Measuring the bias to look to the eyes in individuals with and without autism spectrum disorder

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Thesis summary

The overarching goal of this thesis was to investigate looking patterns in autism spectrum disorder (ASD), which is characterised by difficulties in modulating social eye gaze. Despite a large body of literature investigating where autistic individuals look when viewing a face, there is limited research into first fixation locations and into their capacity for altering looking patterns in line with an instruction. A novel prompting paradigm was used to investigate where individuals looked when viewing a face, how their eye tracking patterns changed in response to an instruction prompt, as well as behavioural performance throughout the task (accuracy and RT). The performance of individuals with ASD and neurotypical development (NT) was tested.

In Study 1 I investigated how accurately and quickly autistic adolescents responded in a forced choice recognition paradigm, where either the eye or mouth region of a face had been changed between the target and foil images. Critically, the ASD group were less accurate overall when compared to the control group, but no group differences were seen between the eye and mouth conditions. In Study 2 eye tracking measures of dwell time and first fixation location were also included and the same paradigm was conducted with NT adults. This group had an initial, and difficult to inhibit, bias to look to the eyes, even when prompted to look to the mouth. In Study 3 the measure of time to first fixate was added to the paradigm, together with development of a control condition, and the same pattern of difficulty to inhibit looks to the eyes was found in typically developing (TD) children. Finally, Study 4 demonstrated that comparable eye tracking patterns were found in ASD and TD children, including this difficult to inhibit bias to look at the eyes.

In summary, this thesis used a novel prompting paradigm and established an initial difficult to inhibit bias to look to the eyes, shown consistently across TD children, NT adults, and autistic children. Therefore, evidence from this paradigm indicates that initial spontaneous looking to the eyes might be an automatic response in autistic individuals.

Declaration

The results presented in this thesis are a combination of secondary data analysis and new data collected as part of my PhD.

The data from Chapter 2 were collected as part of the Special Needs in Autism Project (SNAP). This project involved the collection of a large amount of data, including the face processing task analysed as part of this PhD. I was not involved in the data collection for this task, but I was the first to analyse the data presented in this thesis.

I collected the data from Chapter 3 throughout my MSc Psychology course at the University of Essex. I have previously analysed this data as part of my MSc project, however the analysis conducted for this PhD had a new focus and completely new analysis was conducted, which has not previously been conducted elsewhere.

I collected the data in Chapter 4 and Chapter 5 as part of this PhD at Cardiff University.

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Abbreviations

ASD	Autism spectrum disorder
ADHD	Attention deficit hyperactivity disorder
ADI-R	Autism Diagnostic Interview - Revised
ADOS	Autism Diagnostic Observation Schedule
APA	American Psychiatric Association
DD	Developmental delay
DISCO	Diagnostic Interview for Social and Communication Disorders
DSM	Diagnostic and Statistical Manual of Mental Disorders
DT	Dwell time
Fix	Number of fixations
FSIQ	Full Scale intelligence quotient
IQ	Intelligence quotient
NT	Neurotypical
NVMA	Non-verbal mental age
PIQ	Performance intelligence quotient
ROI	Region of interest
RT	Reaction time
SCQ	Social communication questionnaire
SLI	Specific language impairment
SNAP	Special needs in autism project
TD	Typically developing
VMA	Verbal mental age
VIQ	Verbal intelligence quotient
WASI	Wechsler Abbreviated Scale of Intelligence

Chapter 1: Introduction

This thesis will show the development of a new paradigm to investigate social attention in both the neurotypical (NT) participants and those with autism spectrum disorder (ASD), focussing on the processing of the eye and mouth regions on faces. This paradigm will use both behavioural and eye tracking measures simultaneously to attempt to further understand complex face processing patterns, and how automatic these are in typically developing (TD) children, NT adults, and children and young people with ASD.

In this chapter the topic of social attention will be introduced and the research summarised for both NT and ASD populations. Although the behavioural research in this area will be summarised, the focus of the chapter will be on the eye tracking research that has been conducted. A large number of studies have been conducted comparing face processing patterns in ASD and non-ASD populations, with the majority focussing on dwell time to different regions of interest (ROIs), or the number of fixations to each ROI. In addition, research on alternative eye tracking measures will be discussed, including the location of the first fixation on social stimuli, the time to fixate on each ROI and gaze following paradigms. The discussion of these varying eye tracking measures, alongside the behavioural paradigms, will allow a greater understanding of the wide breadth of research conducted in this area and will start to explore some of the contradictory findings and the clear areas of further research that are required.

