond 'yes') if *C* is negative (Snodgrass & Corwin, 1988).



Data file: Rec 01-All-Data.tsv

Image Path: C:\Documents and Settings\hedl0006.SS\Desktop\FixationClusterTool\Images

DBScan

Distance: 45

Fixations: 12

Regions: 4

Return Fixation: 1.50

S1: 0.54

S2: 0.84

Duration (msec): 5004

39 of 102

Figure 3. Example of fixation clusters used in the analyses of viewer defined fixation patterns.

Results

Eye Movement-Based Measures

Two-way mixed analyses of variance (ANOVAs) with diagnostic group as the between-subjects factor and stimulus type (studied vs. novel) as the within-subjects factor were used to determine the effect of stimulus type and diagnostic group on each of the eye movement-based measures for both the free viewing and recognition test conditions. Descriptive statistics and ANOVA results are reported in Table 6 and Table 7, respectively, for the free viewing condition, and Table 8 and Table 9 for the recognition test.

Table 6

Descriptive Statistics for the Eye Movement-Based Measures for the Free Viewing Condition for Participants with ASD (n = 24) and non-ASD participants (n = 36)

		Viewing Condition		
		Studied	Novel	Overall
Measure	Group	*M (SD)*	*M (SD)*	*M (SE)*
Fixation #	ASD	11.58 (3.56)	12.09 (3.27)	11.83 (.57)
	non-ASD	12.32 (2.25)	12.94 (2.53)	12.63 (.47)
	Overall	12.02 (2.84)	12.60 (2.85)	
Length (ms)	ASD	466 (178)	410 (111)	438 (21)
	non-ASD	391 (75)	361 (65)	376 (17)
	Overall	421 (131)	380 (89)	
1st Fixation (ms)	ASD	272 (91)	281 (93)	276 (14)
	non-ASD	235 (56)	255 (83)	245 (11)
	Overall	250 (74)	266 (87)	

Table 7

Analysis of Variance on Eye Movement-Based Measures for the Free Viewing Condition

Source	*df*	*F*	*p*	η_p^2
Fixation # (N)	1	15.24	< .001	.208
Diagnosis (D)	1	1.18	.282	.02
N × D	1	< 1		
Length (L)	1	18.54	< .001	.242
Diagnosis (D)	1	5.41	.024	.085
L × D	1	1.73	.193	.029
1st Fixation (F)	1	1.88	.176	.031
Diagnosis (D)	1	2.98	.09	.049
F × D	1	< 1		
Error	58			

For both conditions, studied faces elicited fewer fixations than novel faces, and these were of longer duration in the free viewing condition. For the recognition test the first fixation was found to differ between studied and novel faces, with a longer first fixation directed toward studied faces. These results support the main hypothesis that viewing behaviour would differ between studied and novel faces (i.e., the eye movement-based memory effect). Importantly, the first fixation data provide valuable information regarding early, pre-decisional (i.e., implicit) information processing. Between-subjects main effects indicated that fixation length (free viewing) and number of fixations (recognition test) differed significantly between participants with and without an ASD. Overall, participants with an ASD required more fixations to make a recognition decision. However the lack of significant interactions indicated that patterns of viewing behaviour were generally similar between participant groups, with participants both with and without an ASD showing several differences in viewing behaviour for studied compared to novel faces.

Viewer Defined Eye Movement-Based Measures

Two-way mixed analyses of variance (ANOVAs) with diagnostic group as the between-subjects factor and stimulus type (studied vs. novel) as the within-subjects factor were used to determine the effect of stimulus type and diagnostic group on each of the viewer defined eye movement-based measures for both the free viewing and recognition test conditions. Descriptive statistics and ANOVA results are reported in Table 10 and Table 11, respectively, for the free viewing condition, and Table 12 and Table 13 for the recognition test.

For the free viewing and recognition test conditions main effects were evident for all of the viewer defined eye movement-based measures, with the single exception of the return fixation measure in the recognition test condition. These data indicate that viewer defined fixations differed significantly between viewed and novel faces. Overall, these results are consistent with the a priori AOI data above. Furthermore, these data provide further support for the eye movement-based memory effect, and of the implicit effect of memory on viewing behaviour. Importantly, these data are supportive of the influence of memory on implicit visual processing of viewed stimuli by participants with ASD.

Table 8

Descriptive Statistics for the Eye Movement-Based Measures for the Recognition Test Condition for Participants with ASD (n = 24) and non-ASD participants (n = 36)

		Viewing Condition		
		Studied	Novel	Overall
Measure	Group	*M (SD)*	*M (SD)*	*M (SE)*
Fixation #	ASD	6.25 (2.92)	7.29 (3.72)	6.77 (.52)
	non-ASD	4.58 (1.76)	5.71 (2.54)	5.15 (.42)
	Overall	5.25 (2.42)	6.35 (3.14)	
Length (ms)	ASD	246 (41)	254 (46)	250 (8)
	non-ASD	255 (58)	250 (39)	252 (6)
	Overall	251 (52)	252 (42)	
1st Fixation (ms)	ASD	222 (35)	216 (48)	219 (9)
	non-ASD	240 (55)	220 (40)	230 (7)
	Overall	233 (48)	218 (43)	

Table 9

Analysis of Variance on Eye Movement-Based Measures for the Recognition Test Condition

Source	*df*	*F*	*p*	η_p^2
Fixation # (N)	1	20.61	< .001	.262
Diagnosis (D)	1	5.87	.019	.092
N × D	1	< 1		
Length (L)	1	< 1		
Diagnosis (D)	1	< 1		
L × D	1	< 1		
1st Fixation (F)	1	8.44	.005	.127
Diagnosis (D)	1	1.00	.321	.017
F × D	1	2.97	.09	.049
Error	58			

There were also significant main effects for diagnosis in the recognition test condition. This reflects the use by ASD participants of more fixations to reach a recognition decision. Thus, more fixations resulted in significantly more fixations being used in the cluster analysis, and also indicated that ASD participants used more regions of the face to reach a decision. Participants with

ASD also returned to the regions more often than non-ASD participants prior to making a decision. None of the interactions were found to be significant, indicating that the influence of memory on viewing behaviour was consistent between participants with and without an ASD.

Table 10

Descriptive Statistics for the Viewer Defined Eye Movement-Based Measures for the Free Viewing Condition for Participants with ASD (n = 24) and non-ASD participants (n = 36)

		Viewing Condition		
		Studied	Novel	Overall
Measure	Group	*M (SD)*	*M (SD)*	*M (SE)*
# Fixations in Cluster	ASD	8.28 (2.99)	8.61 (2.91)	8.45 (.48)
	non-ASD	8.32 (1.91)	8.65 (2.01)	8.49 (.39)
	Overall	8.31 (2.38)	8.63 (2.39)	
# Regions	ASD	2.37 (.69)	2.50 (.73)	2.43 (.11)
	non-ASD	2.55 (.43)	2.66 (.55)	2.60 (.09)
	Overall	2.48 (.55)	2.60 (.62)	
Return Fixation	ASD	.99 (.53)	1.17 (.57)	1.08 (.09)
	non-ASD	1.14 (.35)	1.27 (.45)	1.21 (.07)
	Overall	1.08 (.43)	1.23 (.50)	

Table 11

Analysis of Variance on Viewer Defined Eye Movement-Based Measures for the Free Viewing Condition

Source	*df*	*F*	*p*	η_p^2
# Fixation (Cluster) (N)	1	4.67	.035	.074
Diagnosis (D)	1	< 1		
N × D	1	< 1		
# Regions (R)	1	5.49	.023	.087
Diagnosis (D)	1	1.36	.248	.023
R × D	1	< 1		
Return Fixation (F)	1	10.39	.002	.152
Diagnosis (D)	1	< 1		
F × D	1	1.20	.279	.02
Error	58			

Table 12

Descriptive Statistics for the Viewer Defined Eye Movement-Based Measures for the Recognition Test Condition for Participants with ASD (n = 24) and non-ASD participants (n = 36)

		Viewing Condition		
		Studied	Novel	Overall
Measure	Group	*M (SD)*	*M (SD)*	*M (SE)*
# Fixations in Cluster	ASD	2.98 (2.31)	3.89 (3.05)	3.43 (.39)
	non-ASD	1.55 (1.38)	2.05 (1.50)	1.80 (.31)
	Overall	2.12 (1.93)	2.79 (2.41)	
# Regions	ASD	1.07 (.59)	1.35 (.83)	1.21 (.11)
	non-ASD	.616 (.44)	.813 (.47)	.714 (.09)
	Overall	.797 (.54)	1.03 (.68)	
Return Fixation	ASD	.534 (.52)	.655 (.39)	.595 (.07)
	non-ASD	.388 (.44)	.419 (.36)	.403 (.06)
	Overall	.45 (.48)	.513 (.39)	

Table 13

Analysis of Variance on Viewer Defined Eye Movement-Based Measures for the Recognition Test Condition

Source	*df*	*F*	*p*	η_p^2
# Fixation (Cluster) (N)	1	11.79	.001	.169
Diagnosis (D)	1	10.80	.002	.157
N × D	1	1.02	.316	.017
# Regions (R)	1	14.65	< .001	.202
Diagnosis (D)	1	12.84	.001	.181
R × D	1	< 1		
Return Fixation (F)	1	1.44	.234	.024
Diagnosis (D)	1	4.21	.045	.068
F × D	1	< 1		
Error	58			

Time Course Analysis for 1000 ms Time Bins

Three-way mixed analyses of variance (ANOVAs), with diagnostic group as the between-subjects factor, and stimulus type (studied vs. novel) and time bin (1-1000 ms, 1001 - 2000, 2001 - 3000, 3001 - 4000, 4001 - 5000) as within-subjects factors, were used to determine the effect of stimulus type and diagnostic group on the average number of fixations and the average fixation length for each time bin for the free viewing condition. Descriptive statistics and ANOVA results are reported in Table 14 and Table 15, respectively. Consistent with the 5 s viewing period, significant main effects were identified for stimulus type for both the number of fixations and the fixation length such that, on average, more fixations of shorter length were directed toward novel compared to viewed faces. This pattern was evident for all time bins, apart from fixation length for the 4001 – 5000 ms time bin, where the average fixation length was greater for novel compared to viewed faces. However, as this difference was in the final 1000 ms of viewing time it does not reflect early processing.

Paired samples comparisons revealed that differences between viewed and novel faces were significant for fixation count for the first (0 – 1000), third (2001 – 3000), and fourth (3001 – 4000) time bins ($p_s < .033$), but not the second (1001 – 2000, $p = .099$) or last (4001 – 5000, $p = .11$) time bins. Differences in fixation length emerged by the second time bin and were significant for the next two 1000 ms bins ($p_s < .016$), but were not significant for the first or last 1000 ms bins ($p_s > .286$). Overall, the influence of memory on viewing behaviour was evident for fixation count within the first 1000 ms viewing period, although the difference in average fixation length did not reach statistical significance until the second bin. This latter result is most likely because fixations during the first 1000 ms viewing period tended to be short for both viewed and novel faces.

Table 14

Descriptive Statistics for 5 × 1000 ms Time Bins for the Eye Movement-Based Measures for the Free Viewing Condition for Participants with ASD (n = 24) and non-ASD Participants (n = 36)

		Time Bin *M (SD)*					
		First	Second	Third	Fourth	Fifth	
Measure / Group	Type	1 – 1000 ms	1001 – 2000 ms	2001 – 3000 ms	3001 – 4000 ms	4001 – 5000 ms	Overall *M (SE)*
# Fixation							
ASD	Studied	3.24 (.72)	2.22 (.84)	2.17 (.80)	1.98 (.80)	1.81 (.77)	2.29 (.12)
	Novel	3.35 (.76)	2.29 (.81)	2.25 (.81)	2.13 (.77)	1.88 (.66)	2.38 (.12)
non-ASD	Studied	3.39 (.42)	2.41 (.59)	2.32 (.58)	2.27 (.53)	1.89 (.46)	2.46 (.10)
	Novel	3.47 (.45)	2.49 (.60)	2.51 (.64)	2.43 (.57)	1.98 (.56)	2.58 (.10)
Overall	Studied	3.33 (.56)	2.33 (.70)	2.26 (.67)	2.16 (.66)	1.86 (.60)	
	Novel	3.42 (.59)	2.41 (.69)	2.41 (.72)	2.31 (.67)	1.94 (.60)	
Length							
ASD	Studied	403 (159)	426 (122)	425 (124)	495 (196)	447 (134)	439 (20)
	Novel	367 (90)	409 (109)	399 (98)	440 (157)	482 (168)	419 (18)
non-ASD	Studied	353 (52)	413 (117)	433 (107)	446 (109)	444 (99)	418 (16)
	Novel	355 (91)	372 (59)	370 (66)	420 (123)	444 (113)	392 (15)
Overall	Studied	373 (110)	418 (118)	430 (113)	466 (150)	445 (113)	
	Novel	360 (90)	386 (84)	382 (81)	428 (137)	459 (137)	

Table 15

Analysis of Variance on 1000 ms Time Bins for the Eye Movement-Based Measures for the Free Viewing Condition

Measure	Source	*df*	*F*	*p*	η_p^2
Fixation #	Type (T)	1,58	12.38	.001	.176
	Time Bin (B)	4,232	293.50	< .001	.835
	Diagnosis (D)	1,58	1.42	.239	.024
	T × D	1,58	< 1		
	B × D	4,232	1.50	.202	.025
	T × B	4,232	< 1		
	T × B × D	4,232	< 1		
Length	Type (T)	1,58	14.37	< .001	.199
	Time Bin (B)	4,232	21.77	< .001	.273
	Diagnosis (D)	1,58	1.06	.308	.018
	T × D	1,58	< 1		
	B × D	4,232	< 1		
	T × B	4,232	3.41	.01	.056
	T × B × D	4,232	1.77	.137	.03

A significant main effect was also evident for time bin. Pairwise comparisons with a Bonferroni adjustment revealed significant differences for fixation count between all the time bins ($p_s < .038$), with the exception of the second and third bins (p = 1.00). Differences between bins were also evident for fixation length (p_s < .006) for all but the difference between the second and third bins, and also between the third and fourth bins (p_s = 1.00). Therefore, as viewing time progressed over the 5 s period the number of fixations decreased as fixation length increased. Particularly, the first 1000 ms viewing period was characterised by more fixations of shorter duration than any of the later time bins.

The main effect for diagnosis and the interactions involving diagnosis were not significant for either measure. This indicates that viewing patterns over each time bin were similar for participants with and without an ASD.

Last, there was a significant interaction for Type × Time bin for fixation length. The interaction resulted from fixations in the final time bin, where fixations for novel faces were longer than for viewed faces. For all other time bins, fixation length was longer for viewed compared to novel faces. No further interactions were significant. Nonetheless, this time bin corresponds with late, rather than early viewing.

In sum, the time course analysis supported the hypothesis that memory influenced viewing behaviour early and consistently across the full 5 s viewing period under free viewing conditions. Furthermore, patterns were similar for participants with and without an ASD. The time course analysis suggested that the first 1000 ms of viewing time was probably the most critical for determining whether the face was a known or novel face, as evidenced by the greater number of fixations of shorter length during this time bin compared to later bins.

Discrimination Performance and Bias

Discrimination performance (*A*') was not significantly different for participants with an ASD (*A' M* = .87, *SD* = .10) compared to non-ASD participants (*A' M* = .90, *SD* = .06), *t*(33.83) = -1.60, *p* = .119. Note, however, that the difference between groups was suggestive of a medium-sized effect, *d* = .47. Response bias (*C*) was not found to differ significantly between groups, *t(58*) = .162, *p* = .87, *d* = .04, with participants with ASD (*C M* = .08, *SD* = .31) and non-ASD participants (*C M* = .07, *SD* = .34) reporting a conservative bias (i.e., tendency to respond 'no') overall.

Table 16

Descriptive Statistics (Means with Standard Deviations in Parentheses) for Average Response Time (ms) for Studied and Novel Faces for the Recognition Test for Participants with ASD (n = 24) and non-ASD participants (n = 36)

	Novel	Studied	Overall
	M (SD)	*M (SD)*	*M (SE)*
ASD	2242 (1183)	1902 (926)	2072 (158)
Non-ASD	1592 (681)	1340 (510)	1466 (129)
Overall	1852 (961)	1565 (752)	

Response Time

A two-way mixed ANOVA with diagnostic group as the between-subjects factor and stimulus type (studied vs. novel) as the within-subjects factor yielded significant main effects for stimulus type and diagnostic group on response time. Descriptive statistics for response time are provided in Table 16, and the ANOVA results are provided in Table 17. The significant main effects indicate that, overall, participants responded more quickly to studied compared to novel faces, and participants with an ASD took significantly longer to respond compared to non-ASD participants. The Diagnosis × Stimulus Type interaction was not significant, indicating that the response time advantage for studied faces was evident in both diagnostic groups.

Table 17

Analysis of Variance on Response Time for the Recognition Test

Source	*df*	*F*	*p*	η_p^2
Response Time (R)	1	19.01	< .001	.247
Diagnosis (D)	1	8.82	.004	.132
R × D	1	< 1		
Error	58			

Discussion

Despite overall slower responding, participants with an ASD did not perform significantly differently to non-ASD participants on the explicit component of the face recognition task. One possible conclusion from these data is that participants with an ASD do not have an explicit memory problem for faces. Two features of the data strongly suggest this conclusion would be premature. First, as noted earlier, the effect size data suggest a medium sized effect for the difference in explicit recognition performance between participants with an ASD and non-ASD participants. Moreover, response times were significantly longer for participants with an ASD compared to non-ASD participants, suggesting overall slower processing speed (assuming both groups had adopted similar speed-accuracy operating characteristics). In addition to these factors, the task itself may not have been sufficiently difficult for differences between groups to emerge fully. This will be addressed in Experiment 3 where task difficulty is increased by including novel images of studied faces.

Eye movement-based measures provided an insight into the early, implicit processing of faces in individuals with an ASD. Consistent with similar studies in typical populations (e.g., Althoff & Cohen, 1999; Bate et al., 2008; Ryan et al., 2007), but not in participants with an ASD (e.g., Sterling et al., 2008), participants with and without an ASD showed several differences in eye movement behaviour toward novel and studied faces. Results were consistent for analyses based on fixations to the whole image, and also for participant defined scanning patterns.

Consistent with Ryan et al. (2007), participants directed fewer and longer duration fixations toward studied compared to novel faces in the free viewing condition. This pattern was also evident when the 5 s viewing period was separated into 1000 ms time bins, with the first 1000 ms of viewing time characterised by significantly more fixations of shorter length compared to later 1000 ms viewing periods. Consistent with Bate et al. (2009), studied faces were characterised by fewer fixations in the recognition test condition. Together with the response time data, this latter finding suggests that, for studied faces, less information is extracted before a decision threshold is reached when compared to novel faces. Overall, the eye movement data reported here support the hypothesis that memory influences the early visual scanning of faces. The significant difference in first fixation length suggests that the influence of memory occurs early and automatically during face processing, prior to explicit awareness of recognition (Ryan et al., 2007). The finding of longer first fixation length for novel faces was consistent with Kafkas and Montaldi (2011) who also reported longer first fixation length for less familiar or novel stimuli. The analyses of the first 1000 ms of viewing time was supportive of the notion that this period may be more critical for establishing identity than later periods. The finding of an early effect for memory for viewed faces for ASD and non-ASD participants contrasts with ERP research that report differences in neurophysiological responses to face stimuli between ASD and non-ASD persons (Dawson, Webb, Wijsman, et al., 2005).

While individuals with an ASD showed differences in eye movement behaviour between studied and novel faces indicative of the influence of memory on implicit visual processing of face stimuli, we did not obtain unequivocal evidence for explicit deficits – although the effect size data suggest this likely was in part due to sample size limitations that often constrain ASD research. Leaving aside issues of power, however, this result is not inconsistent with the complex information processing hypothesis. If the task is not sufficiently demanding, explicit performance in individuals with ASD may appear relatively unaffected. By increasing task complexity, deficits in performance may become more pronounced, allowing for a stronger assessment of the complexity hypothesis. In Experiment 3 previously unseen and altered images of the individual to be identified at test (henceforth ‘target’) were included to increase task difficulty and address this issue. Furthermore, rather than colour images, all images were converted to greyscale and external features (e.g., hairline, ears) were occluded. It was anticipated that these modifications would increase task complexity, thereby increasing the chances of a face recognition deficit becoming evident.

Faces with different emotional expressions were included in the present study in an attempt to enable a reasonable comparison with previous studies which also used happy and neutral faces (i.e., Althoff, 1998; Ryan et al., 2007). As discussed above, results were consistent with these studies. It is not clear, however, that processing the identity of neutral and happy faces occurs in the same manner. For example, recent work by Eisenbarth and Alpers (2011) suggests that visual scanning patterns are dependent on the emotion of the face in typically developing individuals. The implication of this for individuals with ASD who may be impaired at facial expression recognition (e.g., Corden et al., 2008) is unclear. To address this issue the proportion of fixations to the eyes and mouth were analysed for Experiment 2, and also for an emotion recognition task that was conducted at the same time as the present experiments. Results are reported and discussed in Chapter 6. Overall, viewing patterns to the eye and mouth regions were similar for participants with and without an ASD. This finding was consistent with a recent study which examined eye scanning during an emotion recognition task in individuals with ASD (Sawyer et al., 2011). It is therefore unlikely that the use of faces with different expressions had a significant impact on eye movement behaviour between-groups. Nonetheless, stimuli were confined to faces with neutral expressions for Experiment 3.

CHAPTER 4

Experiment 3

In Experiment 3 face recognition was assessed using stimuli sets that were manipulated so that face images presented at test included images that differed from the image presented at study (i.e., images of the target that had not been previously viewed by the participant were included at the test phase). Manipulations to the stimuli were based on the image manipulations used in the CFMT (Duchaine & Nakayama, 2006a) and included changes in pose, lighting, and masking with Gaussian visual noise. Implicit face memory was assessed using the eye movement-based memory effect, and RT and explicit face recognition were examined.

Method

Participants

Participants were 29 individuals with an ASD diagnosis who were paid for their participation and 43 university students who participated for course credit. General recruitment and exclusion criteria were the same as those reported for Experiment 2. In addition, eye tracking equipment problems led to the exclusion of three male participants with ASD and one female non-ASD participant. One further female participant in the non-ASD group who fell within the autistic range on the AQ was also removed (AQ = 33). Descriptive information for the 26 (17 male) participants with an ASD and 41 (14 male) non-ASD participants is provided in Table 18. Participant groups were matched on age and IQ and only differed significantly on the AQ. All participants reported normal or corrected-to-normal vision.

Table 18

Participant Characteristics for Age, IQ, AQ, and Between Group Comparison Statistics

	ASD (n = 26)		non-ASD (n = 41)		
	M (SD)[1]	Range	*M (SD)*	Range	Between Group Comparisons [2]
Age	28.12 (9.54)	18.08-49.58	24.76 (7.42)	18.33-47.67	$t(65) = 1.62$, $p = .11$, $d = .40$
FSIQ	107.69 (14.95)	85-139	109.88 (8.95)	87-131	$t(36.48) = -0.67$, $p = .51$, $d = .19$
VIQ	107.62 (15.08)	86-134	108.66 (9.00)	94-140	$t(36.42) = -0.32$, $p = .75$, $d = .09$
PIQ	106.23 (14.75)	79-134	108.56 (10.55)	79-132	$t(41.16) = -0.70$, $p = .49$, $d = .19$
AQ	30.58 (9.56) [a]	11-43	16.02 (4.97) [a]	9-29	$t(33.67) = 7.17$, $p < .001$, $d = 2.05$

Note. [1] Means with the same letters as superscripts reflect significant differences, $p < .05$. [2] Where Levene's test indicated significantly different variances between groups the adjusted statistics are reported.