Due to the large body of previous literature this review will focus on the measures that will best inform the thesis, therefore when discussing eye tracking studies I will focus on studies of dwell time, first fixations, time to first fixate, as well as measures of gaze following and specific instructions to alter gaze. It is not within the scope of this review to focus on the large number of studies comparing direct and averted gaze, comparisons of face versus body looking or other eye tracking measures that are not specific to comparing eye and mouth looking. This review includes research published until March 2017.

1.1: Introduction to social attention and ASD

Although there is no universal agreed definition of social attention it can be classified into three main conceptual constructs of social visual attention (attention to the social world), social motivation (how engaging with the social world rewards and reinforces a value) and social behaviour (the behaviours used to maintain interaction with the social world through joint attention) (For a discussion of these see Salley & Colombo, 2016). The aspect of social attention focussed on in this thesis is attention to social stimuli, specifically considering how people look at face stimuli.

In humans, social attention is central to interaction and there is an overt attentional bias to look to other people, and to specifically orient to others' faces (Birmingham & Kingstone, 2009). This bias seems to have a biological basis with the human eye having a greater dark iris to white sclera ratio when compared to other primates' eyes, which results in a much faster discrimination of gaze direction (Kobayashi & Kohshima, 1997). This ability to quickly gather information from the eyes also appears to have great importance in a wide range of different interactions including the facilitation of turn taking, exerting social dominance and signalling social defeat (Birmingham & Kingstone, 2009).

This social attention, which appears to be natural in everyday life for NT adults and children, is impaired in those with an ASD. ASD is a neurodevelopmental disorder characterised by deficits in social communication and social interaction and the presence of restricted and repetitive behaviours and interests (American Psychiatric Association, 2013). Within the descriptions of social communication and social interaction there are three subsets to these diagnostic sub-domains: deficits in social-emotional reciprocity, deficits in non-verbal communicative behaviours, and deficits in developing, maintaining and understanding relationships. Deficits in social-emotional reciprocity are common in those with ASD, and in children are often demonstrated through limited imitation of others' behaviour and limited initiation of social interactions. In adults, however, these difficulties in social-emotional reciprocity are often seen though difficulties processing complex social cues, for example when to join a conversation. Even in adults who have developed compensation strategies difficulties can be experienced as a result of the high effort and anxiety involved in doing what is socially intuitive to others. In addition, behaviours associated with deficits in nonverbal communication include absent, reduced or atypical eye contact, gestures and body orientation. An early feature of autism is reduced joint attention, characterised by a reduced level of pointing and showing objects for joint enjoyment, as well as a failure to follow another's pointing or eye gaze. In comparison, in adults some of the nonverbal attention deficits may be more subtle, for example good eye contact may be given during speaking, but there is poor integration of eye contact, gestures and facial expressions during interactions.

There are a wide range of social attention difficulties discussed in the diagnostic criteria (see above), however, these difficulties are often thought to be as the result of difficulty orientating to and subsequently engaging with relevant social stimuli in everyday life, specifically to others' faces and their eyes (e.g. Dawson, Webb, & McPartland, 2005; Sasson, 2006). This difficulty in orienting to faces and the eyes in childhood and throughout adulthood has also been seen in babies and young children who go on to be diagnosed with ASD, through the use of eye tracking (for a review see Falck-Ytter, Bolte, & Gredeback, 2013). In addition, there is a range of research showing that autistic individuals do not use other people's gaze for a range of social-communication purposes in everyday life as well as those who are TD. For example, previous research has found deficits in using eye gaze to establish shared attention (Joseph & Tager-Flusberg, 1997), to regulate turn taking in conversation (Mirenda, Donnellan, & Yoder, 1983), to understand the intentions of others (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995) and to interpret what other people may be feeling (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001).

These difficulties of orienting to the eyes in individuals with ASD can be interpreted using two main theories, firstly the theory of gaze aversion (Hutt & Ounsted, 1966; Kliemann, Dziobek, Hatri, Steimke, & Heekeren, 2010) and secondly the theory of gaze indifference (Cohen, Vietze, Sudhalter, Jenkins, & Brown, 1989; Senju & Johnson, 2009). Moriuchi, Klin, and Jones (2017) suggest that the key differences between these two theories is that in gaze aversion individuals are aware of the social significance of eye gaze and consciously choose to avoid it, whereas gaze indifference suggests individuals have an insensitivity to the social signals of other's eyes.

Atypical eye contact during social interactions, including lack of eye contact or poorly modulated eye contact, is a striking feature of many with ASD. One anecdotal example of this is from John Robison's memoir (Robison, 2007), where he discusses how, as a child, he was often told to look people in the eye and was accused of hiding something or being untrustworthy for not looking people in the eye. He expresses his lack of understanding of what was expected from him and confusion as to why he should look someone in the eye during conversation. This atypical looking style is an integral part of the diagnostic assessment for ASD. For example, the use of eye contact is assessed in the Autism Diagnostic Observation Schedule (ADOS-2: Lord et al., 2012), Autism Diagnostic Interview (ADI-R: Lord, Rutter, & Lecouteur, 1994) and the Diagnostic Interview for Social and Communication Disorders (DISCO: Leekam, Libby, Wing, Gould, & Taylor, 2002; Wing, Leekam, Libby, Gould, & Larcombe, 2002).

However, it is not universally accepted that individuals with ASD do not orient to important social information, central to social attention. For example, Fletcher-Watson, Leekam, Benson, Frank, and Findlay (2009) present evidence that participants with ASD do look to social information preferentially over non-social information in some situations. By presenting adolescents and adults both with and without ASD with two simultaneous social scenes, one with a person present and one without, they found that across both groups a greater amount of the spontaneous viewing time was spent looking at the person present scene. Therefore, it is important to fully explore social attention and any similarities and differences that are seen in ASD.

To fully understand orienting to different regions of the face it is important to consider previous research that has been conducted on both how different face processing tasks are completed, as well as eye tracking studies which enable investigation of where people look at different social stimuli. However, before considering how individuals with ASD process faces it is first important to understand the looking behaviour of NT adults and children when they complete face processing tasks and look at face images. This will enable an understanding of what these patterns are in those who do not have difficulties with social communication and social interaction, therefore enabling a comparison with those with ASD.

1.2: Looking to the eyes and mouth in NT participants

1.2.1: Behavioural studies in NT participants

Various behavioural face processing experiments have been conducted, which highlight the importance of the eye region when processing facial information. In two early studies, McKelvie (1976) and Haig (1985) established that adult participants were better at face recognition when the eye and surrounding areas were available to be processed, as opposed to when these areas were obscured or masked. However, McKelvie (1976) also found that there were no differences in reaction time (RT) when either the eye or mouth were available for processing, and that the participants reported they felt they were able to complete the task as successfully whether the eye or mouth areas were obscured. This suggests that the participants were not aware of the advantage in processing the eyes. In addition, although Haig (1985) only had a sample size of four, he noticed a large amount of individual differences between the participants and where they favoured to look, highlighting the importance of being aware of individual differences in the studies. Fraser, Craig, and Parker (1990) investigated the speed of response to either the omission or substitution of different facial features in line drawn faces. They found that the outline of the face and the eyes were the most salient feature, and both of these resulted in faster detection than the mouth or nose area changes. This finding is in contrast to that of McKelvie (1976) who found that although there was better performance when the eyes were available for processing, there was no difference in RTs.

The development of more sophisticated technology has resulted in alternative methodologies to investigate the importance of different features in identity recognition. One of those most commonly used is the bubble methodology. Schyns, Bonnar, and Gosselin (2002) conducted an experiment where a group of young adults looked at faces where areas of a blurred face picture were randomly uncovered with “bubbles”. It was found that the biggest improvement in identity recognition occurred when the eye and eyebrow regions were revealed, suggesting these were the most important face regions for identity recognition.

These studies that use only behavioural methodologies support the notion that humans orient to the eyes most often when viewing face stimuli. However, it should be noted that the methodologies used in these studies are not ecologically valid, due to the manipulation of the images that is needed to establish which areas of the face are needed for face recognition. The introduction of eye tracking allows investigation of where people look on faces, without manipulating the images so they no longer look realistic and therefore maintaining the integrity of the face in the stimuli.

1.2.2. Studies of dwell time using eye tracking in NT participants

The introduction of eye tracking technology enabled an increased understanding of where participants fixated when they viewed a face. Early eye tracking studies enabled the first investigations of where people looked. In one of these early studies, Yarbus (1967) examined the eye tracking patterns of one participant as they viewed a number of face images. He found that the core features of the eyes, nose and mouth formed a triangle and there were very few fixations outside of this area. In addition, he found that the eyes were fixated more than any of the other features on the face. Building on this early work, Walker-Smith, Gale, and Findlay (1977) conducted an experiment where three adult participants completed two different recognition tasks. They found that all participants looked to the features more than the rest of the face, but the specific features that were fixated varied by participant, with two of the participants looking mostly to one of the eyes, and the other participant looking more to the mouth and nose regions. In line with Haig (1985), this highlights the individual differences between participants. Janik, Wellens, Goldberg, and Dellosso (1978) then conducted a larger scale study, using sixteen participants, to examine where people looked when viewing an emotional face image. The participants were asked to report where they were looking on the face image after completion of the task. It was found that all participants identified the eye and mouth regions as the main places looked to. In addition, analysis of the video data collected showed that the participants looked significantly more to the eye region of the face compared to any other region. These early eye tracking studies add to the findings from the behavioural studies in social attention, which show that the eyes are necessary for identity recognition. These early eye tracking studies also show that as well as the eyes being important for recognition, there is also a preference to look to the eyes, even when not completing an identity recognition task.