Apparatus and Materials

Apparatus (i.e., eye tracker) and general materials (i.e., assessment instruments) were the same as those reported in Experiment 2. Stimuli were faces of non-famous male Caucasian persons aged 20-32 years selected from the Colour Facial Recognition Technology (FERET) database (Phillips et al., 2000; Phillips et al., 1998). The database includes images of up to 13 different labelled poses per individual. The profiles used in the current study included: frontal image; profile left/right (head turned 90° left/right); half left/right (head turned 67.5° left/right); and quarter left/right (head turned 22.5° left/right). Twelve individuals were randomly selected as targets and 108 individuals were randomly selected as foils. Faces were converted to greyscale and set on a white background (960 × 1280 pixels). Images were edited with Adobe Photoshop Elements 7.0 to reveal the inner face only and any prominent marks were removed. Selected images (see below) were modified with Photoshop lighting and a Gaussian mask effect (visual noise).

Targets and foil images were divided into two parallel image sets (Set A, Set B) to allow for counterbalancing between participants. Each target image was matched with a unique foil with the identical profile and of a similar age. As per Duchaine and Nakayama (2006a) images were separated into three sub-sets: ‘identical’ (one front, one quarter left and one quarter right, unaltered); ‘non-identical’ (one front, one of either profile left or right, and one of either half left or right, all with lighting changes); and ‘non-identical with noise’ (one front, one of either profile left or right, and one of either half left or right, all with lighting changes and Gaussian mask).

Procedure

Counterbalancing resulted in four conditions, each consisting of a unique pairing of target and foil images from Set A or Set B. Participants were randomly assigned to one of the four conditions, with eye tracker administration protocols as in Experiment 2.

The experiment consisted of a study and test phase for both a free viewing and a recognition test with the order of test presentation counterbalanced between participants (see Figure 4). Study and test phases were separated by a 5 min break. For the study phase participants were shown 18 target faces from the identical sub-set (Set A or Set B). The three images for each target were presented sequentially for 3 s each, resulting in 9 s total study time for each target. The six targets were then presented together for 10 s and participants were instructed to review the faces (total study time per target was 19 s). Between each image a blank screen was displayed for 500 ms, followed by a screen with a cross randomly displayed in one of the four corners of the monitor. Participants were instructed to fixate on the cross, which was displayed for 800 ms (total inter-stimulus interval of 1300 ms).

For the free viewing condition participants were exposed to 54 target images from the three sub-sets and 54 matched foils presented in a randomised order. Each image was presented for 5 s and preceded by the blank screen and the cross as per the study phase. Participants were instructed to look at the face in any way they wanted.

The recognition test condition was similar to the free viewing condition, except that participants were instructed to identify the faces they had viewed during the study phase. Images used were those from the alternate image set. A standard keyboard was modified so that the left and right ‘Alt’ keys were the only keys visible. The keys were marked either red (foil) or green (target) to indicate recognition, with the order counterbalanced between participants. Participants were instructed to respond as quickly and as accurately as they could. The recognition test was preceded with a brief practice where participants identified previously viewed shapes of differing colours.

For the current experiment analysis of eye movement behaviour was based on the Tobii Studio output, which were described in Experiment 2. Thus, fixation based measures were the average number of fixations, the average fixation length, and the average length of the first fixation. Other dependent variables were RT, discrimination performance (*A′*) and bias (*C*).

Results

Eye Movement-Based Measures

Three-way mixed ANOVAs with stimulus type (target vs. foil) and stimulus category (identical, non-identical, non-identical with noise) as the within-subjects factors, and diagnostic group as the between-subjects factor yielded significant main effects for stimulus category, and several main effects for stimulus type for the eye movement-based measures for the free viewing and the recognition test conditions. Descriptive statistics and ANOVA results are provided in Table 19 and Table 20 for the free viewing condition and Table 21 and Table 22 for the recognition test, respectively. The main effects for stimulus category indicated that modifications to the images had a strong influence on eye movement behaviour.

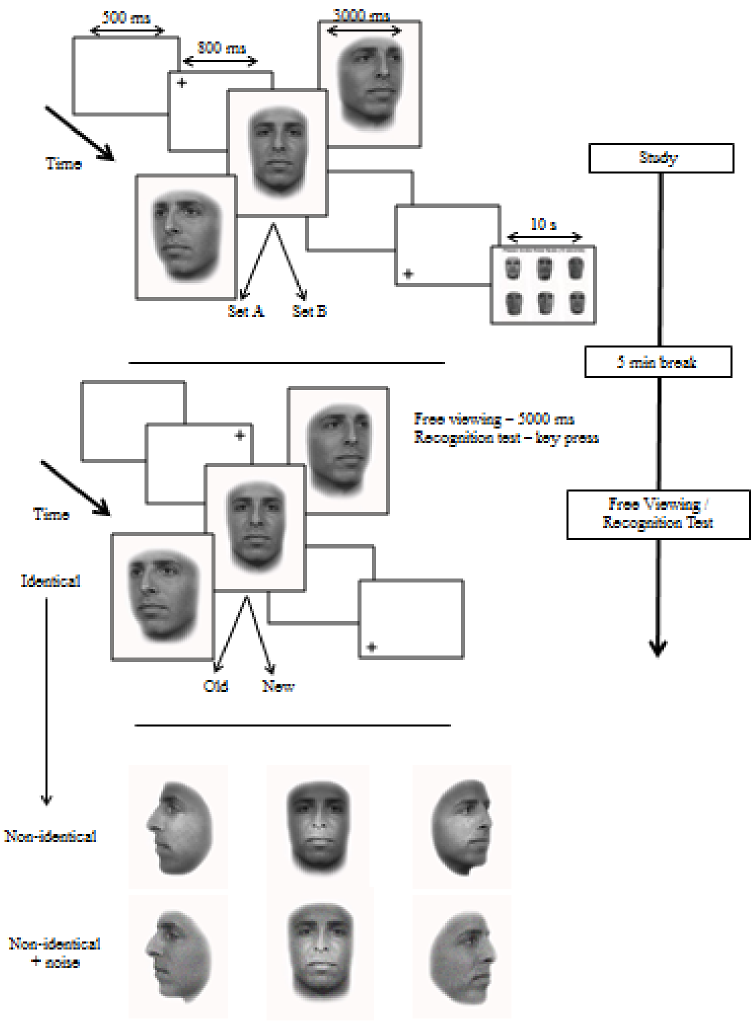


Figure 4. Experimental paradigm for Experiment 3. Images were presented in greyscale, different image sets were used for the free viewing and recognition test conditions. Both test conditions (free viewing, recognition test) were preceded by a study phase. During the study phase three different views of each face were presented, followed by a screen containing all target faces at the end. In the test conditions old and new faces were presented consecutively. Participants made a familiarity decision in the recognition test only.

While the influence of low level features on eye movement behaviour was not the focus of the current study, this finding indicated that features such as lighting, pose and image degradation may be important for visual attention. The main effects for stimulus type, however, indicate that prior viewing had a significant effect on eye movement behaviour, thus providing support for the eye movement-based memory effect hypothesis. The influence of prior viewing on eye movement behaviour was more clearly evident in the recognition test condition than the free viewing condition, suggesting task demands may be an important factor in attention and viewing behaviour. There were generally no significant differences in eye movement behaviour between participants with and without an ASD, with the notable exception of the number of fixations in the recognition test condition. This indicated that participants with an ASD used more fixations to make a recognition decision than non-ASD participants, which is consistent with longer RTs (see below) exhibited by this group.

Given the obvious relationship between RT and number of fixations, the fixation length measures, primarily the length of the first fixation, provided RT independent information regarding early implicit processing for both test conditions, and importantly, for pre-decisional implicit processing for the recognition test.

The Diagnosis × Category interaction on length of the first fixation for the free viewing and recognition test conditions was significant, with shorter first fixations identified for non-identical than non-identical with noise images for non-ASD participants, $t_s(40) > -0.03$, $p_s < .001$, $d_s > .32$, but not for participants with ASD, $t_s(25) < -1.11$, $p_s > .14$, $d_s < .18$ (the reported *t*-test statistics are for both the free viewing and recognition test conditions). While these results suggest first fixation length may not be a sensitive indicator of prior viewing in participants with ASD, the main effect for stimulus type (i.e., target vs. foil) for first fixation length consistently provided an indication of prior viewing for both groups, across both free viewing and recognition test conditions, which actually suggests that it is a sensitive measure of the eye movement-based memory effect.

The Type × Category interaction on number of fixations was also significant for the recognition test condition. Pairwise comparisons with a Bonferroni adjustment revealed that significantly more fixations were directed toward identical foils compared to non-identical foils and non-identical foils compared to non-identical with noise foils ($p_s < .001$), indicating different viewing behaviour between these three categories. However there was no difference in the number of fixations between identical and non-identical targets ($p = 1.00$), suggesting similar viewing behaviour between these categories. This last result suggests that pose and lighting variations had no effect on the number of fixations needed to identify a target. In contrast, fewer fixations were directed toward non-identical with noise targets than either of the other two target categories ($p_s < .002$). An examination of means revealed that average fixation length for the non-identical with noise category was typically longer than for identical or non-identical categories. Thus, while fewer fixations may have been needed to reach a decision, the longer length of these fixations suggests a different viewing strategy for the degraded images, not that participants reached a decision faster for degraded images (see RT analyses below – RTs for non-identical with noise images were not shorter overall compared to the other categories).

Next, paired samples *t*-tests based on type revealed a significant difference in the number of fixations between identical target and foils, $t(66) = 3.66$, $p = .001$, $d = .19$, with more fixations directed to identical foils, but not between target and foil images for either of the other two categories, $t_s(66) < 1.74$, $p_s > .086$, $d_s < .07$. Overall, these results may reflect the close similarity (i.e., pose and lighting) between foils from the identical category and studied target faces such that the degree of similarity may have made it more difficult for participants to dismiss foils that were quite similar to studied target images. Thus, participants may have required more fixations to form a decision.

There was a significant Group × Type × Category interaction for fixation length for the recognition test condition. The three-way interaction was further analysed by comparing the difference in fixation lengths between target and foil images separately for participants with and without an ASD, for each of the stimulus categories. There were no significant differences in fixation length between target and foil images for any stimulus category for participants with an ASD, $t_s(25) < 1.78$, $p_s > .08$, $d_s < .29$. For non-ASD participants, however, fixation length discriminated target from foil images in the identical and non-identical with noise categories, $t_s(40) > 2.24$, $p_s < .03$, $d_s > .15$, although there was no difference in fixation length between target and foil images for the non-identical category, $t(40) = -0.43$, $p = .67$, $d = .03$. Thus, the interaction indicates that, while fixation length discriminated target from foil images in two of the three categories for non-ASD participants, this measure was, overall, not effective in discriminating target from foil images for participants with ASD.

Table 19

Descriptive Statistics for the Eye Movement-Based Measures for the Free Viewing Condition for Participants with ASD (n = 26) and non-ASD Participants (n = 41)

Measure	Group	Type	Category *M (SD)*			Overall *M (SE)*
			Identical	Non-identical	Non-identical + Noise	
# Fixation	ASD	Target	10.51 (3.48)	9.52 (2.93)	8.42 (3.30)	9.48 (.471)
		Foil	10.69 (3.37)	9.46 (3.05)	8.55 (3.22)	9.57 (.467)
	non-ASD	Target	11.02 (1.95)	9.68 (2.20)	8.09 (1.91)	9.60 (.375)
		Foil	11.17 (1.97)	9.84 (1.98)	8.17 (2.02)	9.73 (.372)
	Overall	Target	10.82 (2.63)	9.61 (2.49)	8.22 (2.53)	
		Foil	10.98 (2.59)	9.69 (2.44)	8.32 (2.54)	
Length (ms)	ASD	Target	339 (38)	369 (44)	418 (80)	375 (10)
		Foil	340 (49)	385 (65)	412 (65)	379 (9)
	non-ASD	Target	356 (51)	396 (61)	451 (62)	401 (8)
		Foil	359 (43)	385 (56)	443 (51)	395 (7)
	Overall	Target	349 (47)	385 (56)	438 (71)	
		Foil	351 (46)	385 (59)	431 (59)	
1st Fixation (ms)	ASD	Target	307 (130)	416 (208)	349 (132)	357 (21)
		Foil	259 (60)	330 (118)	364 (147)	318 (16)
	non-ASD	Target	252 (43)	349 (141)	428 (193)	343 (16)
		Foil	243 (27)	285 (46)	416 (207)	315 (13)
	Overall	Target	273 (91)	375 (172)	397 (175)	
		Foil	249 (43)	302 (84)	396 (186)	

Table 20

Analysis of Variance on Eye Movement-Based Measures for the Free Viewing Condition

Measure	Source	*df*	*F*	*p*	η_p^2
Fixation #	Type (T)	(1,65)	1.95	.17	.03
	Category (C)	(2,130)	112.98	< .001	.64
	Diagnosis (D)	(1,65)	< 1		
	T × D	(1,65)	< 1		
	C × D	(2,130)	2.36	.10	.07
	T × C	(2,130)	< 1		
	T × C × D	(2,130)	< 1		
Length	Type (T)	(1,65)	< 1		
	Category (C)	(2,130)	132.35	< .001	.67
	Diagnosis (D)	(1,65)	3.38	.07	.05
	T × D	(1,65)	1.76	.19	.03
	C × D	(2,130)	1.75	.18	.03
	T × C	(2,130)	1.05	.35	.02
	T × C × D	(2,130)	2.22	.11	.03
1st Fixation	Type (T)	(1,65)	10.90	.002	.14
	Category (C)	(2,130)	35.68	< .001	.35
	Diagnosis (D)	(1,65)	< 1		
	T × D	(1,65)	< 1		
	C × D	(2,130)	9.50	< .001	.13
	T × C	(2,130)	2.33	.11	.07
	T × C × D	(2,130)	< 1		

Table 21

Descriptive Statistics for the Eye Movement-Based Measures for the Recognition Test for Participants with ASD (n = 26) and non-ASD Participants (n = 41)

Measure	Group	Type	Category *M (SD)* Identical	Non-identical	Non-identical + Noise	Overall *M (SE)*
# Fixation	ASD	Target	3.82 (1.82)	3.94 (1.81)	3.43 (1.66)	3.73 (.227)
		Foil	4.67 (2.51)	4.02 (1.65)	3.83 (1.64)	4.17 (.257)
	non-ASD	Target	3.13 (.82)	3.06 (.82)	2.65 (.89)	2.95 (.181)
		Foil	3.62 (1.10)	3.05 (1.12)	2.68 (.87)	3.12 (.205)
	Overall	Target	3.40 (1.33)	3.40 (1.35)	2.95 (1.30)	
		Foil	4.03 (1.84)	3.43 (1.41)	3.12 (1.34)	
Length (ms)	ASD	Target	278 (37)	286 (36)	312 (52)	292 (6)
		Foil	281 (39)	298 (41)	305 (33)	295 (6)
	non-ASD	Target	268 (32)	297 (35)	307 (30)	291 (5)
		Foil	279 (33)	295 (27)	319 (43)	298 (5)
	Overall	Target	272 (34)	293 (36)	309 (40)	
		Foil	279 (35)	296 (33)	314 (40)	
1st Fixation (ms)	ASD	Target	243 (47)	267 (57)	286 (81)	266 (9)
		Foil	248 (45)	288 (78)	294 (76)	277 (9)
	non-ASD	Target	243 (33)	264 (41)	324 (93)	277 (7)
		Foil	243 (27)	279 (49)	334 (95)	286 (7)
	Overall	Target	243 (38)	265 (48)	309 (90)	
		Foil	245 (35)	283 (62)	319 (90)	

Table 22

Analysis of Variance on Eye Movement-Based Measures for the Recognition Test

Measure	Source	*df*	*F*	*p*	η_p^2
Fixation #	Type (T)	(1,65)	11.85	.001	.15
	Category (C)	(2,130)	24.52	< .001	.27
	Diagnosis (D)	(1,65)	9.54	.003	.13
	T × D	(1,65)	2.43	.12	.04
	C × D	(2,130)	< 1		
	T × C	(2,130)	6.51	.003	.09
	T × C × D	(2,130)	< 1		
Length	Type (T)	(1,65)	5.08	.03	.07
	Category (C)	(2,130)	61.91	< .001	.49
	Diagnosis (D)	(1,65)	< 1		
	T × D	(1,65)	1.42	.24	.02
	C × D	(2,130)	1.80	.17	.03
	T × C	(2,130)	< 1		
	T × C × D	(2,130)	5.16	.01	.07
1st Fixation	Type (T)	(1,65)	8.27	.005	.11
	Category (C)	(2,130)	31.46	< .001	.33
	Diagnosis (D)	(1,65)	< 1		
	T × D	(1,65)	< 1		
	C × D	(2,130)	4.69	.02	.07
	T × C	(2,130)	1.48	.23	.02
	T × C × D	(2,130)	< 1		

Discrimination Performance, Bias and Error Rates

Results were analysed for discrimination performance (*A′*) and response bias (*C*) using two-way mixed ANOVAs with diagnosis as the between-subjects factor and stimulus category (identical, non-identical, non-identical with noise) as the within-subjects factor. Descriptive results are provided in Table 23. Significant main effects for *A′* indicated that discrimination performance was best for identical images, and deteriorated significantly for both non-identical and non-identical with noise categories, $F(2, 124) = 22.78$, $p < .001$, $\eta_p^2 = .269$. This was interpreted as confirming that task difficulty increased with each of the stimulus manipulations. There was also a significant main effect for diagnosis, $F(1, 62) = 7.09$, $p = .01$, $\eta_p^2 = .103$, supporting the hypothesis of impairment in explicit face recognition in participants with ASD. The Category × Diagnosis interaction was not significant.

The analysis of response bias showed a main effect for category, $F(2, 124) = 8.09$, $p = .001$, $\eta_p^2 = .115$, indicating that responses were more conservative for the non-identical and non-identical with noise categories compared to the identical category. The significant main effect for diagnosis, $F(1, 62) = 5.94$, $p = .018$, $\eta_p^2 = .087$, indicated that, overall, non-ASD participants were more conservative than ASD participants, although both participant groups were generally conservative in their responses (i.e., bias to respond ‘no’), with the single exception of ASD participants who showed a more liberal bias in the identical category. This may indicate a problem with general task demands as participants with an ASD were more likely to respond ‘yes’ when the image viewing angle was the same as that presented during the study phase, whether or not the stimuli was a target or a foil.

Table 23

Mean (with Standard Deviations in Parenthesis) A prime (A') and Response Bias (C) for the Recognition Test for Participants with ASD (n = 24) and non-ASD participants (n = 40)

	A' M (SD)[1]			
	Identical	Non-identical	Non-id + noise	Total
ASD	.76 (.14)[a]	.72 (.17)	.69 (.11)	.74 (.11)[b]
Non-ASD	.87 (.09)[a]	.78 (.11)	.72 (.12)	.80 (.09)[b]
	C M (SD)[1]			
ASD	-.11 (.39)	.09 (.40)[c]	.01 (.45)[d]	-.002 (.34)[e]
Non-ASD	.09 (.48)	.34 (.45)[c]	.28 (.55)[d]	.25 (.43)[e]

Note. [1] Means with the same letters as superscripts reflect significant differences, $p < .05$

Error rates (number of misses for targets and the number of false alarms for foils) were analysed using a three-way mixed ANOVA with diagnosis as the between-subjects factor and stimulus category (identical, non-identical, non-identical with noise) and stimuli type (target vs. foil) as the within-subjects factors. Descriptive statistics are provided in Table 24 and ANOVA results are provided in Table 25. The ANOVA yielded significant main effects for stimulus category, stimulus type, and diagnosis on error rates. It is necessary, however, to investigate the interactions to interpret the pattern of results. The Category ×

Diagnosis interaction was significant, with participants with ASD reporting more errors for the identical category compared to non-ASD participants, $t(62) = 3.82$, $p < .001$, $d = .97$. There was no difference in error rates between groups for the non-identical and the non-identical with noise categories, $t_s(62) < 1.39$, $p_s > .17$, $d_s < .36$.

Table 24

Mean Error Rate (Number of Misses for Targets and Number of False Alarms for Foils) for the Recognition Test for Participants with ASD (n = 24) and non-ASD participants (n = 40)

	Identical	Non-identical	Non-id. + noise	Overall
	M (SD)	*M (SD)*	*M (SD)*	*M (SE)*
		Targets		
ASD	4.71 (3.11)	6.54 (3.72)	6.83 (3.48)	6.03 (.56)
non-ASD	3.75 (2.92)	7.18 (3.35)	8.18 (3.96)	6.37 (.43)
Overall	4.11 (3.00)	6.94 (3.48)	7.67 (3.82)	
		Foils		
ASD	6.04 (3.43)	5.50 (3.19)	6.71 (3.18)	6.08 (.51)
non-ASD	3.03 (2.88)	3.30 (2.56)	4.75 (3.45)	3.69 (.39)
Overall	4.16 (3.41)	4.13 (2.99)	5.48 (3.46)	

The significant Type × Diagnosis interaction revealed that participants with an ASD were significantly worse at correctly identifying foil images compared to non-ASD participants, *t*(62) = 3.71, *p* < .001, *d* = .69 , yet there was no difference between groups for error rates for target images, *t*(62) = -0.482, *p* = .632, *d* = .12. Together, these interactions suggest that participants with an ASD made more errors for foils in the identical category than non-ASD participants. However, given the lack of a significant three-way interaction, this conclusion should be interpreted cautiously. Nonetheless, the result is consistent with the response bias data for this category.

The significant Type × Category interaction revealed that participants made fewer errors overall for identical compared to non-identical and non-identical with noise targets, and fewer errors for identical and non-identical compared to non-identical with noise foils. Changes in pose, lighting and the addition of visual noise had a significant effect on performance – more specifically, the more the image differed, or was degraded, compared to the studied face, the more difficult it was to identify. Moreover, this is consistent with the complexity hypothesis: increasing task difficulty, and thereby cognitive demands, disproportionately affected participants with an ASD compared to non-ASD participants.

RT

Two participants with an ASD and one non-ASD participant were identified as extreme outliers (i.e., > 2 *SD*s from the mean) and their data were removed from the RT analyses. All of the removed participants returned average RTs > 4000 ms for both target and foil images.

Three-way mixed ANOVAs, with stimulus type (target vs. foil) and stimulus condition (identical, non-identical, non-identical with noise) as the within-subjects factors and diagnostic condition as the between-subjects factor, were used to examine RTs for correct and incorrect responses for targets and foils. Because some individuals did not report any errors for some stimulus categories, missing data were replaced with the series mean for the diagnostic group to ensure the maximum inclusion of available data. Replacement of missing data with the series mean did not significantly alter the overall mean for the group, nor the overall results. The number of cells replaced with the series mean for foils (i.e., number of individuals who returned no false alarms) for each category was: identical: ASD = 0, non-ASD = 9; non-identical: ASD = 2, non-ASD = 7; non-identical with noise: ASD = 0, non-ASD = 3. The number of cells replaced for targets (i.e., number of individuals who returned no misses) was: identical: ASD = 2, non-ASD = 6; non-identical: ASD = 1, non-ASD = 2; non-identical with noise: ASD = 0, non-ASD = 4. However, given the resultant underestimation of within-group variation as a result of replacing missing data with group means, and also the small number of data points for those participants who made errors and on which the error analysis was based, the following results should be interpreted cautiously[7].

Descriptive statistics are provided in Table 26 and ANOVA results are provided in Table 27. The analysis for correct responses yielded significant main effects for stimulus type and stimulus category, indicating overall shorter RTs for targets compared to foils, and shorter RTs for identical than non-identical images; however, there was no significant RT difference between non-identical and non-

---

[7] Given these constraints, a more conservative approach might have been to remove the error analysis from the thesis entirely. Nonetheless, a decision was made to include the error analysis and leave it to the reader's discretion to interpret the results.

identical with noise images. Thus, there is clear RT advantage for target (i.e., studied) compared to foil images, and also for identical compared to non-identical and non-identical with noise images.

Table 25

Analysis of Variance on Error Rates for the Recognition Test

Source	*df*	*F*	*p*	η_p^2
Type (T)	1,62	5.93	.018	.087
Category (C)	2,124	35.72	< .001	.366
Diagnosis (D)	1,62	6.36	.014	.093
T × D	1,62	6.45	.014	.094
C × D	2,124	5.33	.006	.079
T × C	2,124	8.35	< .001	.119
T × C × D	2,124	< 1		

A significant main effect for diagnostic category indicated that, overall, RTs for correct decisions were shorter for non-ASD participants compared to participants with ASD. However, none of the interactions involving diagnosis were significant, indicating that an RT advantage, including for previously unseen target images, was evident in both participants with and without an ASD. None of the other interactions were found to be significant.

For incorrect response data, the main effect for stimulus category was found to be significant, with longer RTs for identical images compared to non-identical images. There was, however, no significant RT difference between non-identical and non-identical with noise categories. Thus, longer RTs were associated with both foil and target images that were identical in lighting and pose to the studied faces. The main effect for diagnosis was also significant; as well as longer RTs for correct identifications, participants with an ASD had longer RTs for incorrect responses. None of the remaining main effects or interactions were significant.

Discussion

For Experiment 3 the assessment of explicit recognition performance revealed that participants with an ASD were poorer at discriminating studied from novel faces than non-ASD participants. This contrasts with Experiment 2 where discrimination performance was not found to differ significantly between groups. This may be explained by the inclusion of target images within the test that differed (i.e., in pose, lighting and with the addition of visual noise) from the image presented during study. More errors were made for images that differed from the studied images than for identical images. Other differences in stimulus sets between the two experiments, such as the use of grey-scale images and the occlusion of all but the inner face, may have had a significant effect on performance in Experiment 3. Consistent with other studies (e.g., Behrmann, Avidan, et al., 2006), both correct and error RTs were longer for participants with ASD compared to non-ASD participants.

Although participants with ASD showed an explicit recognition deficit, there was no evidence of an implicit memory deficit for the face stimuli. Analyses of eye movement behaviour provided evidence that, like the control participants, participants with an ASD processed studied and novel faces differently, and this included previously unseen, altered pictures of the studied individual.

Table 26

Mean RT (ms) for Correct and Incorrect Responses for Targets and Foils for Participants with ASD (n = 24) and non-ASD participants (n = 40)

		Identical	Non-identical	Non-id. + noise	Overall
		M (SD)	*M (SD)*	*M (SD)*	*M (SE)*
		Correct			
ASD	Target	1426 (504)	1584 (569)	1556 (478)	1522 (76)
	Foil	1609 (545)	1707 (573)	1786 (661)	1701 (93)
	Overall	1518 (485)	1646 (525)	1671 (539)	
Non-ASD	Target	1195 (254)	1334 (357)	1309 (326)	1279 (59)
	Foil	1401 (393)	1333 (391)	1396 (490)	1377 (72)
	Overall	1298 (301)	1333 (344)	1352 (376)	
		Incorrect			
ASD	Target	1895 (960)	1720 (794)	1805 (937)	1806 (120)
	Foil	1931 (980)	1839 (729)	1856 (729)	1875 (106)
	Overall	1913 (864)	1779 (711)	1830 (729)	
Non-ASD	Target	1705 (761)	1437 (446)	1306 (298)	1483 (93)
	Foil	1583 (468)	1587 (517)	1527 (409)	1566 (82)
	Overall	1644 (531)	1512 (399)	1417 (301)	

Table 27

Analysis of Variance on RT for Correct and Incorrect Responses for the Recognition Test

Response type and source	*df*	*F*	*p*	η_p^2
Correct				
Type (T)	1,62	18.17	< .001	.227
Category (C)	2,124	7.53	.001	.108
Diagnosis (D)	1,62	7.71	.007	.111
T × D	1,62	1.57	.22	.025
C × D	2,124	1.92	.15	.03
T × C	2,124	3.00	.09	.046
T × C × D	2,124	1.29	.28	.02
Incorrect				
Type (T)	1,62	2.38	.13	.037
Category (C)	2,124	4.55	.037	.068
Diagnosis (D)	1,62	5.57	.021	.082
T × D	1,62	< 1		
C × D	2,124	1.14	.32	.018
T × C	2,124	1.60	.21	.025
T × C × D	2,124	1.02	.37	.016

Differences in the length of the first fixation between target and foil images provided evidence that the influence of memory on the visual processing of studied images occurred early in both participant groups. Of interest, the influence of memory on eye movement behaviour was more clearly evident in the recognition test condition than the free viewing condition. Consistent with Ryan et al. (2007) task demands influenced the effect of memory on eye movements; however, unlike Ryan et al. who reported longer first fixations to studied faces, first fixations were typically shorter for studied compared to novel faces. This difference in first fixation length could be accounted for by methodological differences. First, images in the present study were presented serially, while Ryan et al. presented target and foil images in parallel. This factor alone may account for the differences between the studies. Second, Ryan et al. included images that contained hair, make-up, and other differences that were excluded in the present study.

There were consistent and strong effects for category, irrespective of whether the image was a target or foil. Foil images that were the same or similar in pose and lighting to studied faces elicited eye movement behaviour that was more similar to studied images than images that differed in lighting and pose. This result might be interpreted in terms of an interaction between top-down and bottom-up influences on eye movement behaviour. As discussed in the introduction, bottom-up low level features also influence eye movement behaviour (Foulsham & Underwood, 2008; Hannula et al., 2010). However, while visual saliency models offer an alternate framework for the conceptualisation of the present studies, the focus here was on the influence of memory on visual processing. Nonetheless, it is important to acknowledge that both the physical properties of the stimulus and prior memory influence eye movement behaviour, with the affects for category (i.e., lighting and pose) most likely reflecting the former, and the effects for type (i.e., whether or not the image was of a novel stimulus) more likely to be reflected in the latter. The influence of low-level features on visual scanning in individuals with an ASD offers a pertinent area for future research.

In sum, results from Experiment 2 and Experiment 3 were supportive of the hypothesis that memory influences eye movement behaviour. More specifically, eye movement behaviour can be successfully analysed to assess the influence of implicit memory and early visual processing in individuals with an ASD. Significantly, Experiment 3 showed that the influence of memory on eye movements was not constrained by the use of identical images, but was evident for novel and degraded images of unfamiliar studied faces. These results provide evidence of the influence of memory on implicit visual processing during face recognition in individuals with an ASD. This is in direct contrast to similar findings reported by Sterling et al. (2008) who reported no difference in eye movement behaviour for familiar compared to novel faces in a group of participants with an ASD. Thus, implicit memory processes for faces may be intact in individuals with an ASD.

Second, results from the three experiments reported thus far were consistent with an explicit impairment in face recognition in ASD. Consistent with previous studies (Klin et al., 1999; O'Hearn et al., 2010; Wolf et al., 2008), participants with an ASD were worse at explicit face recognition. The effects were sharper in Experiment 1 and Experiment 3, which were both more demanding due to the occlusion of outer face features and the use of new images of targets, thereby increasing cognitive demands. It has been suggested that, in ASD, overloading attention and working memory systems may cause processing systems to fail (Marco, Hinkley, Hill, & Nagarajan, 2011).

These results have implications for the understanding of the origin of the face recognition deficit in ASD. In contrast to hypotheses that place the origin of the face recognition deficit in ASD in the social domain (e.g., Dawson et al., 2002; Dawson, Webb, & McPartland, 2005; Dawson, Webb, Wijsman, et al., 2005; Grelotti et al., 2005; Klin et al., 1999; McPartland et al., 2011; Sterling et al., 2008), the present results can be interpreted as evidence of spared early processing in the face of disrupted complex information processing (e.g., Behrmann, Avidan, et al., 2006; Behrmann, Thomas, et al., 2006; Minshew & Goldstein, 1998, 2001; Minshew et al., 1992; D. L. Williams, Goldstein, & Minshew, 2005; D. L. Williams et al., 2006). Conceptually, this moves the origin of the face recognition deficit in ASD away from that of a failure of early visual processing of faces and toward that of a deficit in the integration of multiple processes responsible for higher-order information processing.

Nonetheless, the hypothesis that the differences in explicit face recognition between participants with and without an ASD were not, at least in part, influenced by failure to develop face expertise as a result of low motivation to attend to social stimuli cannot be dismissed entirely. Poorly developed expertise for faces could contribute to a deficit in higher-order areas that are necessary for explicit face recognition, without affecting early visual processing or implicit memory. If the evidence here is interpreted as indicating individuals with ASD are competent at implicit but not explicit face recognition, then this would suggest dissociation between implicit and explicit face recognition in this group.

While there are several different explanations for dissociations between explicit and implicit memory, including suggestions that implicit and explicit recognition, or face processing more generally, are served by multiple systems (e.g., Bauer, 1984; Burton, Young, Bruce, Johnston, & Ellis, 1991), Farah, O'Reilly, and Vecera (1993) argue that the simplest explanation is that damage to a single face processing system may manifest when assessed explicitly, as explicit tasks are more cognitively demanding than implicit tasks. Thus, a logical next step is to further examine the mechanisms that contribute to the apparent dissociation between implicit and explicit memory processes in persons with ASD.

To assess the hypothesis that the face processing system is served by a single system that may be damaged in ASD, Experiment 4 assessed configural face processing. Again, assessment was based on the influence of memory on implicit visual processing, and explicit face recognition performance. Configural processing refers to the process of integrating featural information into a coherent whole. Significantly, configural processing provides a marker of expertise in face processing: unlike objects, face processing is significantly advantaged by configural processing, the disruption of which affects performance (e.g., face recognition). Persons with an ASD, however, are thought to rely on featural information processing. This bias may, in fact, be advantageous for processing inverted faces, which are normally processed less efficiently than upright faces because inversion disrupts configural processing. By examining the presence of featural and configural processing implicitly, and comparing implicit processing with explicit recognition, it may be possible to determine whether implicit visual processing and explicit face recognition in ASD are subserved by the same, or dissociated processes.

CHAPTER 5

Experiment 4

The previous studies are indicative of dissociation between explicit late stage processing and implicit early-stage processing in association with face recognition in ASD. It was suggested that poor performance on explicit face recognition may be associated with a general deficit in late, complex information processing in this group of individuals. In contrast, early implicit processing may be spared. An alternate explanation is that damage to the face processing system may only be evident when assessed explicitly, with damage to the implicit system being harder to detect (Farah et al., 1993). To examine implicit processing more closely, Experiment 4 examined whether individuals with ASD showed evidence of configural processing during a face recognition task when assessed at implicit and explicit levels.

The term ‘Face Inversion Effect’ (FIE) is used to describe the effect on performance (e.g., lengthened RTs and reduced recognition performance) of inverting stimuli during a face recognition task. Inversion disrupts configural face processing and forces reliance on featural processing. In typical individuals upright faces are recognised faster and more accurately than inverted faces. In contrast, studies of the FIE in individuals with ASD have been mixed, with some studies failing to report a FIE in participants with an ASD (Hobson et al., 1988; Langdell, 1978; McPartland, Dawson, Webb, Panagiotides, & Carver, 2004). Other studies, however, indicate that older or higher functioning individuals with ASD may develop a FIE (Lahaie et al., 2006; Scherf et al., 2008; Teunisse & de Gelder, 2003). It may be that these individuals become aware of the social advantage associated with faces and, through practice, develop face processing skills that are more similar to those of non-ASD individuals.

There is evidence that the FIE is evident during both implicit and explicit face processing. Thus, the FIE provides an opportunity to assess the hypothesised dissociation between implicit and explicit face processing in ASD. Event-related potential (ERP; Jacques et al., 2007) and behavioural studies (Boehm et al., 2006) indicate face inversion affects face recognition prior to explicit recognition (e.g., within the first 130-160 ms; Jacques et al., 2007; Jacques & Rossion, 2006) during the encoding stage (Itier & Taylor, 2004; Rhodes, Brake, & Atkinson, 1993). Jacques et al. (2007) showed that, compared to repeated upright faces, the N170 and N250r (the N170 is sensitive to faces and the N250r is sensitive to face repetition) responses to previously viewed faces are delayed and reduced in magnitude when faces are presented upside down, mirroring the behavioural effect of face inversion. This study provides indirect evidence that face inversion influences processing and identification of individual faces during the time period associated with implicit recognition.

Further evidence that face inversion affects processing changes during recognition can be found in a study by Boehm et al. (2006). Specifically, Boehm et al. examined the influence of memory on face recognition using RT. While upright and inverted studied faces showed RT advantages, the size of the effect was greater for upright compared to inverted faces. RT effects were also evident for repeating unfamiliar upright faces, but not for repeating unfamiliar inverted faces. Overall, an RT advantage was greater for studied compared to novel faces. The authors argue that the RT advantage for studied inverted but not novel inverted faces was driven by the memory based representation of the face (absent in the unfamiliar face condition). The RT advantage for upright compared to inverted studied faces, the RT advantage for studied compared to novel faces, and the RT advantage for upright but not inverted novel faces was attributed to configural processing. Based on these results, Boehm et al. concluded that face processing is served by dual processes: one that is reliant on configural processing, and the other that relies on a representation of the image stored in memory (the memory based representational code). Both of these processes influence recognition, but the degree of influence differs depending on the nature of the task and stimulus presentation (i.e., upright vs. inverted, familiar vs. unfamiliar).

According to Diamond and Carey (1986; Rhodes et al., 1993), three types of information can be used for recognition: isolated features (recognised without reference to several parts of the stimulus); first-order relational features (based on unconstrained relationship between parts, such as the components of a landscape); and second-order relational features (where the relationship between parts is constrained, as in a face where eyes appear above the nose). Memory based representational coding is not reliant on first- or second- order relations because it is not affected by inversion. Thus, memory based representational coding can be understood to be driven by featural coding.

Drawing on the work described above which indicates that, like explicit recognition, implicit face processing may be subserved by configural and featural processes, and given the feature based preference evident in individuals with an ASD, this preference should be evident at the implicit level. If the feature bias extends to implicit face processing then, compared to non-ASD persons, individuals with an ASD should show an advantage for processing of inverted faces (i.e., they will be relatively less affected by the FIE). This should be evidenced by (a) memory based influence on implicit visual processing, and (b) a RT advantage. Alternatively, individuals with an ASD may show evidence of configural processing implicitly, but not explicitly. If this is the case, processing differences should emerge between upright and inverted faces at the implicit level, but not at the explicit level. This would provide support for the hypothesised dissociation between implicit processing and explicit face recognition in ASD, and for impairment in later, high-order complex information processing, but not in implicit processing stages.

Given (a) the importance of examining process-oriented behavioural measures associated with face recognition (Joseph & Tanaka, 2003), (b) explicit face recognition impairment evident in many individuals with an ASD, and (c) the absence of obvious implicit memory impairment, the current experiment used eye-movements and RT to determine whether there was evidence of atypical reliance on feature over configural information during implicit face processing. A standard inverted face recognition methodology was used to disrupt configural processing. It was predicted that memory effects (i.e., eye movement-based memory effects, RT advantage) would be evident for studied (target) compared to novel (foil) faces. Second, consistent with the FIE, it was predicted that differences would emerge between inverted and upright faces, with shorter RTs, differences in fixations, and better overall discrimination performance for upright compared to inverted faces, although the degree to which the FIE was evident would depend on diagnosis (see below). Third, if participants with an ASD are less affected by face inversion as predicted by preference for featural based information processing, it was predicted that an interaction between the FIE and diagnosis would emerge. Specifically, it was expected that participants with ASD would show relatively superior performance on inverted faces compared to non-ASD participants as evidenced by a smaller overall difference between upright and inverted recognition performance. Furthermore, if the implicit processing of upright and inverted faces is similar in ASD participants it was expected there would be no difference in the size of the RT advantage for upright and inverted studied faces. Conversely, it was predicted that the size of the RT advantage would differ for inverted and upright faces in the non-ASD control group. Consistent with the previous experiments, it was expected participants with ASD would show overall poorer performance than non-ASD participants on measures of explicit face recognition.

Method

Participants

Participants were 26 individuals with an ASD diagnosis who were paid for their participation and 34 university students who participated for course credit. General recruitment and exclusion criteria were the same as those reported for Experiment 2 and Experiment 3. One female participant in the non-ASD group who fell within the autistic range on the AQ was removed (AQ = 33). Descriptive information for the 26 (16 male) participants with an ASD and 33 (19 male) non-ASD participants is provided in Table 28. Participant groups were matched on age and IQ and only differed significantly on the AQ. All participants reported normal or corrected-to-normal vision.

Apparatus and Materials

Apparatus (i.e., eye tracker) and general materials (i.e., assessment instruments) were the same as those reported in Experiment 2 and Experiment 3. Stimuli were 72 front view faces of non-famous male Caucasian persons selected from the Computer Vision Laboratory (CVL) Face Database (Peer, 2011; Solina et al., 2003). The database consists of individuals aged from 18 years. Images were paired based on age and complexion and were divided into two image sets (Set A, Set B) each consisting of 36 images. Faces were converted to greyscale and set on a black background (study images were 1246 × 908 pixels, test images were 1373 × 999 pixels). Images were edited with Adobe Photoshop Elements 7.0 to reveal the inner face only (i.e., ears and hairline were removed) and any prominent marks were removed. Images were then inverted so that there were four image sets (Set A Upright/Inverted, Set B Upright/Inverted). Four conditions were arranged consisting of a unique combination of 18 upright and 18 inverted images from each of the four image sets. In each condition 36 images were designated as target images, and 36 images were designated as foil images.

Procedure

Participants were randomly assigned to one of the four conditions to ensure presentation of upright and inverted, and target and foil, images were counterbalanced between participants. General procedure related to administration and calibration of the eye tracker was the same as those in Experiment 2 and Experiment 3.

Table 28

Participant Characteristics for Age, IQ, AQ, and Between Group Comparison Statistics

	ASD (n = 26)		non-ASD (n = 33)		
	M (SD)[1]	Range	*M (SD)*	Range	Between Group Comparisons [2]
Age	28.91 (9.49)	18.83-50.42	24.99 (9.98)	18.17-54.17	$t(57) = 1.53$, $p = .13$, $d = .40$
FSIQ	106.58 (15.07)	85-139	112.12 (9.32)	94-131	$t(39.54) = -1.64$, $p = .11$, $d = .46$
VIQ	107.19 (15.02)	86-134	111.42 (10.43)	90-140	$t(42.77) = -1.22$, $p = .23$, $d = .33$
PIQ	104.73 (14.95)	79-134	109.94 (10.66)	93-131	$t(43.57) = -1.50$, $p = .14$, $d = .41$
AQ	30.42 (9.45) [a]	11-43	14.42 (5.00) [a]	5-23	$t(35.87) = 7.81$, $p < .001$, $d = 2.19$

Note. [1] Means with the same letters as superscripts reflect significant differences, $p < .05$. [2] Where Levene's test indicated significantly different variances between groups the adjusted statistics are reported

The experiment consisted of three study phases and one test phase (Figure 5). Study and test phases were separated by a 3 min break. For each study phase participants were shown 36 target faces (18 upright, 18 inverted) from the appropriate condition in randomised order. The aim was to present images to the participants without their awareness that the images would be used in a subsequent recognition test, thus avoiding intentional and explicit attention to specific details that might aid recall during the recognition test. Thus, participants were advised that they would be judging the faces on a set of personality attributes. Specifically, they were told they would be shown a face and then they would be required to assess the face on how ‘nice’ (or sincere or friendly) they considered the person to be. Presentation of the face was followed by a 7-point scale with the relevant attribute (e.g., *nice* = 1, *not nice* = 7). Between each image a blank screen was displayed for 500 ms, followed by a screen with a cross randomly displayed in one of the four corners of the monitor. Participants were instructed to fixate on the cross, which was displayed for 800 ms (total inter-stimulus interval of 1300 ms). One attribute was used for each of the three study phases; however, the same images were used in each phase. Thus, participants were shown the 36 target images three times. Each face was presented for 3 s, resulting in 9 s total study time per image. Prior to beginning, participants were presented with upright and inverted images of cartoon dog faces which allowed a brief practice and to ensure instructions were understood.

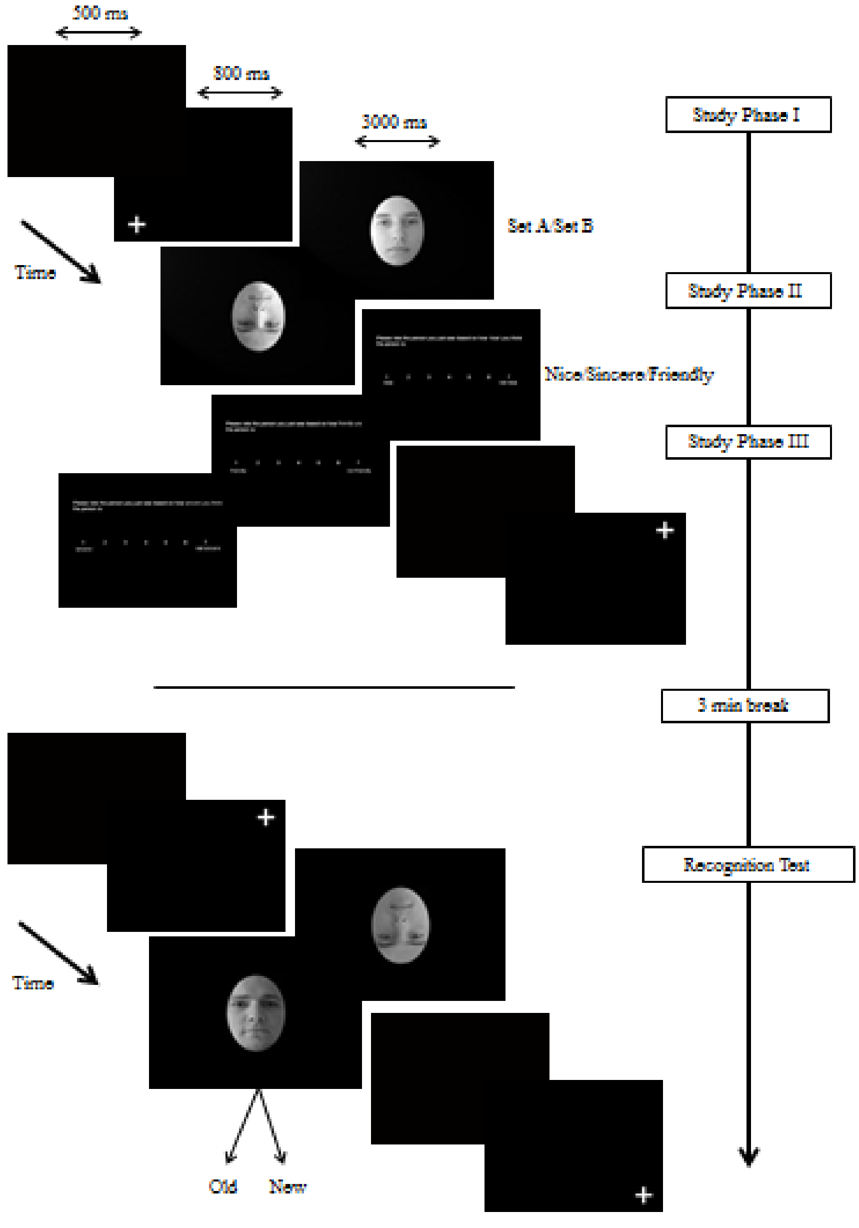


Figure 5. Experimental paradigm for Experiment 4. Images were presented in greyscale. The study phase was repeated three times. Each study phase used the same images which were presented randomly. In the test conditions old and new faces were presented consecutively. Faces that were inverted in the study phase were also inverted in the test. Participants made a timed recognition decision in the recognition test.

Following the break participants began the recognition test condition. To minimise recognition based on low-level visual features (see Jacques et al., 2007), images presented during the recognition test were 5% larger than the images presented during the study phase. To further ensure images presented at test were not identical to images presented during the study phase, target and foil images were altered using lighting effects available in Photoshop™. At test, participants were advised that the images had been altered but that they must try and recognise the faces of the people shown in the study phase, irrespective of whether or not the photo differed from the previously viewed image. Participants were shown 72 images (36 targets, 36 foils) in randomised order. The orientation (i.e., upright, inverted) of target images in the study phase was maintained in the recognition test. Participants were instructed to try and identify the faces they had viewed during the study phase. A standard keyboard was modified so that the left and right ‘Alt’ keys were the only keys visible. The keys were marked either red (foil) or green (target) to indicate recognition, with the order counterbalanced between participants. Participants were instructed to respond as quickly and as accurately as they could, thus speed and accuracy were given equal emphasis. The recognition test was preceded with a practice where participants identified the faces of cartoon dogs, half of which had been presented as a practice during the first study phase.

Results

Eye Movement-Based Measures

Three-way mixed ANOVAs with stimulus type (target vs. foil) and stimulus category (upright vs. inverted) as the within-subjects factors, and diagnostic group as the between-subjects factor were used to analyse the eye movement data. Descriptive statistics are provided in Table 29, and ANOVA results are provided in Table 30. Consistent with previous experiments, participants with an ASD used more fixations than non-ASD participants to respond. Unlike previous experiments, however, the only significant main effects were found for the number of fixations, with significant main effects for type and diagnosis. Furthermore, and also inconsistent with the previous experiments, both upright and inverted targets were characterised by significantly more fixations than foils. The lack of significant effects for fixation length and length of the first fixation indicated that fixations were not affected by stimuli type or category. Overall, these results do not support the hypothesis that eye movement behaviour would be influenced by inversion. Moreover, eye movement behaviour was relatively homogenous across stimuli conditions. This may reflect the high level of homogeneity between the stimuli themselves.

Discrimination Performance, Bias and Error Rates

Descriptive statistics for discrimination performance (*A′*) and response bias (*C*) are provided in Table 31. Results were analysed for *A′* and *C* using two-way mixed ANOVAs with diagnosis as the between-subjects factor and stimulus category (upright vs. inverted) as the within-subjects factor. Significant main effects for *A′* indicated that discrimination performance was significantly better for upright than inverted faces, $F(1, 57) = 95.24$, $p < .001$, $\eta_p^2 = .626$, supporting the hypothesised face inversion effect. There was also a significant main effect for diagnosis, $F(1, 57) = 16.52$, $p < .001$, $\eta_p^2 = .225$, supporting the hypothesised impairment in explicit face recognition in participants with ASD. The Category ×

Diagnosis interaction was not significant, $F < 1$, indicating both participant groups were affected by face inversion. These results do not support the hypothesis that participants with ASD would be less affected by inversion than non-ASD participants.

The analysis of response bias showed a main effect for category, $F(1, 57) = 7.60$, $p = .008$, $\eta_p^2 = .118$, indicating that responses were more liberal for inverted faces. Neither the main effect for diagnosis, $F < 1$, nor the Category × Diagnosis interaction, $F(1, 57) = 3.16$, $p = .08$, $\eta_p^2 = .052$, were significant, indicating that the liberal response bias was consistent across participant groups.

Descriptive statistics for error rates (number of misses for targets and the number of false alarms for foils) for upright, inverted target and foil images for participants with and without an ASD are provided in Table 32. A three-way mixed ANOVA, with diagnostic category as the between-subjects factor, and stimulus category (upright vs. inverted) and stimuli type (target vs. foil) as the within-subjects factors (see Table 33), yielded significant main effects for stimulus category and stimulus type on error rates. However, the Category × Type interaction was significant. Further analysis revealed that error rates were similar for upright targets and foils, $t(58) = .514$, $p = .61$, $d = .09$, but more errors were made for inverted foils than inverted targets, $t(58) = 3.20$, $p = .002$, $d = .75$. Nonetheless, as predicted by the inversion effect, more errors were reported both for inverted compared to upright targets, $t(58) = -4.33$, $p < .001$, $d = .65$, and for inverted compared to upright foils, $t(58) = -8.13$, $p < .001$, $d = 1.34$. Consistent with the analysis of discrimination performance, there was a significant main effect for diagnosis indicating participants with ASD made more errors than non-

ASD participants. No other interactions were significant, suggesting inversion affected recognition performance similarly in participants with and without an ASD.

RT

Three-way mixed ANOVAs, with stimulus type (target vs. foil) and stimulus category (upright vs. inverted) as the within-subjects factors and diagnostic condition as the between-subjects factor, were used to examine RTs for correct identification of targets and foils, and for errors. Again, given the small number of data points for those participants who made errors and on which the error analysis was based, RT results pertaining to error data should be interpreted cautiously. Descriptive statistics are provided in Table 34 and ANOVA results are provided in Table 35. The analysis for correct identifications yielded significant main effects for stimulus type and stimulus category, indicating overall shorter RTs for targets compared to foils, and shorter RTs for upright compared to inverted images. Thus, there is clear evidence of an RT advantage for target (i.e., studied) compared to foil images, and also for upright compared to inverted images. This latter finding is consistent with the FIE.

A significant diagnostic condition main effect indicated that, overall, RTs for correct decisions were shorter for non-ASD participants compared to participants with ASD, which is consistent with previous results. Notably, however, none of the interactions were significant, indicating that the FIE was evident, and had a similar influence, on participants with and without ASD. Participants with an ASD did not, therefore, show a RT advantage over non-ASD participants for inverted face recognition.

Table 29

Descriptive Statistics for the Eye Movement-Based Measures for Participants with ASD (n = 26) and non-ASD Participants (n = 33)

			Category		
			Upright	Inverted	Overall
	Group	Type	*M (SD)*	*M (SD)*	*M (SE)*
# Fixation	ASD	Target	4.62 (1.45)	4.76 (1.49)	4.69 (.24)
		Foil	4.70 (1.42)	4.56 (1.58)	4.63 (.22)
	non-ASD	Target	4.23 (1.13)	4.24 (1.09)	4.24 (.21)
		Foil	3.94 (.93)	3.83 (.97)	3.88 (.20)
	Overall	Target	4.40 (1.29)	4.47 (1.30)	
		Foil	4.28 (1.22)	4.15 (1.31)	
Length (ms)	ASD	Target	352 (84)	337 (60)	344 (11)
		Foil	338 (65)	349 (86)	344 (11)
	non-ASD	Target	329 (61)	335 (52)	332 (10)
		Foil	339 (53)	325 (53)	332 (10)
	Overall	Target	339 (73)	336 (55)	
		Foil	338 (58)	336 (70)	
1st Fixation (ms)	ASD	Target	286 (78)	276 (62)	281 (10)
		Foil	279 (63)	279 (79)	279 (10)
	non-ASD	Target	291 (60)	279 (43)	285 (9)
		Foil	289 (40)	289 (62)	289 (9)
	Overall	Target	289 (68)	278 (52)	
		Foil	285 (51)	285 (70)	

Table 30

Analysis of Variance on Eye Movement-Based Measures

Measure	Source	*df*	*F*	*p*	η_p^2
Fixation #	Type (T)	1	7.04	.01	.11
	Category (C)	1	< 1		
	Diagnosis (D)	1	4.06	.049	.067
	T × D	1	3.65	.061	.06
	C × D	1	< 1		
	T × C	1	1.18	.282	.02
	T × C × D	1	< 1		
Length	Type (T)	1	< 1		
	Category (C)	1	< 1		
	Diagnosis (D)	1	< 1		
	T × D	1	< 1		
	C × D	1	< 1		
	T × C	1	< 1		
	T × C × D	1	2.89	.095	.048
1st Fixation	Type (T)	1	< 1		
	Category (C)	1	2.30	.135	.039
	Diagnosis (D)	1	< 1		
	T × D	1	< 1		
	C × D	1	< 1		
	T × C	1	< 1		
	T × C × D	1	< 1		
	Error	57			

Table 31

Mean A prime (A') and Response Bias (C) for Participants with ASD (n = 26) and non-ASD participants (n = 33)

	A' M (SD)[1]		
	Upright	Inverted	Total
ASD	.76 (.12)[a]	.56 (.12)[b]	.68 (.08)[c]
Non-ASD	.83 (.08)[a]	.65 (.11)[b]	.76 (.08)[c]
	C M (SD)[1]		
ASD	-0.04 (.26)	-0.10 (.44)	-0.07 (.29)
Non-ASD	-0.001 (.35)	-0.26 (.44)	-0.14 (.33)

Note. [1] Means with the same letters as superscripts reflect significant differences, $p < .05$

For error data, the main effect for type was found to be significant, with longer RTs for targets than foils. However, the main effect for category was not significant, indicating that inversion did not have an impact on RT for incorrect decisions. The main effect for diagnosis was found to be significant; consistent with longer RTs for correct responses, participants with an ASD reported longer RTs for incorrect responses. None of the interactions were significant.

Size of the RT advantage for Upright and Inverted Faces

To determine the size of the RT advantage for each diagnostic group, a value was calculated by subtracting the RT for targets from the RT for foils ($RT_{ADVANTAGE} = RT_{foil} – RT_{target}$) for upright and inverted faces (Table 36). The size of the RT advantage for upright faces was then compared with the size of the

Table 32

Mean Error Rate (Number of Misses for Targets and Number of False Alarms for Foils) for Participants with ASD (n = 26) and non-ASD participants (n = 33)

	Upright *M (SD)*	Inverted *M (SD)*	Overall *M (SE)*
		Targets	
ASD	5.31 (2.90)	7.65 (3.19)	5.48 (.36)
non-ASD	4.15 (2.15)	5.61 (2.69)	4.21 (.32)
Overall	4.66 (2.55)	6.51 (3.07)	
		Foils	
ASD	5.65 (2.28)	8.96 (3.41)	8.31 (.26)
non-ASD	4.27 (2.61)	8.94 (3.49)	7.27 (.23)
Overall	4.88 (2.55)	8.95 (3.43)	

RT advantage for inverted faces. Given the large standard deviations the results should be interpreted with caution. Nevertheless, while the difference in the size of the RT advantage for upright and inverted faces was not significant for either participants with ASD ($M_{\text{difference}}$ = -5.75 ms), $t(25) = -0.054$, $p = .957$, $d = .01$, or non-ASD participants ($M_{\text{difference}}$ = -76.69 ms), $t(32) = -1.63$, $p = .114$, $d = .28$, the effect size for the mean difference between upright and inverted faces for non-ASD participants, while small, was considerably greater than the effect size for ASD participants. Although statistically non-significant, the trend toward a difference in the size of the RT advantage for upright and inverted faces in non-

ASD but not in ASD participants provides a suggestion that upright and inverted faces are processed more similarly by individuals with ASD.

Table 33

Analysis of Variance on Error Rates

Measure and source	*df*	*F*	*p*	η_p^2
Type (T)	1	105.69	< .001	.65
Category (C)	1	6.53	.013	.103
Diagnosis (D)	1	13.63	.001	.193
T × D	1	< 1		
C × D	1	< 1		
T × C	1	8.03	.006	.1232
T × C × D	1	2.34	.132	.039
Error	57			

Discussion

Experiment 4 provided mixed results. Consistent with previous experiments reported in this thesis, participants with ASD performed worse than non-ASD participants on the explicit recognition test, for both upright and inverted faces. With the exception of number of fixations, eye movement behaviour was, however, relatively insensitive to the FIE. Overall, eye movement behaviour was fairly homogeneous across stimuli, and also across participant groups.

Table 34

Mean RT (ms) for Correct and Incorrect Responses for Targets and Foils for Participants with ASD (n = 26) and non-ASD participants (n = 33)

		Upright *M (SD)*	Inverted *M (SD)*	Overall *M (SE)*
			Correct	
ASD	Target	1324 (314)	1474 (469)	1399 (62)
	Foil	1559 (492)	1714 (671)	1637 (88)
	Overall *M (SE)*	1442 (61)	1594 (83)	
Non-ASD	Target	1186 (288)	1294 (328)	1240 (55)
	Foil	1327 (297)	1512 (424)	1420 (78)
	Overall *M (SE)*	1257 (54)	1403 (74)	
Totals	Target	1247 (305)	1373 (403)	
	Foil	1429 (408)	1601 (551)	
			Incorrect	
ASD	Target	1747 (723)	1714 (610)	1731 (100)
	Foil	1522 (583)	1373 (319)	1448 (67)
	Overall *M (SE)*	1635 (95)	1544 (73)	
Non-ASD	Target	1424 (425)	1415 (466)	1420 (89)
	Foil	1332 (390)	1311 (344)	1322 (60)
	Overall *M (SE)*	1378 (84)	1363 (65)	
Totals	Target	1567 (592)	1547 (550)	
	Foil	1416 (489)	1339 (332)	

Table 35

Analysis of Variance on RT for Correct and Incorrect Responses

Measure and source	*df*	*F*	*p*	η_p^2
Correct				
Type (T)	1	23.52	< .001	.292
Category (C)	1	24.55	< .001	.301
Diagnosis (D)	1	4.13	.047	.067
T × D	1	< 1		
C × D	1	< 1		
T × C	1	< 1		
T × C × D	1	< 1		
Error	57			
Incorrect				
Type (T)	1	13.05	.001	.186
Category (C)	1	1.10	.298	.019
Diagnosis (D)	1	4.67	.035	.076
T × D	1	3.07	.085	.051
C × D	1	< 1		
T × C	1	1.00	.32	.017
T × C × D	1	< 1		
Error	57			

It is possible that this high level of homogeneity contributed to the lack of significant effects for the eye movement-based measures. Alternatively, it might be argued that the current study was not effective in eliciting an effect. Significant main effects for both RT and discrimination performance, however, suggest this was not the case. First, participants were better at discriminating upright from inverted faces, as predicted by the FIE. Second, in contrast to studies that have failed to demonstrate clear RT effects for the FIE (Scherf et al., 2008), there was clear evidence that RTs were shorter for target images compared to foils, and there was a RT advantage for upright compared to inverted faces. These results are consistent with other studies that have assessed the FIE in typical populations (Boehm et al., 2006; Jacques et al., 2007).

Table 36

Mean (with Standard Deviations in Parenthesis) RT advantage (ms) for Upright and Inverted Faces for Participants with ASD (n = 26) and non-ASD Participants (n = 33)

	Category	
	Upright	Inverted
ASD	235 (437)	241 (564)
Non-ASD	141 (212)	218 (307)

Another possible explanation for the lack of fixation-based effects in the current experiment is that task demands may have affected visual processing and negated the eye movement-based memory effect. Previous research suggests that task demands may have a strong influence on eye movements. For example, Althoff and Cohen (1999) found that a manipulation whereby participants were instructed to (a) view the face as if they were reading it (i.e., left to right, top to bottom), or (b) fixate the features of the head in a particular order (i.e., top of the head, left ear etc.) negated several eye movement measures that were evident during a free viewing study. Ryan et al. (2007) also found that task demands influenced the direction of disproportionate viewing of studied faces such that fixations for studied faces were shorter than novel faces in a free viewing condition, but were longer in a recognition test condition. Ryan et al. suggest that "task demands exert an early and lasting influence on eye movement scanning behaviour" (p. 515). While the Ryan et al. study is not directly comparable to the present study due to methodological differences, these results suggest that the use of inverted faces may have placed sufficient demand on the visual processing system to override the eye movement-based memory effect.

Task demands and/or methodological differences between this and the previous experiments may also have contributed to the unexpected finding of significantly more fixations being directed toward targets than foils. Nonetheless, this finding is also inconsistent with Althoff and Cohen (1999) who argued that novel stimuli elicit more fixations of shorter duration because information is being sampled at a higher rate for stimuli for which there is no memory influence. The results here are not, therefore, encompassed by this explanation. An alternate explanation is that familiarity interacted with the high level of ambiguity and difficulty of the task, leading participants to use more fixations, hence increasing sampling for targets. The potential for an interaction between viewing behaviour, level of familiarity, and task difficulty (or ambiguity) in face recognition provides an avenue for future research.

The other task demand that may have suppressed the eye-movement based memory effect at retrieval was the inclusion of the judgement task (where participants judged the face on how nice, friendly, or sincere it was) at encoding. Bruce and Young (1986) and more recently Calder and Young (2005) have argued that expression and identity processing may be either functionally separable, or at the least show a relative segregation. Thus, the judgement task may have interfered with identity processing at the encoding stage. While the intention of the judgement task was to ensure participants studied the faces without being aware that they would be later used in a recognition task, this manipulation may have affected identity encoding.

It was predicted that preference for local processing (Behrmann, Avidan, et al., 2006; Jolliffe & Baron-Cohen, 1997) would lead to individuals with an ASD doing comparatively better than non-ASD participants at identification of inverted faces. There was, however, limited support for this hypothesis for implicit processing or with the explicit measures of face recognition. Participants with an ASD showed clear evidence of the FIE, both in terms of RT, and for error data. Typically, evidence of an FIE is interpreted to indicate that configural face processing was disrupted. Thus, these results suggest that individuals with ASD may be reliant on configural processing for face recognition. This is consistent with other studies of high functioning adults with an ASD (Lahaie et al., 2006; Scherf et al., 2008; Teunisse & de Gelder, 2003), but not with studies involving children, or individuals who may be low functioning (Hobson et al., 1988; Langdell, 1978).

The size of the RT advantage did, however, provided some tentative support for the hypothesis that individuals with ASD might process inverted and upright faces similarly. The mean difference in the RT advantage between upright and inverted faces was 6 ms for participants with ASD; however the difference was 77 ms for non-ASD participants. This result is somewhat consistent with van der Geest et al. (2002) who reported that, unlike non-ASD children, fixation time to the face was not influenced by face orientation in children with ASD. Nonetheless, this interpretation should be dealt with cautiously given the sizeable variance evident in both groups and the failure of mean differences to reach statistical significance. RT effects using inverted and upright faces may, however, provide an avenue for further research regarding differences in visual information processing in individuals with ASD.

It was argued that individuals with ASD might show a preference or bias for feature based processing of face stimuli. Because stimuli used in the current experiment were cropped to reveal only the inner face, participants may have been forced to rely on configural strategies for identification. Thus, the absence of external features, and the high homogeneity of stimuli, may have meant that reliance on featural strategies would have proved relatively ineffective for identification compared to recognition tasks that include outer features. Nonetheless, whether participants with ASD develop configural processing strategies naturally, or are able to employ configural processing strategies for face processing when required, RT results from the current study indicated that face recognition in ASD most likely involves some degree of configural processing. Results here are consistent with the complex information processing hypothesis. Because there was evidence of a RT advantage for target faces, albeit reduced for inverted faces, it is plausible that in ASD information integration, as is most likely required for conscious recognition, is susceptible to failure when faced with increased cognitive demands. Specifically, this is consistent with the hypothesised dissociation between implicit processing of visual information and explicit face recognition. None of the evidence presented here is supportive of a failure of implicit processing of visual information from faces. On the other hand, there is consistent evidence supportive of an overall impairment in explicit face recognition, as evidenced by poorer overall recognition performance, and slower RTs.

The next chapter provides a slight digression from the theme pursued thus far, taking advantage of the rich eye movement database to addressing the issue of whether individuals with ASD exhibit abnormal looking behaviour toward faces. Specifically, it has been argued that individuals with ASD may be more reliant on the mouth than the eyes for recognition decisions. The facial regions that individuals with ASD attend to during face processing tasks have received considerable attention in the literature (e.g., Langdell, 1978; van der Geest et al., 2002). Analyses on looking behaviour to the eye and mouth region were performed on data from Experiment 2 and Experiment 4 as both studies provided information concerning the proportion of fixations directed to these regions. Because scanning behaviour may be related to the analysis of emotions (Eisenbarth & Alpers, 2011; van der Geest et al., 2002), data from an emotion identification test that was administered during the administration of Experiment 2 were also analysed.

CHAPTER 6

Attention to the Eye and Mouth Region

Chapter 6 addressed the issue of whether individuals with ASD exhibit abnormal attention to the eye and mouth regions during face processing tasks. Specifically, fixation data from the free viewing, emotion recognition, and upright and inverted face recognition test conditions from Experiment 2 and Experiment 4 were analysed. Atypical attention to the eye and mouth region during face processing, and particularly during face recognition, has been widely reported in the ASD literature (e.g., Corden et al., 2008; Dalton et al., 2005; Langdell, 1978; Pelphrey et al., 2002; Rutherford et al., 2007; Spezio et al., 2007; van der Geest et al., 2002). If attention patterns to the eye and mouth region are atypical in individuals with ASD during face processing tasks, then this would suggest the underlying processes involved may also be atypical. Moreover, atypical attention to the face and mouth regions has been used to support the argument that socially salient information from faces is processed atypically in individuals with ASD and, furthermore, theoretically links the social deficit in autism with social attention (Norbury et al., 2009). Abnormal attention to face regions during face processing therefore forms an important element of the social motivation hypothesis.

Langdell (1978) first reported atypical attention to the upper and lower face regions during a recognition task in children (*n* = 20) with ASD. While young children with ASD (M_{age} = 9.8, *SD* = 1 years) were better able to recognise their peers from photos revealing only the bottom half of the face, older children (M_{age} = 14.1, *SD* = 1.1 years) were able to use both the upper and lower halves of faces effectively in the recognition task. It has been proposed that reduced attention to socially salient regions of the face, such as the eyes, may derail socialisation in individuals with ASD (Klin et al., 2002).

Several eye tracking studies have reported reduced fixation time on the eyes and atypical attention to the mouth region in individuals with ASD (Corden et al., 2008; Dalton et al., 2005; Pelphrey et al., 2002; Rutherford et al., 2007; Spezio et al., 2007). For example, in an innovative study, Klin et al. (2002) noted that, when viewing naturalistic social scenes (extracts from the film version of "Who's Afraid of Virginia Woolf?"), the best predictor of ASD was reduced attention to the eye region of the film's characters. Participants with an ASD (n = 15, M_{age} = 15.4, SD = 7.2 years), who all had at least average cognitive ability, showed increased fixation time to the mouth region, which was positively associated with social adaptation and lower rates of social impairment. Participants with an ASD also focused two times less on the eye region compared to controls (n = 15, M_{age} = 17.9, SD = 5.6 years). There was, however, no evidence of a relationship between social functioning and fixations to the eyes.

To investigate this anomaly, Norbury et al. (2009) revisited the study by Klin et al. using short video-taped social stories. In contrast to Klin et al., these authors contrasted viewing patterns of individuals with ASD with and without language impairments (both groups n = 14, M_{age} = 14.9, SD = 1.2-1.4 years respectively), who were matched on other aspects of autism severity and non-verbal ability, and typically developing controls (n = 18, M_{age} = 14.5, SD = .9 years). These authors reported that ASD individuals with no language impairment spent significantly less time fixating the eyes than controls. Although no differences were reported for fixations to the mouth region, fixations to the mouth were positively associated with better socio-communicative development. In contrast, no difference between participants with ASD with language impairments and controls was found for fixations to either the eye or mouth region. Nonetheless, Norbury et al. reported no association between attention to the eye region and social adaptation (fixations to the eyes was actually negatively associated with adaptive communication), challenging the assumption of an association between looking at the eyes and social development in ASD.

A further line of investigation that has received some recent attention in the ASD literature is the possible relationship between face recognition performance and the region viewed. Recently, Kirchner et al. (2011) found a significant negative relationship between the number of fixations to the mouth and performance on the Cambridge Face Memory Test (CFMT) in participants with an ASD but not in neurotypical controls; however, fixations to the eyes did not predict variance in face recognition scores. Although previous studies had reported abnormal fixation of the lower region of the face and/or avoidance of the eyes in individuals with an ASD (Corden et al., 2008; Klin et al., 2002; Rutherford et al., 2007; Spezio et al., 2007), the study by Kirchner et al. was the first to report a relationship between performance on a standardised face recognition test and gaze patterns. Similarly, the current analyses compared performance on the CFMT and gaze patterns to the eyes and mouth.

Abnormal fixations to the eye and mouth region in individuals with ASD may be related to the emotional content of the face (van der Geest et al., 2002). Van Der Geest et al. examined fixation patterns for faces displaying angry, happy, neutral, and surprised emotions in 17 children with an ASD (M_{age} = 10.6, *SD* = 2.1) and 17 controls (M_{age} = 10.1, *SD* = 1.3) matched on age and IQ. No differences between groups were found for the number of fixations directed to the eye or mouth region, for any of the face groups. No other differences in fixation patterns were found.

Similarly, Kirchner et al. (2011) examined fixation patterns while participants with ASD (*n* = 20, M_{age} = 31.9, *SD* = 7.6) and IQ matched controls (*n* = 21, M_{age} = 31.8, *SD* = 7.4) completed the Multifaceted Empathy Test (MET). Specifically, these authors sought to determine whether the degree of socio-emotional salience of a stimulus would have an effect on fixation patterns. They hypothesised that the emotion recognition task would trigger more typical fixation patterns (e.g., more attention to the eyes). If, however, individuals with an ASD were more reliant on the mouth for emotion recognition, then this may trigger an increase in the proportion of fixations to the mouth region in ASD participants. These authors reported no differences between groups on length of fixation time on the eyes or mouth; however, participants with ASD who spent shorter fixation time on the eyes and more time on the mouth performed more poorly on the emotion recognition test. A regression analysis showed that gaze to the mouth region was a significant predictor of performance on the test.

To examine fixation patterns to the eye and mouth region during the processing of emotional information, an emotion identification task was administered during the administration of Experiment 2. Furthermore, the inclusion of the emotion identification task allowed for comparison of attention to the eye and mouth region under differing test conditions (i.e., free viewing, emotion recognition, explicit recognition).

Finally, analysis of data from Experiment 4 allowed for the examination of differences in fixation patterns to the eyes and mouth for upright and inverted face processing. Previously, McPartland et al. (2011) examined the relationship between fixations to the eyes and mouth in upright and inverted faces in participants with an ASD (*n* = 15) and typical peers (*n* = 17). While both groups of participants devoted more attention to the upper face region for both upright and inverted faces, the difference between the proportion of fixations to the eyes and the mouth was reduced for inverted compared to upright faces. This indicated increased viewing of the mouth for inverted compared to upright faces. Nevertheless, no between groups differences in viewing patterns were found to be significant. Van der Geest et al. (2002) also examined viewing patterns of upright and inverted faces. These authors, however, found that the eye region of inverted faces was fixated longer and more often than the eye region of upright faces and the opposite effect was reported for fixations to the mouth. Furthermore, children with autism fixated the eye and mouth region less than control children. Given mixed results across studies, there is a need for further investigation of the relationship between regions viewed and face processing in ASD.

Thus, the present chapter examined the proportion of fixations to the eyes and mouth regions using data from Experiment 2 and Experiment 4. Data were examined using both upright and inverted faces during free viewing and a recognition test. Gaze patterns were also examined during a simple emotion identification test. Proportions of fixations to face regions were also compared between test conditions. Finally, relationships between the proportion of fixations to the eye and mouth regions and face recognition performance were also examined. Given the mixed findings of previous research, no specific hypotheses were made.

Method

Participants

Participants were those reported in Experiment 2 and Experiment 4.

Materials

Apparatus and materials were reported in Experiment 2 and Experiment 4. Stimuli for the emotion test in Experiment 2 were the same as those reported earlier, except that new images were used. For data analysis Areas of Interest (AOIs) which identified the eye and mouth region were hand drawn on the stimulus using the tools supplied in Tobii Studio™ (Figure 6 provides an example from Experiment 2). AOIs were copied across images so that equivalence was maintained with respect to total area covered by the AOI. The proportion of fixations falling within the eye and mouth AOIs relative to the total number of fixation to the head AOI were calculated and subject to further analysis.

Procedure

The general procedures were reported in Experiment 2 and Experiment 4. The procedure for the emotion test was the same as for the free viewing condition from Experiment 2, with the following exception: after the face was displayed for 5 s the participant was required to make a decision as to whether they thought the face was happy or not. Stimuli were either happy or neutral (Figure 7), and had either been viewed during the study phase or were novel faces. After the face was displayed a new screen was presented with a heading “Do you think the face you just saw was happy?" Participants used the mouse to respond "YES" or "NO". Once the participant responded, the next trial was initiated. Participants were randomly assigned to one of two conditions (Set A, Set B) to ensure counterbalancing of stimuli between participants. Thus, either Set A or Set B was presented during the study session, and the alternate set provided the novel stimuli for the test condition.

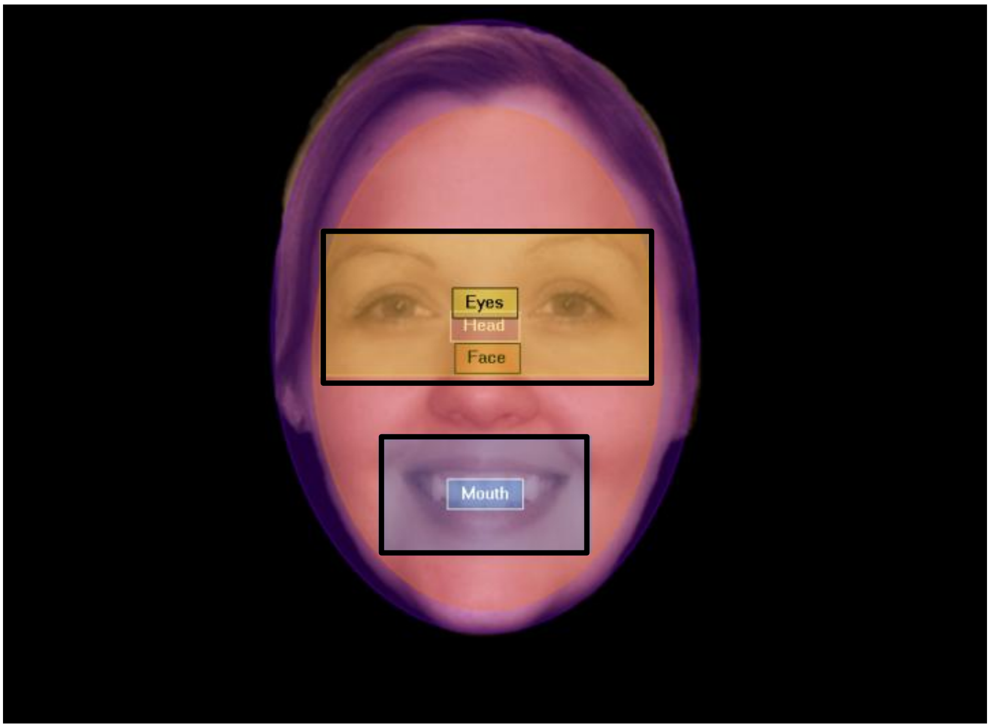


Figure 6. Sample image from Experiment 2 with AOIs drawn around the eyes and mouth. The proportion of fixations falling within the eye and mouth AOIs relative to the total proportion of fixations to the face was calculated. Similar AOIs were drawn on the stimuli from Experiment 4.

Figure 7. Example of neutral (left) and happy (right) stimuli from the emotion recognition condition of Experiment 2.

Results

Percentage of Correct Responses for the Emotion Test

For the percentage of correct responses for the emotion recognition test, there was no significant difference between participants with ASD (*M* = 90.63, *SD* = 8.24) and non-ASD participants (*M* = 91.43, *SD* = 7.18), *t*(57) = -0.40, *p* = .69, *d* = .10. This might be expected given the task was a simple emotion identification task and individuals with ASD are more likely to have difficulty with complex emotion identification (Sawyer et al., 2011).

Proportion of Fixations to the Eye and Mouth Regions

Results for Experiment 2 and Experiment 4 are reported separately.

Experiment 2. For Experiment 2, the effect of diagnosis and viewing condition on proportion of fixations to the eye and mouth regions was examined for the free viewing emotion and recognition test conditions using three-way mixed ANOVAs, with diagnosis as the between-subjects factor, and type (viewed vs. novel) and region (eye vs. mouth) as the within-subjects factors. Descriptive statistics are provided in Table 37 and ANOVA results are provided in Table 38. All three test conditions yielded significant main effects for region which indicated that overall, proportionally more fixations were directed toward the eye region than the mouth region. None of the main effects for type or diagnosis were significant.

There was a significant interaction between region and type in the free viewing condition. While fixations to the eye region did not differ significantly between studied and novel faces, $t(59) = -1.78$, $p = .08$, $d = .10$, a significantly higher proportion of fixations was directed to the mouth of novel compared to studied faces, $t(59) = 2.32$, $p = .024$, $d = .13$. This difference, however, accounted for less than 1% of the total fixations directed to the face.

The Region × Type × Diagnosis interaction in the emotion recognition category was, however, found to be significant. While there were no significant differences between groups for the proportion of fixations to the eye regions or proportion of fixations to the mouth region of novel faces, the difference between proportion of fixations to the mouth region of viewed faces approached significance, $t(58) = 1.85$, $p = .07$, $d = .49$. Thus, for viewed faces, there was a trend of medium effect size for participants with an ASD to direct proportionally more fixations to the mouth compared to non-ASD participants.

Table 37

Experiment 2 Percent Fixations to the Eye and Mouth Regions for the Free Viewing, Emotion Recognition and Recognition Test

			Type		
			Viewed (%)	Novel (%)	Overall
Test Condition	Region	Group	*M (SD)*	*M (SD)*	*M (SE)*
Free Viewing	Eye	ASD	63.66 (16.34)	61.91 (14.87)	62.79 (2.89)
		non-ASD	64.43 (14.71)	63.19 (12.72)	63.81 (2.36)
		Overall	64.12 (15.25)	62.68 (13.51)	
	Mouth	ASD	13.10 (8.54)	14.80 (8.96)	13.95 (1.50)
		non-ASD	13.31 (7.27)	13.82 (5.94)	13.56 (1.23)
		Overall	13.22 (7.34)	14.21 (7.24)	
Emotion Test	Eye	ASD	56.87 (12.37)	58.12 (13.52)	57.50 (2.52)
		non-ASD	61.73 (12.80)	60.73 (11.83)	61.23 (2.05)
		Overall	59.79 (12.75)	59.68 (12.49)	
	Mouth	ASD	25.98 (7.61)	23.48 (7.53)	24.73 (1.55)
		non-ASD	21.90 (8.87)	23.38 (8.01)	22.64 (1.27)
		Overall	23.53 (8.56)	23.42 (7.76)	
Recognition Test	Eye	ASD	62.36 (18.79)	62.08 (16.91)	62.22 (3.64)
		non-ASD	60.64 (18.85)	59.87 (17.43)	60.26 (2.97)
		Overall	61.33 (18.69)	60.75 (17.11)	
	Mouth	ASD	18.41 (11.63)	18.33 (11.81)	18.37 (2.23)
		non-ASD	18.88 (11.43)	18.84 (9.94)	18.86 (1.82)
		Overall	18.69 (11.42)	18.64 (10.63)	

Table 38

Experiment 2 Analysis of Variance on Percent Fixations to Eye and Mouth Regions for the Free Viewing, Emotion Recognition and Recognition Test

Test Condition	Source	*df*	*F*	*p*	η_p^2
Free Viewing	Region (R)	1	333.12	< .001	.852
	Type (T)	1	< 1		
	Diagnosis (D)	1	< 1		
	R × D	1	< 1		
	T × D	1	< 1		
	R × T	1	5.12	.027	.081
	R × T × D	1	< 1		
Emotion Test	Region (R)	1	203.58	< .001	.778
	Type (T)	1	< 1		
	Diagnosis (D)	1	< 1		
	R × D	1	1.36	.249	.023
	T × D	1	1.14	.289	.019
	R × T	1	< 1		
	R × T × D	1	7.26	.009	.111
Recognition Test	Region (R)	1	138.55	< .001	.705
	Type (T)	1	< 1		
	Diagnosis (D)	1	< 1		
	R × D	1	< 1		
	T × D	1	< 1		
	R × T	1	< 1		
	R × T × D	1	< 1		
	Error	58			

Finally, to explore differences in fixations between the free viewing, emotion, and recognition tests, a four-way mixed ANOVA was performed with type (viewed, novel), region (eyes, mouth), test condition (free viewing, emotion identification, recognition test) as the within-subjects factors, and diagnosis as the between-group factor. The ANOVA results are provided in Table 39. The main effect for region was significant, indicating that more fixations were directed to the eyes than the mouth. Of further interest, there was a significant main effect for test condition, which was moderated by a Region × Test interaction. Overall, while there were no significant differences between test conditions for fixations to the eye region ($p_s > .08$), more fixations were directed toward the mouth in the recognition test condition than the free viewing condition, and in the emotion identification condition than the recognition test ($p_s < .001$). This suggests that participants used information from the mouth for recognition decisions, but were most reliant on the mouth for the emotion identification condition. Given that the faces were either smiling or had neutral expressions, it is not surprising that the mouth was fixated more in the emotion recognition task than the other conditions as the expression of the mouth provided considerable information regarding emotion. The Region × Condition interaction and the Region × Type × Diagnosis interactions reported above were also evident in the significant four-way Type × Region × Condition × Diagnosis interaction; however, no new information was revealed by further analysis of this interaction (i.e., differences were accounted for by differences in fixations to the mouth between test conditions).

Table 39

Experiment 2 Analysis of Variance on Percent Fixations to Eye and Mouth Regions for all Test Conditions (Free Viewing, Emotion, Recognition)

Source	*df*	*F*	*p*	η_p^2
Type (T)	1,58	1.25	.269	.021
Region (R)	1,58	263.53	< .001	.820
Test Condition (C)	2,116	14.36	< .001	.198
Diagnosis (D)	1,58	< 1		
T × D	1,58	< 1		
R × D	1,58	< 1		
C × D	2,116	1.01	.369	.017
T × R	1,58	1.11	.296	.019
T × C	2,116	< 1		
R × C	2,116	15.86	< .001	.215
T × C × D	2,116	< 1		
T × R × D	1,58	1.21	.276	.02
T × C × D	2,116	< 1		
R × C × D	2,116	1.42	.247	.024
T × R × C	2,116	2.39	.096	.04
T × R × C × D	2,116	3.69	.028	.06

Experiment 4. For Experiment 4, the proportion of fixations to the eye and mouth regions was examined using a four-way mixed ANOVA, with type (target vs. foil), category (upright vs. inverted) and region (eye vs. mouth) as the

within-subjects factors and diagnosis as the between-subjects factor. Descriptive statistics are provided in Table 40 and ANOVA results are provided in Table 41. The ANOVA yielded a significant main effect for region, indicating that a greater proportion of fixations were directed toward the eye region than the mouth region. All other main effects and interactions, however, were not significant. The lack of significant effects indicated that participants from both groups directed more fixations to the eyes compared to the mouth, and this was evident for both upright and inverted faces. Participants with an ASD did not direct proportionately more fixations to the mouth region, or fewer fixations to the eye region, compared to non-ASD participants.

Relationship between Fixations to the Eyes and Mouth and Discrimination Performance

Correlations between the proportion of fixations to the eye and mouth regions and discrimination performance (*A′*) were examined for all participants (combined), and for participants with an ASD and non-ASD participants separately for Experiment 2 (Table 42) and Experiment 4, where fixations toward upright and inverted faces were examined (Table 43).

For Experiment 2, combined group discrimination performance correlated positively with increased proportion of fixations to the eye region for studied and novel faces, and negatively with proportion of fixations to the mouth region for novel faces. For non-ASD participants the proportion of fixations to the eye and mouth region correlated with discrimination performance, but only for novel faces. The relationship between discrimination performance and proportion of fixations to the eyes and mouth was not significant for participants with an ASD.

Table 40

Experiment 4 Percent Fixations to the Eye and Mouth Regions for Upright and Inverted Faces for Participants with ASD (n = 26) and non-ASD participants (n = 33)

Category/ Region	Group	Type Target (%) *M (SD)*	 Foil (%) *M (SD)*	 Overall *M (SE)*
Upright				
Eye	ASD	60.07 (21.43)	53.72 (18.80)	56.89 (3.13)
	non-ASD	60.51 (21.40)	59.65 (19.25)	60.08 (2.78)
	Overall	60.31 (21.23)	57.03 (19.12)	
Mouth	ASD	13.30 (11.44)	18.56 (13.68)	15.93 (1.92)
	non-ASD	11.84 (11.91)	16.77 (15.01)	14.31 (1.71)
	Overall	12.48 (11.63)	17.56 (14.34)	
Inverted				
Eye	ASD	54.91 (18.88)	58.46 (22.08)	56.69 (3.08)
	non-ASD	59.86 (16.94)	61.11 (22.27)	60.49 (2.74)
	Overall	57.68 (17.83)	59.95 (22.03)	
Mouth	ASD	18.36 (11.43)	13.11 (10.66)	15.74 (1.91)
	non-ASD	17.59 (14.53)	11.85 (13.08)	14.72 (1.70)
	Overall	17.93 (13.15)	12.41 (11.99)	

Table 41

Experiment 4 Analysis of Variance on Percent Fixations to the Eye and Mouth Regions

Source	*df*	*F*	*p*	η_p^2
Type (T)	1	2.33	.133	.039
Category (C)	1	< 1		
Region (R)	1	222.91	< .001	.796
Diagnosis (D)	1	< 1		
T × D	1	1.28	.262	.022
C × D	1	1.02	.316	.018
R × D	1	< 1		
T × C	1	1.37	.246	.024
T × R	1	< 1		
C × R	1	< 1		
T × C × D	1	1.04	.313	.018
T × R × D	1	2.198	.144	.037
C × R × D	1	< 1		
T × C × R	1	2.57	.115	.043
T × C × R × D	1	< 1		
Error	57			

For Experiment 4, no correlations between discrimination performance and the proportion of fixations to the eye and mouth region were significant. Data from Experiment 4, therefore, provided no evidence that participants who were better at face recognition spent more time fixating the eyes in comparison to the mouth region compared to participants who were worse at face recognition, irrespective of the orientation of the face.

Table 42

Experiment 2 Correlations for Percent Fixations to the Eye and Mouth Regions with Discrimination Performance (A')

		A Prime		
Region	Type	ASD	Non-ASD	Combined
Eyes	Studied	.34	.23	.26**
	Novel	.30	.31*	.27**
Mouth	Studied	-0.27	-0.15	-0.20
	Novel	-0.21	-0.30*	-0.24*
	n	24	36	60

**p* = .07, ***p* = .04

Discussion

In contrast to previous studies (Corden et al., 2008; Pelphrey et al., 2002; Rutherford et al., 2007; Spezio et al., 2007), but consistent with Kirchner et al. (2011), the current analysis of the proportion of fixations to the eye and mouth region in Experiments 2 and 4 provided no evidence that proportion of fixations to these regions differed between participants with an ASD and non-ASD participants. Furthermore, given that all participants had no diagnosed language impairment, the findings contrast with Norbury et al. (2009) who found differences in fixation patterns to the eyes in participants with no, but not in participants with, language impairment compared to controls. Obviously differences in study design, particularly that Norbury et al. examined fixations to social videos of peer interactions whereas the current analyses were restricted to the viewing of still images, make direct comparisons between the studies difficult. Nonetheless, the present results are also not supportive of differences in viewing patterns from studies that used still images (Langdell, 1978).

Table 43

Experiment 4 Correlations for Percent Fixations to the Eye and Mouth Regions, for Upright and Inverted Faces, with Discrimination Performance (A')

		A Prime		
Region	Category	ASD	Non-ASD	Combined
Eyes	Upright	.11	-0.19	.01
	Inverted	.10	-0.24	-0.06
Mouth	Upright	.02	-0.05	-0.001
	Inverted	-0.05	-0.07	-0.08
	n	26	33	59

Analysis of data from Experiment 2 provided some preliminary support that gaze patterns may be related to face recognition performance. When participant groups were combined, the overall proportion of fixations directed to the eye region was found to be positively related to recognition performance and there was a negative relationship between the proportion of fixations to the mouth region for novel faces; however, the relationship only trended toward significance in non-ASD participants when groups were examined separately. Nonetheless, the data from Experiment 4 were not consistent with this and provided no evidence of a significant relationship between face recognition performance and proportion of fixations to the eye or mouth regions, either in participants with or without an ASD. Furthermore, and in contrast to McPartland et al. (2011), Experiment 4 provided no evidence that proportionally more fixations would be directed toward the mouth of inverted faces compared with upright faces.

The cumulative evidence from the analysis of fixation data to the eye and mouth regions from Experiment 2 and Experiment 4 is that, at least for face recognition tasks using still images, attention patterns to the eye and mouth region differ little between participants with and without an ASD. More specifically, there was no strong evidence that individuals with an ASD were not equally reliant on information from the eye region during face recognition tasks, or show any preference for the mouth over the eye region.

CHAPTER 7

General Discussion

This thesis reported four experiments designed to investigate cognitive processes underpinning the face recognition impairment which characterise individuals with a diagnosis of an ASD. Specifically, the influence of memory on implicit visual processing in association with explicit face recognition was examined in participants with ASD and an IQ matched control group of non-ASD persons. This investigation employed eye scanning methodology which, in addition to standard measures of face recognition such as discrimination performance and RT, provided an opportunity to examine the influence of memory on early visual processing of faces. Importantly, eye movement data allowed for a comparison of the influence of early, implicit memory on the processing of information of previously viewed and novel faces. For example, eye movement recordings allowed for an examination of the length of the first fixation, which represents a timeframe prior to conscious awareness of the identity of the face (e.g., the length of the first fixation was typically in the range of 200 ms to 250 ms). In the case of the recognition memory test this timeframe allowed for the examination of information prior to a recognition decision. Other eye movement based measures provided further information regarding unconscious processing of faces, and allowed for comparisons in fixation patterns between participants with and without an ASD.

The main issue addressed was (a) whether there was evidence of an explicit face recognition deficit in ASD, and (b) given evidence of an explicit face recognition deficit, was implicit visual processing of faces also affected. This issue underlies an important consideration of the origin of the face processing impairment in ASD. While it has been argued that the deficit may be a result of a failure for a specialised face processing system to develop in individuals with ASD which affects early face processing, I argued that evidence of dissociation between implicit visual processing and explicit recognition would implicate late-, but not early- stage processes. Further, this might indicate a deficit in complex information processing, rather than in basic visual processes. Specifically, it was argued complex information processing is likely to be involved in explicit recognition and conscious awareness, but not in implicit visual information processing, or in the influence of implicit memory on these processes.

The second issue that was addressed was whether individuals with ASD show evidence of an advantage for inverted face recognition when assessed at both implicit and explicit levels. It was argued this would provide further information regarding implicit face processing in ASD. Specifically, studies have reported that inverted faces are processed similarly to upright faces by persons with ASD, possibly because these individuals are less reliant on configural processing strategies than non-ASD persons.

The third issue that was examined here was whether individuals with ASD show atypical viewing strategies such as a reliance on the mouth and/or avoidance of the eyes during face processing, and whether there was a relationship between viewing strategy and recognition performance.

First, Experiments 1, 3 and 4 provided clear evidence of an explicit face recognition deficit in individuals with ASD when compared to matched controls. Although not as clear cut, an analysis of effect sizes on the discrimination task in

Experiment 2 also suggested an explicit deficit in face recognition in ASD participants. Of interest, an analysis of age-standardised scores on the CFMT in Experiment 1 revealed a large variance in performance in participants with ASD ranging from severe face recognition deficits to typical performance. This result was consistent with recent research by Wilson, Palermo, Burton, and Brock (2011) who also found large performance variations in children with ASD (M_{age} = 10.07, *SD* = 2.05) ranging from normal to severely impaired based on age-standardised scores on a face identity recognition task. The theoretical issues related to the heterogeneity in individual performance are discussed in detail shortly.

Second, Experiments 2 and 3 provided evidence that, relative to explicit recognition, the influence of memory on implicit visual processing of faces may not be affected in individuals with ASD. Participants with and without ASD showed different eye movement responses to novel compared to studied faces, indicative of the influence of implicit memory on behaviour and visual processing.

To investigate implicit visual processing of faces more closely, implicit processing and explicit face recognition performance for upright and inverted faces were examined in Experiment 4. This study failed to identify the expected ASD advantage for inverted versus upright face identification. Nonetheless, the small difference in the RT advantage between upright and inverted faces (6 ms) for participants with ASD offered some indication that upright and inverted faces may be processed more similarly in this group. In comparison, there was a larger difference in the size of the face inversion based RT advantage for non-ASD participants (77 ms); although this interpretation should be dealt with cautiously given the limitations mentioned earlier (i.e., variance and failure to reach statistical significance). Overall, however, RT and discrimination performance results supported other recent findings (e.g., Damiano et al., 2011; Lahaie et al., 2006) suggesting at least some adults with ASD do use configural processing for faces.

Analysis of Eye Movement Data

Given the reliance on eye movement data for the claim that implicit processing for faces may be intact in some individuals with ASD, it is important to address potential criticisms related to the application and analysis of the eye movement-based measures used here. First, the analysis of eye movement data over the full 5 s viewing period in the free viewing phases could be criticised as it reflects visual processing that is most likely occurring after conscious awareness of familiarity or identification of studied faces. The analysis of eye movement data in the recognition test, which occurred prior to the decision, was one way that this issue was addressed. However, because the inclusion of the recognition test increased task demands, the advantage of examining data under non-demanding conditions was lost. The analysis of fixation data from the 1000 ms time bins in Experiment 2 also went some way toward addressing this issue; data were consistent with the results for the 5 s viewing period and, furthermore, the analysis of time bin data allowed for an examination of the time course of the influence of memory on viewing behaviour. The most potent response to this criticism, however, may be found in the analysis of first fixation data. Overall, the length of the first fixation was found to provide a consistent indication of the influence of prior viewing on eye movement behaviour. This result was consistent with previous studies (Hsiao & Cottrell, 2007, 2008; Kafkas & Montaldi, 2011; Ryan et al., 2007), thus providing support for the relationship between the first fixation and memory. Importantly, given the short time-frame of the first fixation, it represents very early processing of face information, and thus should be unaffected by changes in processing that may occur once a face is consciously identified as studied or novel, or by feelings of familiarity.

Nevertheless, given that face recognition most likely occurs around 200 msec after stimulus presentation (Jacques et al., 2007; Jacques & Rossion, 2006; Tanaka, 2001), fixation based measures occurring after this time period may not reflect the very early stages of face recognition. Although the analysis of first fixation data was aimed at assessing early face recognition, it is possible that face processing and recognition may occur prior to this first fixation. This criticism highlights a methodological limitation of eye-tracking in measuring very early stages of cognitive processing. Eye-tracking, therefore, should be viewed as a complementary (e.g., to ERP studies), rather than definitive, method for exploring very early cognitive processes. The argument that eye movement-based measures reflect the influence of memory on face processing is, however, less affected by this criticism. Specifically, eye-movements can be useful in revealing aspects of memory not typically assessed by different methods. Hannula et al. (2010) suggest a comprehensive account of brain-behaviour relationships can be achieved by the combined use of eye-tracking, neurophysiological and neuroimaging methods. Further, this approach is consistent with the “converging evidence” approach to cognitive neuroscience (p.1). Although the use of ERP or similar measures was beyond the scope of the current thesis, a combined approach would be appropriate for future research.

A second potential criticism is that fixation based data from the recognition test was relative to RT: more fixations were recorded for participants who took longer to make an explicit decision. The decision to include an analysis of the total number of fixations was driven primarily by the between-groups comparisons. Importantly, the number of fixations provided an indication of the data extracted from the image and assumed to be used in the decisional process by participants with an ASD compared to non-ASD participants. Nonetheless, several measures were taken to address the issue of the co-dependency between RT and the number of fixations measure for the recognition test condition. Consistent with the position forwarded above, the length of the first fixation provided a sensitive measure of the strength of recognition memory that was independent from the overall number of fixations used in the decisional process. The average length of the fixations provided a further eye movement-based measure that was independent from the total number of fixations.

Finally, to attest to the overall value of the eye movement-based measures, possibly the most pertinent points are that (a) the overall pattern of results for the eye movement-based measures was evident between different measures using different analyses (e.g., cluster analysis), across different experimental paradigms, using different stimuli and involving different participant groups, and (b) results derived from the eye movement-based measures were consistent with the pattern of RT data.

In sum, no single eye movement-based measure or analysis was expected to provide definitive evidence of the influence of memory on implicit face processing in ASD. Together, however, the combined use of different eye movement-based measures, RT, and measures of explicit recognition performance was intended to provide a broad picture of implicit processing and explicit face recognition performance in ASD. The general consistency of results across the different studies provides support for the methodology and interpretation of results. It is now appropriate to turn to the theoretical implications of these findings.

Theoretical Perspective

It was argued here that face recognition performance in ASD may be affected by a deficit in complex information processing. Complex stimuli (e.g., faces) may be more likely to tax information processing systems and integration capacity compared to simple or less complex objects (Minshew et al., 2008), with the deficit most apparent under explicit recognition conditions. In comparison, implicit, automatic processes might be spared. Experiments 2, 3, and 4 provided evidence of dissociation between implicit visual processing and explicit face recognition in participants with ASD. Moreover, the lack of differences in measures of implicit based face processing between individuals with and without ASD contrasted sharply with the differences found between groups when explicit face recognition was assessed.

Two theoretical perspectives were developed to explain this apparent dissociation. First, these results are consistent with a complex information processing deficit in ASD (Minshew & Goldstein, 1998; Minshew, Goldstein, & Siegel, 1997; Minshew, Sweeney, & Luna, 2002; Minshew et al., 2008). It was argued the complex nature of the stimuli, and the reliance on resource intensive processes (Aloisi et al., 2004), would present a taxing information processing task for individuals with ASD. This would reveal an ASD specific limitation in information processing (Minshew et al., 2008). More specifically, it was argued that the complexity of the task might cause processing systems involved in conscious awareness of identity and, by extension, explicit decision making, to fail (Marco et al., 2011). Thus, the dissociation was defined in terms of a deficit in effortful, resource intensive processing coupled with spared automatic and, therefore, less demanding information processing (Aloisi et al., 2004). Overall, eye movement analyses revealed that participants with ASD exhibited more fixations to the faces than non-ASD participants, and there was no difference between-groups in the pattern of fixations to different regions (i.e., both groups exhibited more fixations to the eyes than the mouth, and proportions of fixations to these regions were similar between-groups). The difference in explicit recognition between groups cannot, therefore, be accounted for by reduced attention to the stimulus (Dalton et al., 2005).

Minshew et al. (2008) provide a neurological explanation for the failure in complex information processing in ASD. These authors proposed that underdeveloped neocortical systems disproportionately impact connectivity between unimodal cortices (i.e., with connections to one sensory modality) and heteromodal cortex (i.e., which receive and integrate information from unimodal areas), which impacts connectivity with the frontal cortex. Under-connectivity between memory and executive systems (e.g., Minshew et al., 2008) which are responsible for the integration of information might therefore explain the apparent dissociation between implicit processing and explicit face recognition. For recognition memory, damage to pathways between primary sensori-motor, and unimodal areas and heteromodal and other convergence zones would invariably affect recall (Damasio, 1989). More specifically, Damasio (1989) proposed that integration of information between early sensory cortices and downstream higher-order association cortices is a central requirement for conscious recall. Minshew et al. (2008) further argued that basic cognitive processes, such as visual processes, may be spared due to increased local connectivity.

The current results are thus consistent with the neurological models proposed by Minshew et al. (2008) and Damasio (1989). Specifically, implicit memory and its influence on implicit visual processing was found to be relatively unaffected in ASD such that early motor responses (i.e., eye movements) were influenced by the activation of visual memory processes that respond to the presentation of a previously viewed stimulus. Moreover, the current studies demonstrated that recognition memory appears to breakdown at the level of conscious awareness where, for complex stimuli such as faces, recognition is reliant on the integration of multiple features and the involvement of higher-order processing and integration systems. This contrasts with the recognition of simple stimuli that can be achieved with recognition of a few features. In contrast to faces, simple objects are less likely to tax information processing and integration capacity (Minshew et al., 2008).

The complex information processing hypothesis is not without challenge. Recently, Bradshaw, Shic, and Chawarska (2011) used eye tracking to investigate preferential looking (which indicates recognition) at novel or studied faces and simple (e.g., teapot) and complex objects (rectangular frame filled with different geometric shapes that formed a unique pattern) in 21 young children with ASD (M_{age} = 39, *SD* = 10 months) and a control group of 21 typically developing children (M_{age} = 36, *SD* = 7 months). Children with ASD showed preferential viewing of novel simple and complex objects (the novelty preference), but not faces, whereas typically developing children showed preferential viewing of simple objects and faces, but not complex objects. The young children with ASD appeared to be superior at recognising complex geometric figures but impaired at face recognition. At first, these results appear to contradict the argument for a complex information processing deficit in ASD. However, superior recognition of complex geometric shapes might also be accounted for by the featural processing bias in ASD, and a keen awareness of detail. Rather than processing the complex geometric figure holistically, as was inferred by the authors, the young children with ASD may have been highly tuned to change in any of the single components of the object. This is consistent with the autistic profile, where individuals are highly sensitive to small changes in their environment. The Bradshaw et al. study does not, therefore, clearly demonstrate an advantage in complex information processing of geometric shapes as there is no evidence that the geometric shapes were processed as a whole, and the attention to change of an individual part of the overall shape would not constitute complex information processing. Moreover, others have consistently provided evidence of a complex information processing deficit in ASD (e.g., Minshew & Goldstein, 1998). The Bradshaw et al. study is of interest though, as it supports the general findings of a lack of attention to faces, compared to non-social stimuli, in young children with

ASD.

Returning to the current studies, one limitation is that, while differences in eye movement behaviour were used here to imply that implicit visual processing of face information may be unaffected in ASD, or at the least less affected when compared to the clear deficit in explicit face recognition, the measures did not provide a quantitative measure of implicit face recognition performance. It is possible that quantitative differences in implicit face recognition performance do exist between groups, but were not detected using the current methodology. Given this possibility, it may be premature to dismiss the social motivation hypothesis. As Farah et al. (1993) suggest, explicit tasks are more cognitively demanding than implicit tasks. Thus, damage to the face processing system may be more likely to be detected using explicit measures of performance. Nonetheless, failure to provide evidence of the influence of memory on implicit visual processing of faces would have been more consistent with the position that damage to a general face processing system is the primary origin of the recognition deficit in ASD.

Second, it is also possible that early processes may not be affected by experience with faces whereas later processes are. If this were the case, the apparent dissociation between implicit and explicit face recognition could still be consistent with the social motivation hypothesis.

Third, both the complex information processing and the social motivation hypotheses may offer partial explanations of the results presented here. The explicit face recognition deficit in ASD may arise from damage to, or underdevelopment of the face processing system because of a failure to orientate to faces during early development, and this underdevelopment is compounded by a deficit in complex information processing. As highlighted by Farah et al. (1993, see above), subtle deficits in face recognition and face processing may be more likely to be detected when assessed explicitly. Low quality output from early stage face processing system may have a cascade effect when it is fed into late stage processes such as those involved in conscious awareness of identity. Early, implicit visual processing and associated memory processes may therefore be less likely to be affected by the quality of the output from the face processing system which is fed to high-order systems.

Another consideration is that the more automatic and effortless these processes become (e.g., through practice) the more likely individuals are to show improvements in performance. As Damiano et al. (2011) demonstrated, after 2-weeks of targeted intervention, individuals with ASD were able to significantly enhance their ability to identify individual complex objects (i.e., Greebles) and to develop expertise with the stimuli (assessed by performance on an inversion task). Similarly, individuals with ASD who are motivated to study faces, to learn to recognise and remember the names of individuals or to better interpret facial expressions and emotions, may develop expertise with faces and thus, reduce the degree of effortful (i.e., complex) processing involved in face processing. One implication of this is that social skills may be underdeveloped in many individuals due to their dependence on these experiences.

Recent work has shown that practice with faces is associated with changes in cortical responses to faces. A study by DeGutis, Bentin, Robertson, and D’Esposito (2007) with an individual with developmental prosopagnosia who was trained in face tasks showed that behavioural improvements in face processing were associated with neurological changes. Specifically, the N170 response to faces became more typical, and fMRI measures revealed significant changes in neural connectivity between face regions. It is thus plausible that similar changes at a neurological level may occur in individuals with ASD. Given the most significant and large studies reporting face recognition deficits have involved children and young adolescents (Klin et al., 1999; Wolf et al., 2008), it is possible that these studies have failed to capture improvements in performance that may be evident in older individuals.

Compared to non-ASD persons, therefore, face processing skills may develop much later in individuals with ASD, possibly as faces are gradually perceived as being valuable or necessary for successful social interaction. This may be during the course of intervention programs where attention to faces and emotion identification is taught and reinforced, or it may be an outcome of adolescents becoming more interested in socialising and ‘fitting in’ (Hedley & Young, 2006). The different time-course for the development of face processing skills in individuals with ASD compared to non-ASD persons highlights the need for research involving individuals from a range of age-groups. Given that other skills (e.g., language) may appear much later in ASD, it may be that the development of face processing skills may be similarly delayed.

To briefly summarise, early disruption of neurological systems involved in face processing may lead to a reduction in the quality of the information processed by higher-order systems. Poor quality information fed from poorly developed neurological areas, coupled with difficulties in complex information processing, may result in the high degree of face processing difficulties reported in many individuals with ASD. In many older or less severely affected individuals such as the individuals who participated in the present studies, practice with faces over time may provide an opportunity to overcome these difficulties and to gradually develop skills that approach typical levels.

The studies that make up this thesis do not provide evidence that poor face processing is not a core component of autism, nor that early failure to attend to faces may not influence the developmental course of neural networks involved in face processing. These studies do, however, indicate that some skills, such as implicit visual processing of faces, and the influence of memory on these processes, may be less affected or indeed preserved. The underlying cause of this anomaly requires further investigation. Implicit face recognition should also be directly assessed to see whether there is consistency between visual processing and the influence of memory on these processes, and a quantitative measure of implicit recognition performance.

Heterogeneity in Face Recognition Skills in ASD

One feature of Experiment 1 was the typical levels of face recognition performance of many participants with ASD. Brock and colleagues (e.g., Brock, 2011; C. E. Wilson et al., 2011) have recently stressed the need for an appreciation of the heterogeneity of symptom severity and cognitive impairment in ASD. In contrast, others argue that the focus should be on the identification of the neurological underpinnings of the core difficulties in social information processing common to ASDs (Pelphrey, Shultz, Hudac, & Vander Wyk, 2011). Individual variability in face recognition performance is an example of the need for appreciating heterogeneity while attempting to understand the contribution of core underlying mechanisms that manifest in the social deficit typical of ASD. On the one hand, abnormalities in face processing, particularly the identification of atypical neurological responses (e.g., the reduced N170 to faces) during emotion processing and face recognition tasks, are thought to play a significant role in the development of social processing difficulties in ASD and moreover, are linked to a general impairment in the development of the 'social brain' (Pelphrey et al., 2011). Furthermore, there is little doubt that research regarding the development of face processing in ASD has provided valuable insights into the development of typical face processing (Grelotti, Gauthier, & Schultz, 2002). On the other hand, the current studies (particularly Experiment 1), and also similar results from C. E. Wilson et al. (2011), consistently suggest that face recognition is a highly heterogeneous skill in individuals with ASD and, furthermore, may not be strongly associated with symptom severity (at least in individuals who are relatively high functioning and of average intelligence).

Of course, it may be that performance on face recognition tasks, although at typical levels for age in many individuals with ASD, is achieved through compensatory mechanisms utilising different brain regions to non-ASD individuals. As Pelphrey et al. (2011) point out, the complex interaction between genetics, brain and behaviour throughout development leads to quite different expressions of autistic symptoms at an individual level. Given the high degree of heterogeneity in face recognition skills in individuals with ASD, it may be valuable to also examine and compare the neurological profiles of individuals with good and poor face recognition skills. This would provide the opportunity to look for common underlying neurological profiles in the face of differing behavioural manifestations of the disorder.

Nevertheless, it is relevant that the relationship between the development of face processing skills and general social functioning in ASD has not yet been substantially supported in the literature, such that there is currently little empirical evidence that indicates that poor face recognition is associated with poor social development. The lack of a significant relationship between autistic traits and face recognition performance in Experiment 1 provides one example of this, but others have also failed to find a significant relationship between face recognition performance and symptom severity (e.g., C. E. Wilson et al., 2011). It may be that developing face processing skills, and paying attention to the face, is important for individuals who are keen to develop social relationships with others. This in turn may lead to the development of compensatory face processing mechanisms in these individuals. Participants in the current series of studies who all had formal diagnoses of Aspergers Syndrome may be likely to seek out social relationships (Hedley & Young, 2006) and, therefore, may be more likely to develop face processing skills (although to varying degrees) due to increased interest in social interaction. It may be useful, therefore, to evaluate social functioning in a sufficiently large sample of individuals identified as having poor face recognition skills to determine whether or not there is a significant relationship between the two skills sets, as is implied by the social motivation hypothesis.

Fixations to the Eye and Mouth Regions

Finally, the data from Experiments 2 and 4 (see Chapter 6) did not provide any evidence of an increased attention to the mouth or reduced attention to the eye region in participants with an ASD, or of a strong relationship between face recognition performance and attention to these regions. One plausible explanation for this finding is that differences in fixation patterns to the eyes and mouth are task dependent. Tasks that require the analysis of complex emotions may be more likely to elicit differences compared to recognition based tasks. Recently Sawyer, Williamson, and Young (2011) investigated fixation patterns to the eyes and mouth during a complex and basic emotion recognition task in participants with ASD ($n = 29$, $M_{\text{age}} = 21.6$, $SD = 9.8$). These authors failed to identify any differences in fixations to the eye or mouth region between the ASD participants and a matched control group of non-ASD participants ($n = 24$, $M_{\text{age}} = 24.0$, $SD = 9.2$), for both the basic and complex emotion recognition tasks. Overall, however, participants with ASD were worse at emotion recognition for both simple and complex emotions.

The lack of between-group differences in attention to the eye and mouth region reported here may also result from the use of still images. Notably, Klin et al. (2002) found participants with ASD spent more time fixating the mouth while viewing a social interaction during a movie. More recently, however, the Klin et al. study was repeated by Norbury et al. (2009). Contrary to Klin et al., Norbury et al. found no differences in fixations to the eye region between controls and individuals with ASD who had language impairment; however individuals with ASD with developed language skills spent more time fixating the mouth, and less time fixating the eyes. Thus, differences in viewing patterns to the eyes and mouth may be dependent on the level of communicative competence, and the individual's reliance on the mouth for interpreting language. Overall, these results and the studies reported here provide evidence that individuals with an ASD do not direct proportionately more fixations to the mouth for face or emotion recognition tasks compared to non-ASD persons. Nevertheless, it may be that individuals with developed language skills may fixate the mouth more during naturalistic social exchanges (Klin et al., 2002; Norbury et al., 2009).

Future Directions

The studies reported here examined differences in eye movement behaviour toward previously viewed and novel faces. This focus, however, overlooked the potential relationship between eye movement patterns at encoding and subsequent retrieval. Given that fixation patterns at encoding have been shown to influence recognition memory strength (Kafkas & Montaldi, 2011), it may be that individuals who exhibit poor face recognition performance are characterised by differences in eye movement behaviour at encoding. More specifically, the encoding strategy and processes engaged at encoding are likely to influence the strength and quality of the long-term memory trace. If faces do not demand the attentional resources at encoding that are required for successful recall, the recognition performance could be affected. This could explain the superior recognition performance of complex patterns (e.g., Bradshaw et al., 2011) which may be more likely to capture the attention of children with ASD. In a recent study Snow et al. (2011) found a relationship between scanning at encoding and recognition performance in individuals with ASD (n = 22, M_{age} = 15.96, SD = 2.44) and non-ASD controls (n = 21, M_{age} = 16.81, SD = 1.90), with more fixations at encoding associated with better memory performance for participants with ASD (all images were displayed for 2500 ms at encoding, and total gaze time was equivalent between participant groups). Stimuli used in this study were fans and faces. Of note, non-ASD participants reported more fixations to faces than fans at encoding, yet no significant difference in the number of fixations to fans and faces were found for participants with ASD. This study provides evidence that eye movements during encoding of faces may affect subsequent recognition performance. The role of encoding of information from faces in individuals with ASD demands further attention, particularly to determine whether this factor distinguishes individuals who do not exhibit face recognition deficits from those who do.

REFERENCES

Aloisi, B. A., McKone, E., & Heubeck, B. G. (2004). Implicit and explicit memory performance in children with attention deficit/hyperactivity disorder. *British Journal of Developmental Psychology, 22*, 275-292. doi:10.1348/026151004323044618

Althoff, R. R. (1998). *Eye-movement-based memory assessment: The use of eye movement monitoring as an indirect measure of memory.* Unpublished doctoral dissertation, University of Illinois, Urbana-Champaign, Urbana.

Althoff, R. R. (1999). Eye movement-based memory assessment: The use of eye movement monitoring as an indirect measure of memory. (amnesia, perceptual processing). *Dissertation Abstracts International: Section B: The Sciences and Engineering, 59*, pp.

Althoff, R. R., & Cohen, N. J. (1999). Eye-movement-based memory effect: A reprocessing effect in face perception. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*, 997-1010. doi:10.1037/0278-7393.25.4.997

Althoff, R. R., Cohen, N. J., McConkie, G., Wasserman, S., Maciukenas, M., Azen, R., & Romine, L. (1999). Eye movement-based memory assessment. In W. Becker, H. Deubel & T. Mergner (Eds.), *Current Oculomotor Research* (pp. 293-302). New York: Kluwer Academic.

Althoff, R. R., Maciukenas, M., & Cohen, N. J. (1993). Indirect assessment of memory using eye movement monitoring. *Society for Neuroscience Abstracts, 19*, 439.

Annaz, D. (2006). *The development of Visuo-spatial processing in children with Autism, Down Syndrome and Williams Syndrome*. Thesis. University of London. London.

Annaz, D., Karmiloff-Smith, A., Johnson, M. H., & Thomas, M. S. C. (2009). A cross-syndrome study of the development of holistic face recognition in children with Autism, Down Syndrome, and Williams Syndrome. *Journal of Experimental Child Psychology, 102*, 456-486. doi:10.1016/j.jecp.2008.11.005

APA. (2000). *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision*. Washington, D.C.: American Psychiatric Association.

APA. (2011). A 09 Autism Spectrum Disorder: Proposed Revision. American Psychiatric Association DSM-5 Development Task Force. Retrieved May 6, 2011, from http://www.dsm5.org/ProposedRevisions/Pages/proposedrevision.aspx?rid=94#

Ashwin, C., Wheelwright, S., & Baron-Cohen, S. (2006). Finding a face in the crowd: testing the anger superiority effect in Asperger Syndrome. *Brain and Cognition, 61*, 78-95. doi:10.1016/j.bandc.2005.12.008

Avidan, G., & Behrmann, M. (2008). Implicit familiarity processing in congenital prosopagnosia. *Journal of Neuropsychology, 2*, 141-164. doi:10.1348/174866407x260180

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind. Learning, development, and conceptual change*: Cambridge, MA: The MIT Press.

Baron-Cohen, S., Ring, H. A., Wheelwright, S., Bullmore, E. T., Brammer, M. J., Simmons, A., & Williams, S. (1999). Social intelligence in the normal and autistic brain: an fMRI study. *European Journal of Neuroscience, 11*, 1891-1898. doi:10.1046/j.1460-9568.1999.00621.x

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*, 5-17. doi:10.1023/A:1005653411471

Barton, J. J. S., Cherkasova, M. V., Hefter, R., Cox, T. A., O'Connor, M., & Manoach, D. S. (2004). Are patients with social developmental disorders prosopagnosic? Perceptual heterogenity in the Asperger and social-emotions processing disorders. *Brain, 127*, 1706-1716. doi:10.1093/brain/awh194

Barton, J. J. S., Radcliffe, N., Cherkasova, M. V., Edelman, A., & Intriligator, J. M. (2006). Information processing during face recognition: The effects of familiarity, inversion, and morphing on scanning fixations. *Perception, 35*, 1089-1105. doi:10.1068/p5547

Barton, J. J. S., Radcliffe, N., Cherkasova, M. V., & Edelman, J. A. (2007). Scan patterns during the processing of facial identity in prosopagnosia. *Experimental Brain Research, 181*, 199-211. doi:10.1007/s00221-007-0923-2

Bate, S., Haslam, C., & Hodgson, T. L. (2009). Angry faces are special too: Evidence from the visual scanpath. *Neuropsychology, 23*, 658-667. doi:10.1037/a0014518

Bate, S., Haslam, C., Tree, J. J., & Hodgson, T. L. (2008). Evidence of an eye movement-based memory effect in congenital prosopagnosia. *Cortex, 44*, 806-819. doi:10.1016/j.cortex.2007.02.004

Bauer, R. M. (1984). Autonomic recognition of names and faces in prosopagnosia: a neuropsychological application of the Guilty Knowledge Test. *Neuropsychologia, 22*, 457-469. doi:10.1016/0028-3932(84)90040-x

Behrmann, M., Avidan, G., Leonard, G. L., Kimchi, R., Luna, B., Humphreys, K., & Minshew, N. J. (2006). Configural processing in autism and its relationship to face processing. *Neuropsychologia, 44*, 110-129. doi:10.1016/j.neuropsychologia.2005.04.002

Behrmann, M., Thomas, C., & Humphreys, K. (2006). Seeing it differently: Visual processing in autism. *Trends in Cognitive Sciences, 10*, 258-264. doi:10.1016/j.tics.2006.05.001

Benton, A., Sivan, A., Hamsher, K., Varney, N., & Spreen, O. (1994). *Benton Facial Recognition Test*. Florida: Psychological Assessment Resources.

Blair, R. J. R., Frith, U., Smith, N., Abell, F., & Cipolotti, L. (2002). Fractionation of visual memory: agency detection and its impairment in autism. *Neuropsychologia, 40*, 108-118. doi:10.1016/S0028-3932(01)00069-0

Boehm, S. G., Klostermann, E. C., Sommer, W., & Paller, K. A. (2006). Dissociating perceptual and representation-based contributions to priming of face recognition. *Consciousness and Cognition, 15*, 163-174. doi:10.1016/j.concog.2005.06.001

Boucher, J., & Lewis, V. (1992). Unfamiliar face recognition in relatively able autistic children. *Journal of Child Psychology and Psychiatry, 33*, 843-859. doi:10.1111/j.1469-7610.1992.tb01960.x

Boucher, J., Lewis, V., & Collis, G. M. (1998). Familiar face and voice matching and recognition in children with autism. *Journal of Child Psychology and Psychiatry, 39*, 171-181. doi:10.1111/1469-7610.00311

Boucher, J., Lewis, V., & Collis, G. M. (2000). Voice processing abilities in children with autism, children with specific language impairments, and young typically developing children. *Journal of Child Psychology and Psychiatry, 41*, 847-857. doi:10.1111/1469-7610.00672

Bowler, D. M., Matthews, N. J., & Gardiner, J. M. (1997). Asperger's syndrome and memory: Similarity to autism but not amnesia. *Neuropsychologia, 35*, 65-70. doi:10.1016/S0028-3932(96)00054-1

Bowles, D. C., McKone, E., Dawel, A., Duchaine, B., Palermo, R., Schmalzl, L., . . . Yovel, G. (2009). Diagnosing prosopagnosia: Effects of ageing, sex, and participant–stimulus ethnic match on the Cambridge Face Memory Test and Cambridge Face Perception Test. *Cognitive Neuropsychology, 26*, 423 - 455. doi:10.1080/02643290903343149

Bradshaw, J., Shic, F., & Chawarska, K. (2011). Face-specific recognition deficits in young children with Autism Spectrum Disorders *Journal of Autism and Developmental Disorders, 41*, 1429-1435. doi:10.1007/s10803-010-1150-4

Brock, J. (2011). Commentary: Complementary approaches to the developmental cognitive neuroscience of autism – reflections on Pelphrey et al. (2011). *Journal of Child Psychology and Psychiatry, 52*, 645-646. doi:10.1111/j.1469-7610.2011.02414.x

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology, 77*, 305-327. doi:10.1111/j.2044-8295.1986.tb02199.x

Buckner, R. L., Petersen, S. E., Ojemann, J. G., Miezin, F. M., Squire, L. R., & Raichle, M. E. (1995). Functional anatomical studies of explicit and implicit memory retrieval tasks. *Journal of Neuroscience*, *15*, 12-29.

Burton, A. M., Young, A. W., Bruce, V., Johnston, R. A., & Ellis, A. W. (1991). Understanding covert recognition. *Cognition, 39,* 129-166. doi:0010-0277(91)90041-2

Calder, A. J., & Young, A. W. (2005). Understanding the recognition of facial identity and facial expression. *Nature Reviews Neuroscience, 6*, 641-651. doi:10.1038/nrn1724

Campbell, R., Lawrence, K., Mandy, W., Mitra, C., Jeyakuma, L., & Skuse, D. (2006). Meanings in motion and faces: Developmental associations between the processing of intention from geometrical animations and gaze detection accuracy. *Development and Psychopathology, 18*, 99-118. doi:10.1017/S0954579406060068

Celani, G., Battacchi, M. W., & Arcidiacono, L. (1999). The understanding of the emotional meaning of facial expressions in people with autism. *Journal of Autism and Developmental Disorders*, *29*, 57-66. doi:10.1023/A:1025970600181

Charman, T. (2003). Why is joint attention a pivotal skill in autism? *Philosophical Transactions of the Royal Society of London B Biological Science, 358*, 315-324. doi:10.1098/rstb.2002.1199

Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2000). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive Development, 15*, 481-498. doi:10.1016/S0885-2014(01)00037-5

Chawarska, K., & Shic, F. (2009). Looking but not seeing: Atypical visual scanning and recognition of faces in 2 and 4-Year-old children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders, 39*, 1663-1672. doi:10.1007/s10803-009-0803-7

Clifford, S., Young, R., & Williamson, P. (2007). Assessing the early characteristics of autistic disorder using video analysis. *Journal of Autism and Developmental Disorders, 37*, 301-313. doi:10.1007/s10803-006-0160-8

Corden, B., Chilvers, R., & Skuse, D. (2008). Avoidance of emotionally arousing stimuli predicts social-perceptual impairment in Asperger's syndrome. *Neuropsychologia, 46*, 137-147. doi:10.1016/j.neuropsychologia.2007.08.005

Crawford, J. R., Cayley, C., Lovibond, P. F., Wilson, P. H., & Hartley, C. (2011). Percentile norms and accompanying interval estimates from an Australian general adult population sample for self-reported mood scales (BAI, BDI, CRSD, CES-D, DASS, DASS-21, STAI-X, STAI-Y, SRDS, and SRAS). *Australian Psychologist, 46*, 3-14. doi:10.1111/j.1742-9544.2010.00003.x

Crookes, K., & McKone, E. (2009). Early maturity of face recognition: No childhood development of holistic processing, novel face encoding, or face space. *Cognition, 111*, 219-247. doi:10.1016/j.cognition.2009.02.004

Dalton, K. M., Nacewicz, B. M., Johnstone, T., Schaefer, H. S., Gernsbacher, M. A., Goldsmith, H. H., . . . Davidson, R. J. (2005). Gaze fixation and the neural circuitry of face processing in autism. *Nature Neuroscience, 8*, 519-526. doi:10.1038/nn1421

Damasio, A. R. (1989). Time-locked multiregional retroactivation: A systems-level proposal for the neural substrates of recall and recognition. *Cognition, 33*, 25-62. doi:10.1016/0010-0277(89)90005-X

Damiano, C., Churches, O., Ring, H. A., & Baron-Cohen, S. (2011). The development of perceptual expertise for faces and objects in Autism Spectrum Condition. *Autism Research, 4*, 297-301. doi:10.1002/aur.205

Davies, S., Bishop, D., Manstead, A. S. R., & Tantam, D. (1994). Face perception in children with autism and Asperger's syndrome. *Journal of Child Psychology and Psychiatry, 35*, 1033-1057. doi:10.1111/j.1469-7610.1994.tb01808.x

Dawson, G., Carver, L., Meltzoff, A. N., Panagiotides, H., McPartland, J., & Webb, S. J. (2002). Neural correlates of face and object recognition in young children with autism spectrum disorder, developmental delay, and typical development. *Child Development, 73*, 700-717. doi:10.1111/1467-8624.00433

Dawson, G., Webb, S. J., Carver, L., Panagiotides, H., & McPartland, J. (2004). Young children with autism show atypical brain responses to fearful versus neutral facial expressions of emotion. *Developmental Science, 7,* 340-359. doi:10.1111/j.1467-7687.2004.00352.x

Dawson, G., Webb, S. J., & McPartland, J. (2005). Understanding the nature of face processing impairment in Autism: Insights from behavioral and electrophysiological studies. *Developmental Neuropsychology, 27*, 403-424. doi:10.1207/s15326942dn2703_6

Dawson, G., Webb, S. J., Wijsman, E. M., Schellenberg, G. D., Estes, A., Munson, J., & Faja, S. (2005). Neurocognitive and electrophysiological evidence of altered face processing in parents of children with autism: Implications for a model of abnormal development of social brain circuitry in autism. *Development and Psychopathology, 17,* 679-697. doi:10.1017/S0954579405050327

DeGutis, J. M., Bentin, S., Robertson, L. C., & D'Esposito, M. (2007). Functional plasticity in ventral temporal cortex following cognitive rehabilitation of a congnital prosopagnosic. *Journal of Cognitive Neuroscience, 19*, 1790-1802. doi:10.1162/jocn.2007.19.11.1790

Di Lollo, V. (2010). Iterative reentrant processing: A conceptual framework for perception and cognition. In V. Coltheart (Ed.), *Tutorials in Visual Cognition* (pp. 9-42). New York: Psychology Press.

Diamond, R., & Carey, S. (1986). Why faces are and are not special: an effect of expertise. *Journal of Experimental Psychology: General, 115*, 107-117. doi:10.1037/0096-3445.115.2.107

Drakeford, J. L., Edelstyn, N. M. J., Oyebode, F., Calthorpe, W. R., Srivastava, S., & Mukherjee, T. (2007). Recognition memory for neutral faces in depression. *Journal of Neurology, Neurosurgery and Psychiatry, 78*, 782.

Duchaine, B., & Nakayama, K. (2006a). The Cambridge Face Memory Test: results for neurologically intact individuals and an investigation of its validity using inverted face stimuli and prosopagnosic participants. *Neuropsychologia, 44*, 576-585. doi:10.1016/j.neuropsychologia.2005.07.001

Duchaine, B., & Nakayama, K. (2006b). Developmental prosopagnosia: a window to content-specific face processing. *Current Opinion in Neurobiology, 16*, 166-173. doi:10.1016/j.conb.2006.03.003

Duchaine, B., & Weidenfeld, A. (2003). An evaluation of two commonly used tests of unfamiliar face recognition. *Neuropsychologia, 41*, 713-720.

Duchaine, B., & Yovel, G. (2008). Face recognition. In I. Basbaum, A. Kaneko, G. M. Shepherd & G. Westheimer (Eds.), *The Senses: A Comprehensive Reference* (Vol. 2, pp. 329-358). San Diego: Academic Press.

Eisenbarth, H., & Alpers, G. W. (2011). Happy mouth and sad eyes: Scanning emotional facial expressions. *Emotion, 11*, 860-865. doi:10.1037/a0022758

Ellis, H. D., Ellis, D. M., Fraser, W., & Deb, S. (1994). A preliminary study of right hemisphere cognitive deficits and impaired social judgments among young people with Asperger syndrome. *European Child & Adolescent Psychiatry, 3*, 255-266. doi:10.1007/BF01978114

Ellis, H. D., Young, A. W., & Koenken, G. (1993). Covert face recognition without prosopagnosia. *Behavioural Neurology, 6*, 27-32.

Farah, M. J., O'Reilly, R. C., & Vecera, S. P. (1993). Dissociated overt and covert recognition as an emergent property of a lesioned neural network. *Psychological Review, 100*, 571-588. doi:10.1037/0033-295x.100.4.571

Foulsham, T., & Underwood, G. (2008). What can saliency models predict about eye movements? Spatial and wequential aspects of fixations during encoding and recognition. *Journal of Vision, 8*, 1-17. doi:10.1167/8.2.6

Gauthier, I., Behrmann, M., & Tarr, M. J. (1999). Can face recognition really be dissociated from object recognition? *Journal of Cognitive Neuroscience, 11*, 349-370. doi:10.1162/089892999563472

Gepner, B., Deruelle, C., & Grynfeltt, S. (2001). Motion and emotion: a novel approach to the study of face processing by young autistic children. *J Autism Dev Disord, 31*, 37-45.

Germine, L., Duchaine, B., & Nakayama, K. (2011). Where cognitive development and aging meet: Face learning ability peaks after age 30. *Cognition, 118*, 201-210. doi:10.1016/j.cognition.2010.11.002

Ghaziuddin, M., Ghaziuddin, N., & Greden, J. (2002). Depression in Persons with Autism: Implications for Research and Clinical Care. *Journal of Autism and Developmental Disorders, 32,* 299-306. doi:10.1023/a:1016330802348

Gillberg, C., & Gillberg, I. C. (1989). Asperger syndrome - Some epidemiological considerations: A research note. *Journal of Child Psychology and Psychiatry, 30,* 631-638. doi:10.1111/j.1469-7610.1989.tb00275.x

Golan, O., Ashwin, E., Granader, Y., McClintock, S., Day, K., Leggett, V., & Baron-Cohen, S. (2010). Enhancing Emotion Recognition in Children with Autism Spectrum Conditions: An Intervention Using Animated Vehicles with Real Emotional Faces. *Journal of Autism and Developmental Disorders, 40,* 269-279. doi:10.1007/s10803-009-0862-9

Golan, O., Baron-Cohen, S., Hill, J. J., & Rutherford, M. D. (2007). The 'Reading the Mind in the Voice' test-revised: a study of complex emotion recognition in adults with and without autism spectrum conditions. *Journal of Autism and Developmental Disorders, 37,* 1096-1106. doi:10.1007/s10803-006-0252-5

Gordon, B., & Stark, S. (2007). Procedural learning of a visual sequence in individuals with autism. *Focus on Autism and Other Developmental Disabilities, 22,* 14-22. doi:10.1177/10883576070220010201

Grelotti, D. J., Gauthier, I., & Schultz, R. (2002). Social interest and the development of cortical face specialization: What autism teaches us about face processing. *Developmental Psychobiology, 40,* 213-225. doi:10.1002/dev.10028

Grelotti, D. J., Klin, A., Gauthier, I., Skudlarski, P., Cohen, D. J., Gore, J. C., . . . Schultz, R. T. (2005). fMRI activation of the fusiform gyrus and amygdala to cartoon characters but not to faces in a boy with autism. *Neuropsychologia, 43,* 373-385. doi:10.1016/j.neuropsychologia.2004.06.015

Hadjikhani, N., Chabris, C. F., Joseph, R. M., Clark, J., McGrath, L., Aharon, I., . . . Harris, G. J. (2004). Early visual cortex organization in autism: an fMRI study. *Neuroreport, 15,* 267-270. doi:10.1097/00001756-200402090-00011

Hannula, D. E., Althoff, R. R., Warren, D. E., Riggs, L., Cohen, N. J., & Ryan, J. D. (2010). Worth a glance: Using eye movements to investigate the cognitive neuroscience of memory. *Frontiers in Human Neuroscience, 4*, 1-16. doi:10.3389/fnhum.2010.00166

Hauck, M., Fein, D., Maltby, N., Waterhouse, L., & Feinstein, C. (1998). Memory for faces in children with autism. *Child Neuropsychology, 4,* 187-198. doi:10.1076/chin.4.3.187.3174

Hedley, D., & Young, R. (2006). Social comparison processes and depressive symptoms in children and adolescents with Asperger syndrome. *Autism, 14*. doi:10.1177/1362361306062020

Henderson, J. M., Williams, C., & Falk, R. J. (2005). Eye movements are functional during face learning. *Memory and Cognition, 33*, 98-106. doi:10.3758/BF03195300

Henry, J. D., & Crawford, J. R. (2005). The 21 item version of the Depression Anxiety Stress Scales (DASS-21): Normative data and psychometric evaluation in a large non-clinical sample. *British Journal of Clinical Psychology, 44,* 227-239. doi:10.1348/014466505X29657

Herlitz, A., & Yonker, J. E. (2002). Sex Differences in Episodic Memory: The Influence of Intelligence. *Journal of Clinical and Experimental Neuropsychology, 24,* 107 - 114. doi:10.1076/jcen.24.1.107.970

Herzmann, G., Danthiir, V., Schacht, A., Sommer, W., & Wilhelm, O. (2008). Toward a comprehensive test battery for face cognition: assessment of the tasks. *Behavior Research Methods, 40,* 840-857. doi:10.3758/BRM.40.3.840

Herzmann, G., Danthiir, V., Wilhelm, O., Sommer, W., & Schacht, A. (2007). Face memory: A cognitive and psychophysiological approach to the assessment of antecedents of emotional intelligence. In G. Matthews, M. Zeidner & R. Roberts (Eds.), *The Science of Emotional Intelligence: Knowns and Unknowns* (pp. 305-336). Oxford: Oxford University Press.

Hobson, R. P., Ouston, J., & Lee, A. (1988). What's in a face? The case of autism. *British Journal of Psychology, 79,* 441-453. doi:10.1111/j.2044-8295.1988.tb02745.x

Hoekstra, R. A., Bartels, M., Cath, D. C. Æ., & Boomsma, D. I. (2008). Factor structure, reliability and criterion validity of the Autism-Spectrum Quotient (AQ): A study in Dutch population and patient groups. *Journal of Autism and Developmental Disorders, 38*, 1555-1566. doi:10.1007/s10803-008-0538-x

Holm, L. (2007). *Predictive eyes precede retrieval: Visual recognition as hypothesis testing.* Unpublished doctoral dissertation, Umea University, Sweden.

Holm, L., Eriksson, J., & Andersson, L. (2008). Looking as if you know: Systematic object inspection precedes object recognition. *Journal of Vision, 8*, 1-7. doi:10.1167/8.4.14

Hsiao, J. H., & Cottrell, G. (2007). The influence of number of eye fixations on face recognition. *Journal of Vision, 7*. doi:10.1167/7.9.494

Hsiao, J. H., & Cottrell, G. (2008). Two fixations suffice in face recognition. *Psychological Science, 19,* 998-1006. doi:10.1111/j.1467-9280.2008.02191.x

Hubl, D., Bolte, S., Feineis-Matthews, S., Lanfermann, H., Federspiel, A., Strik, W., . . . Dierks, T. (2003). Functional imbalance of visual pathways indicates alternative face processing strategies in autism. *Neurology, 61,* 1232-1237.

Itier, R. J., & Taylor, M. J. (2004). Face recognitin and configural processing: A developmental ERP study using upright, inverted, and contrast-reversed faces. *Journal of Cognitive Neuroscience, 16*, 487-502. doi:10.1162/089892904322926818

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic and intentional uses of memory. *Journal of Memory and Language, 30,* 513-541. doi:10.1016/0749-596X(91)90025-F

Jacques, C., d'Arripe, O., & Rossion, B. (2007). The time course of the inversion effect during individual face discrimination. *Journal of Vision, 7*, 1-9. doi:10.1167/7.8.3

Jacques, C., & Rossion, B. (2006). The speed of individual face categorization. *Psychological Science*, *17*, 485-492. doi:10.1111/j.1467-9280.2006.01733.x

Jemel, B., Mottron, L., & Dawson, M. (2006). Impaired Face Processing in Autism: Fact or Artifact? *Journal of Autism and Developmental Disorders, 36*, 91-106. doi:10.1007/s10803-005-0050-5

Jolliffe, T., & Baron-Cohen, S. (1997). Are people with autism and Asperger syndrome faster than normal on the Embedded Figures Test? *Journal of Child Psychology and Psychiatry, 38,* 527-534. doi:10.1111/j.1469-7610.1997.tb01539.x

Joseph, R. M., & Tanaka, J. (2003). Holistic and part-based face recognition in children with autism. *Journal of Child Psychology and Psychiatry, 44*, 529-542. doi:10.1111/1469-7610.00142

Kafkas, A., & Montaldi, D. (2011). Recognition memory strength is predicted by pupillary responses at encoding while fixation patterns distinguish recollection from familiarity. *The Quarterly Journal of Experimental Psychology*. doi:10.1080/17470218.2011.588335

Kanner, L. (1943, 1971). Follow-up study of eleven autistic children originally reported in 1943. *Journal of Autism and Childhood Schizophrenia, 1*, 119-145. doi:10.1007/BF01537953

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience, 17*.

Kanwisher, N., & Moscovitch, M. (2000). The cognitive neuroscience of face processing: An introduction. *Cognitive Neuropsychology, 17*, 1-11. doi:10.1080/026432900380454

Kanwisher, N., Stanley, D., & Harris, A. (1999). The fusiform face area is selective for faces not animals. *Neuroreport, 10*, 183-187. doi:10.1097/00001756-199901180-00035

Kanwisher, N., & Yovel, G. (2006). The fusiform face area: a cortical region specialized for the perception of faces. *Philosophical Transactions of the Royal Society B-Biological Sciences, 361*, 2109-2128. doi:10.1098/rstb.2006.1934

Kirchner, J. C., Hatri, A., Heekeren, H. R., & Dziobek, I. (2011). Autistic symptomatology, face processing abilities, and eye fixation patterns. *Journal of Autism and Developmental Disorders, 41*, 158-167. doi:10.1007/s10803-010-1032-9

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with Autism. *Archives of General Psychiatry, 59*, 809-816. doi:10.1001/archpsyc.59.9.809

Klin, A., Sparrow, S. S., de Bildt, A., Cicchetti, D. V., Cohen, D. J., & Volkmar, F. R. (1999). A normed study of face recognition in autism and related disorders. *Journal of Autism and Developmental Disorders, 29*, 499-508. doi:10.1023/A:1022299920240

Lahaie, A., Mottron, L., Arguin, A., Berthiaume, C., Jemel, B., & Saumier, D. (2006). Face perception in high-functioning autistic adults: Evidence for superior processing of face parts, not for a configural face-processing deficit. *Neuropsychology, 20*, 30-41. doi:10.1037/0894-4105.20.1.30

Langdell, T. (1978). Recognition of faces: An approach to the study of autism. *Journal of Child Psychology and Psychiatry, 19*, 255-268. doi:10.1111/j.1469-7610.1978.tb00468.x

Leopold, D. A., & Rhodes, G. (2010). A comparative view of face perception. *Journal of Comparative Psychology, 124*, 233-251. doi:10.1037/a0019460

Light, L. L., Singh, A., & Capps, J. L. (1986). Dissociation of memory and awareness in young and older adults. *Journal of Clinical and Experimental Neuropsychology, 8*, 62-74. doi:10.1080/01688638608401297

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism Diagnostic Interview-Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 24*, 659-685. doi:10.1007/BF02172145

Lovibond, S. H., & Lovibond, P. F. (1995). *Manual for the Depression Anxiety Stress Scales* (2nd ed.). Sydney: Psychology Foundation.

Maljkovic, V., & Nakayama, K. (2000). Priming of popout: A short-term implicit memory system beneficial for rapid target selection. *Visual Cognition, 7,* 571-595. doi:10.1080/135062800407202

Marco, E. J., Hinkley, L. B. N., Hill, S. S., & Nagarajan, S. S. (2011). Sensory processing in Autism: A review of neurophysiological findings. *Pediatric Research, 69,* 48R-54R. doi:10.1203/PDR.0b013e3182130c54

McPartland, J., Dawson, G., Webb, S. J., Panagiotides, H., & Carver, L. (2004). Event-related brain potentials reveal anomalies in temporal processing of faces in autism spectrum disorder. *Journal of Child Psychology and Psychiatry, 45*, 1235-1245. doi:10.1111/j.1469-7610.2004.00318.x

McPartland, J., Webb, S. J., Keehn, B., & Dawson, G. (2011). Patterns of visual attention to faces and objects in autism spectrum disorder. *Journal of Autism and Developmental Disorders, 41,* 148-157. doi:10.1007/s10803-010-1033-8

Minear, M., & Park, D. C. (2004). A lifespan database of adult facial stimuli. *Behavior Research Methods, Instruments, and Computers, 36,* 630-633. doi:10.3758/BF03206543

Minshew, N. J., Bodner, K. E., & Williams, D. L. (2009). *Facial recognition, configural processing, and concept frmation in High-Functioning Autism*. Paper presented at the International Meeting for Autism Research, Chicago.

Minshew, N. J., & Goldstein, G. (1998). Autism as a disorder of complex information processing. *Mental Retardation and Developmental Disabilities Research Reviews, 4*, 129-136. doi:10.1002/(SICI)1098-2779(1998)4:2<129::AID-MRDD10>3.0.CO;2-X

Minshew, N. J., & Goldstein, G. (2001). The pattern of intact and impaired memory functions in autism. *Journal of Child Psychology and Psychiatry, 42*, 1095-1101. doi:10.1111/1469-7610.00808

Minshew, N. J., Goldstein, G., Muenz, L. R., & Payton, J. B. (1992). Neuropsychological functioning in nonmentally retarded autistic individuals. *Journal of Clinical and Experimental Neuropsychology, 14*, 749-761. doi:10.1080/01688639208402860

Minshew, N. J., Goldstein, G., & Siegel, D. J. (1997). Neuropsychologic functioning in autism: Profile of a complex information processing disorder. *Journal of the International Neuropsychological Society, 3*, 303-316.

Minshew, N. J., Sweeney, J., & Luna, B. (2002). Autism as a selective disorder of complex information processing and underdevelopment of neocortical systems. *Molecular Psychiatry, 7*, S14-S15.

Minshew, N. J., Williams, D. L., & McFadden, K. (2008). Information processing, neural connectivity, and neuronal organization. In A. W. Zimmerman (Ed.), *Autism: Current Clinical Neurology* (pp. 381-405). Totowa, NJ, USA: Humana Press.

Mostofsky, S. H., Goldberg, M. C., Landa, R. J., & Denckla, M. B. (2000). Evidence for a deficit in procedural learning in children and adolescents with autism: Implications for cerebellar contribution. *Journal of the International Neuropsychological Society, 6,* 752-759. doi:10.1017/S1355617700677020

Müller, R. A., Cauich, C., Rubio, M. A., Mizuno, A., & Courchesne, E. (2004). Abnormal activity patterns in premotor cortex during sequence learning in autistic patients. *Biological Psychiatry, 56,* 323-332.

Mundy, P., & Crowson, M. (1997). Joint attention and early social communication: implications for research on intervention with autism. *Journal of Autism and Developmental Disorders, 27,* 653-676. doi:10.1023/A:1025802832021

Murphy, K., McKone, E., & Slee, J. (2003). Dissociations between implicit and explicit memory in children: The role of strategic processing and the knowledge base. *Journal of Experimental Child Psychology, 84,* 124-165. doi:10.1016/S0022-0965(03)00002-X

Nelson, C. A. (2001). The development and neural bases of face recognition. *Infant and Child Development, 10,* 3-18. doi:10.1002/icd.239

Norbury, C. F., Brock, J., Cragg, L., Einav, S., Griffiths, H., & Nation, K. (2009). Eye-movement patterns are associated with communicative competence in autistic spectrum disorders. *Journal of Child Psychology and Psychiatry, 50,* 834-842. doi:10.1111/j.1469-7610.2009.02073.x

O'Hearn, K., Schroer, E., Minshew, N. J., & Luna, B. (2010). Lack of developmental improvement on a face memory task during adolescence in autism. *Neuropsychologia, 48*, 3955-3960. doi:10.1016/j.neuropsychologia.2010.08.024

Osterling, J., & Dawson, G. (1994). Early recognition of children with autism: A study of first birthday home videotapes. *Journal of Autism and Developmental Disorders, 24*, 247-257. doi:10.1007/BF02172225

Parkin, A. J., & Russo, R. (1990). Implicit and explicit memory and the automatic/effortful distinction. *European Journal of Cognitive Psychology, 2*, 71-80. doi:10.1080/09541449008406198

Parkin, A. J., & Streete, S. (1988). Implicit and explicit memory in young children and adults. *British Journal of Psychology, 79,* 361-369. doi:10.1111/j.2044-8295.1988.tb02295.x

Peer, P. (2011). CVL Face Database. Retrieved from http://www.lrv.fri.uni-lj.si/facedb.html

Pellicano, E., Jeffery, L., Burr, D., & Rhodes, G. (2007). Abnormal adaptive face-coding mechanisms in children with Autism Spectrum Disorder. *Current Biology, 17,* 1508-1512. doi:10.1016/j.cub.2007.07.065

Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B. D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders, 32,* 249-261. doi:10.1023/A:1016374617369

Pelphrey, K. A., Shultz, S., Hudac, C. M., & Vander Wyk, B. C. (2011). Research Review: Constraining heterogeneity: the social brain and its development in autism spectrum disorder. *Journal of Child Psychology and Psychiatry, 52*, 631-644. doi:10.1111/j.1469-7610.2010.02349.x

Phillips, P. J., Moon, H., Rizvi, S. A., & Rauss, P. J. (2000). The FERET Evaluation Methodology for Face Recognition Algorithms. *IEEE Trans. Pattern Analysis and Machine Intelligence*, *22*, 1090-1104. doi:10.1109/34.879790

Phillips, P. J., Wechsler, H., Huang, J., & Rauss, P. (1998). The FERET database and evaluation procedure for face recognition algorithms. *Image and Vision Computing Journal*, *16*, 295-306. doi:10.1016/S0262-8856(97)00070-X

Pierce, K., Haist, F., Sedaghat, F., & Courchesne, E. (2004). The brain response to personally familiar faces in autism: findings of fusiform activity and beyond. *Brain, 127*, 2703-2716. doi:10.1093/brain/awh289

Pierce, K., Muller, R. A., Ambrose, J., Allen, G., & Courchesne, E. (2001). Face processing occurs outside the fusiform 'face area' in autism: evidence from functional MRI. *Brain, 124,* 2059-2073. doi:10.1093/brain/124.10.2059

Renault, B., Signoret, J. L., Debruille, B., Breton, F., & Bolgert, F. (1989). Brain potentials reveal covert facial recognition in prosopagnosia. *Neuropsychologia, 27,* 905-912. doi:10.1016/0028-3932(89)90066-3

Renner, P., Klinger, L. G., & Klinger, M. R. (2000). Implicit and explicit memory in autism: Is autism an amnesic disorder? *Journal of Autism and Developmental Disorders, 30,* 3-14. doi:10.1023/A:1005487009889

Rhodes, G., Brake, S., & Atkinson, A. P. (1993). What's lost in inverted faces? *Cognition, 47,* 25-57. doi:10.1016/0010-0277(93)90061-Y

Richler, J. J., Cheung, O. S., & Gauthier, I. (2011). Holistic processing predicts face recognition. *Psychological Science, 22,* 464-471. doi:10.1177/0956797611401753

Rizzo, M., Hurtig, R., & Damasio, A. R. (1987). The role of scanpaths in facial recognition and learning. *Annals of Neurology, 22,* 41-45. doi:10.1002/ana.410220111

Russell, R., Duchaine, B., & Nakayama, K. (2009). Super-recognizers: People with extraordinary face recognition ability. *Psychonomic Bulletin and Review, 16*, 252-257. doi:10.3758/Pbr.16.2.252

Rutherford, M. D., Clements, K. A., & Sekuler, A. B. (2007). Differences in discrimination of eye and mouth displacement in autism spectrum disorders. *Vision Research, 47,* 2099-2110. doi:10.1016/j.visres.2007.01.029

Rutherford, M. D., & Towns, A. M. (2008). Scan path differences and similarities during emotion perception in those with and without Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders, 38,* 1371-1381. doi:10.1007/s10803-007-0525-7

Ryan, J. D., Hannula, D. E., & Cohen, N. J. (2007). The obligatory effects of memory on eye movements. *Memory, 15*, 508-525. doi:10.1080/09658210701391022

Sanders, J. L. (2009). Qualitative or quantitative differences between Asperger’s Disorder and Autism? Historical considerations. *Journal of Autism and Developmental Disorders, 39*, 1560-1567. doi:10.1007/s10803-009-0798-0

Sawyer, A. C. P., Williamson, P., & Young, R. (2011). Can gaze avoidance explain why individuals with Asperger's Syndrome can't recognise emotions from facial expressions? *Journal of Autism and Developmental Disorders*. doi:10.1007/s10803-011-1283-0

Scherf, K. S., Behrmann, M., Minshew, N. J., & Luna, B. (2008). Atypical development of face and greeble recognition in autism. *Journal of Child Psychology and Psychiatry, 49*, 838-847. doi:10.1111/j.1469-7610.2008.01903.x

Scherf, K. S., Luna, B., Minshew, N. J., & Behrmann, M. (2010). Location, location, location: Alterations in the functional topography of face- but not object- or place-related cortex in adolescents with autism. *Frontiers in Human Neuroscience, 4*, 1-16. doi:10.3389/fnhum.2010.00026

Schultz, R. T. (2005). Developmental deficits in social perception in autism: the role of the amygdala and fusiform face area. *International Journal of Developmental Neuroscience, 23*, 125-141. doi:10.1016/j.ijdevneu.2004.12.012

Schultz, R. T., Gauthier, I., Klin, A., Fulbright, R. K., Anderson, A. W., Volkmar, F., . . . Gore, J. C. (2000). Abnormal ventral temporal cortical activity during face discrimination among individuals with autism and Asperger syndrome. *Archives of General Psychiatry, 57*, 331-340. doi:10.1001/archpsyc.57.4.331

Scott, F. J., Baron-Cohen, S., Bolton, P., & Brayne, C. (2002). The CAST (Childhood Asperger Syndrome Test): preliminary development of a UK screen for mainstream primary-school-age children. *Autism, 6*, 9-31. doi:10.1177/1362361302006001003

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117*, 34-50. doi:10.1037/0096-3445.117.1.34

Snow, J., Ingeholm, J. E., Levy, I. F., Caravella, R. A., Case, L. K., Wallace, G. L., & Martin, A. (2011). Impaired visual scanning and memory for faces in high-functioning Autism Spectrum Disorders: It's not just the eyes. *Journal of the International Neuropsychological Society, 17*, 1-9. doi:10.1017/S1355617711000981

Solina, F., Peer, P., Batagelj, B., Juvan, S., & Kovač, J. (2003). *Color-based face detection in the '15 seconds of fame' art installation.* Paper presented at the Mirage 2003, Conference on Computer Vision / Computer Graphics Collaboration for Model-based Imaging, Rendering, Image Analysis and Graphical Special Effects, INRIA Rocquencourt, France.

Spezio, M. L., Adolphs, R., Hurley, R. S. E., & Piven, J. (2007). Abnormal use of facial information in High-Functioning Autism. *Journal of Autism and Developmental Disorders, 37,* 929-939. doi:10.1007/s10803-006-0232-9

Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments, and Computers, 31,* 137-149. doi:10.3758/BF03207704

Sterling, L., Dawson, G., Webb, S., Murias, M., Munson, J., Panagiotides, H., & Aylward, E. H. (2008). The role of face familiarity in eye tracking of faces by individuals with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 38,* 1666-1675. doi:10.1007/s10803-008-0550-1

Tanaka, J. (2001). The entry point of face recognition: Evidence for face expertise. *Journal of Experimental Psychology: General, 130,* 534-543. doi:10.1037/0096-3445.130.3.534

Teunisse, J. P., & de Gelder, B. (2003). Face processing in adolescents with autistic disorder: The inversion and composite effects. *Brain and Cognition, 52*, 285-294. doi:10.1016/S0278-2626(03)00042-3

Trepagnier, C., Sebrechts, M. M., & Peterson, R. (2002). Atypical face gaze in autism. *CyberPsychology and Behavior, 5*, 213-217. doi:10.1089/109493102760147204

Valentine, T. (1988). Upside-down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology, 79,* 471-491. doi:10.1111/j.2044-8295.1988.tb02747.x van der Geest, J. N., Kemner, C., Verbaten, M. N., & van Engeland, H. (2002). Gaze behavior of children with pervasive developmental disorder toward human faces: A fixation time study. *Journal of Child Psychology and Psychiatry, 43*, 669-678. doi:10.1111/1469-7610.00055

Vickers, D. (1979). *Decision processes in visual perception*. New York: Academic Press.

Volkmar, F. R., Sparrow, S. S., Rende, R. D., & Cohen, D. J. (1989). Facial perception in autism. *Journal of Child Psychology and Psychiatry, 30*, 591-598. doi:10.1111/j.1469-7610.1989.tb00270.x

Warrington, E. K. (1984). *Recognition Memory Test*. Windsor, UK: NFER-Nelson.

Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence*. San Antonio, TX: Harcourt Assessment Inc.

White, S., Hill, E., Winston, J., & Frith, U. (2006). An islet of social ability in Asperger Syndrome: judging social attributes from faces. *Brain and Cognition, 61*, 69-77. doi:10.1016/j.bandc.2005.12.007

Wilkinson, D. A., Best, C. A., Minshew, N. J., & Strauss, M. S. (2010). Memory awareness for faces in individuals with Autism. *Journal of Autism and Developmental Disorders, 40*, 1371-1377. doi:10.1007/s10803-010-0995-x

Williams, D. L., Goldstein, G., Carpenter, P. A., & Minshew, N. J. (2005). Verbal and spatial working memory in Autism. *Journal of Autism and Developmental Disorders, 35*, 747-756. doi:10.1007/s10803-005-0021-x

Williams, D. L., Goldstein, G., & Minshew, N. J. (2005). Impaired memory for faces and social scenes in autism: Clinical implications of memory dysfunction. *Archives of Clinical Neuropsychology, 20*, 1-15. doi:10.1016/j.acn.2002.08.001

Williams, D. L., Goldstein, G., & Minshew, N. J. (2006). The profile of memory function in children with autism. *Neuropsychology, 20*, 21-29. doi:10.1037/0894-4105.20.1.21

Williams, J., Scott, F., Stott, C., Allison, C., Bolton, P., Baron-Cohen, S., & Brayne, C. (2005). The CAST (Childhood Asperger Syndrome Test). *Autism, 9,* 45-68. doi:10.1177/1362361305049029

Wilmer, J. B., Germine, L., Chabris, C. F., Chatterjee, G., Williams, M., Loken, E., . . . Duchaine, B. (2010). Human face recognition ability is specific and highly heritable. *Proceedings of the National Academy of Sciences, USA, 107*, 5238-5241. doi:10.1073/pnas.0913053107

Wilson, C. E., Freeman, P., Brock, J., Burton, A. M., & Palermo, R. (2010). Facial Identity Recognition in the Broader Autism Phenotype. *PloS One, 5*. doi:10.1371/journal.pone.0012876

Wilson, C. E., Palermo, R., Burton, A. M., & Brock, J. (2011). Recognition of own- and other-race faces in autism spectrum disorders. *The Quarterly Journal of Experimental Psychology*. doi:10.1080/17470218.2011.603052

Wilson, C. E., Palermo, R., Schmalzl, L., & Brock, J. (2010). Specificity of impaired facial identity recognition in children with suspected developmental prosopagnosia. *Cognitive Neuropsychology, 27*, 30-45. doi:10.1080/02643294.2010.490207

Wilson, R., Blades, M., Coleman, M., & Pascalis, O. (2009). Unfamiliar face recognition in children with autistic spectrum disorders. *Infant and Child Development*. doi:10.1002/icd.638

Wilson, R., Pascalis, O., & Blades, M. (2007). Familiar face recognition in children with autism: The differential use of inner and outer face parts. *Journal of Autism and Developmental Disorders, 37*, 314-320. doi:10.1007/s10803-006-0169-z

Wilson, T. W., Rojas, D. C., Reite, M. L., Teale, P. D., & Rogers, S. J. (2007). Children and adlescents with autism exhibit reduced MEG steady-state gamma responses. *Biological Psychiatry*, 192-197. doi:10.1016/j.biopsych.2006.07.002

Wolf, J. M., Tanaka, J. W., Klaiman, C., Cockburn, J., Herlihy, L., Brown, C., . . . Schultz, R. T. (2008). Specific impairment of face-processing abilities in children with autism spectrum disorder using the Let's Face It! skills battery. *Autism Research, 1*, 329-340. doi:10.1002/aur.56

Woodbury-Smith, M. R., Robinson, J., Wheelwright, S., & Baron-Cohen, S. (2005). Screening adults for Asperger Syndrome using the AQ: a preliminary study of its diagnostic validity in clinical practice. *Journal of Autism and Developmental Disorders, 35*, 331-335. doi:10.1007/s10803-005-3300-7

Yardley, L., McDermott, L., Pisarski, S., Duchaine, B., & Nakayama, K. (2008). Psychosocial consequences of developmental prosopagnosia: a problem of recognition. *Journal of Psychosomatic Research, 65*, 445-451. doi:10.1016/j.jpsychores.2008.03.013

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology, 81*, 141-145. doi:10.1037/h0027474

Young, A. W. (1998). *Face and mind*. New York: Oxford University Press.

Young, R., & Posselt, M. (2011). Using the Transporters DVD as a learning tool for children with Autism Spectrum Disorders (ASD). *Journal of Autism and Developmental Disorders*, 1-8. doi:10.1007/s10803-011-1328-4

Yovel, G., & Kanwisher, N. (2004). Face perception: Domain specific, not process specific. *Neuron*, *44*, 889-898. doi:10.1016/S0896-6273(04)00728-7

Zhu, Q., Song, Y., Hu, S., Li, X., Tian, M., Zhen, Z., . . . Liu, J. (2010). Heritability of the Specific Cognitive Ability of Face Perception. *Current Biology, 20*, 137-142. doi:10.1016/j.cub.2009.11.067