More recently eye tracking has developed to be more sophisticated with the use of computers and infrared cameras to objectively analyse exactly where people are fixating and sacadding on an image whilst sitting in front of a screen. The use of this technology allows the study of a larger sample of people and commonly uses the measures of dwell time and number of fixations to different ROIs to enable an understanding of for how long (dwell time) and how often (number of fixations) people look to different regions of the screen. As well as these measures, eye trackers also enable the investigation of where someone first looked to (first fixation), what order they looked to the different ROIs (scan pathway) and how long they took to fixate to the different ROIs. This section will focus on the use of eye tracking to establish how much people look to specific regions of the face (dwell time and number of fixations to a ROI), and the issues of first fixations and the amount of time to first fixate to ROIs will be discussed later. Using these new technologies, earlier findings of increased dwell time to the eyes compared to the mouth in the NT population have been replicated (e.g. Brielmann, Bulthoff, & Armann, 2014; Henderson, Williams, & Falk, 2005; Itier, Villate, & Ryan, 2007; Laidlaw, Risko, & Kingstone, 2012).

A large number of eye tracking studies have tried to clarify some of the more complex details of these fixation patterns. For example, Heisz and Shore (2008) examined how fixation patterns changed over time. They examined eye looking patterns to faces over four days as the faces became more familiar. It was found that, overall, the young adult participants looked longer and more often to the eye region, compared to any other feature, as we would expect in line with the previous eye tracking research. In addition, they found that as an image became more familiar to participants fewer fixations were made overall to the face. However, proportionally more fixations were made to the eye region as the image became more familiar and fewer fixations were made to the nose, mouth, forehead, cheek and chin areas of the face.

One interpretation of this reported eye bias is that people are just automatically looking to the top of an image, rather than the eyes specifically attracting attention. This hypothesis was tested by Levy, Foulsham, and Kingstone (2013) who compared looking patterns across a range of characters that did not all have eyes in the traditional place. In this study, three sorts of static computerised images were presented to participants to view; humans, creatures with the eyes on the face (humanoids) and creatures with the eyes on other body parts (monsters). The amount of looking to the human and monster eyes did not differ significantly, although there was slightly reduced looking to the humanoids’ eye regions. This suggests that it is the eyes that are the important feature and not just their location towards the top of the image.

1.3 Eye and mouth looking in ASD

1.3.1. Behavioural studies in ASD Participants

As was the case with studies of social in attention in the NT population, various studies have also been conducted with individuals with ASD to try to understand the importance of the different facial features in face processing. Overall, in participants with ASD it has been found that there is a general deficit for remembering and identifying faces across a range of different paradigms (for a review see Weigelt, Koldewyn, & Kanwisher, 2012). Studies have also investigated the relative importance of the eye and mouth regions in ASD. A popular task is the change detection paradigm, whereby participants have to identify a change to either the eye or mouth region. When presenting images with eye or mouth region displaced, Rutherford, Clements, and Sekuler (2007) found that the autistic adolescents and young adults performed significantly worse for the eye discrimination trials compared to the matched control group, but no difference was seen in the mouth trials. Wolf et al. (2008) presented images that had both featural (size of the feature) and configural changes (distance between features) to the eye and mouth region to children with ASD and a control group. They found the ASD group were less sensitive to both featural and configural changes to the eye region when compared to the control group, but no differences were seen in either mouth condition. Riby, Doherty-Sneddon, and Bruce (2009) also examined the effects of featural and configural changes on the eye and mouth regions in a change detection task in children and adolescents. They found that the TD participants detected changes to the eye region more accurately than those to the mouth area. However, they found the opposite pattern in their ASD group; this group detected changes to the mouth more accurately than changes to the eyes. In addition, using the same stimuli that will be used in the paradigm throughout this thesis Joseph and Tanaka (2003) found that, in a recognition paradigm where either the eyes or mouth had been altered, TD children were more accurate in trials where the eyes had changed and worse in trials where the mouth had changed and the ASD children showed the opposite pattern, with better performance on the eye change trials when compared to the mouth change trials.

However, Bar-Haim, Shulman, Lamy, and Reuveni (2006) did not find this deficit in processing the eye region when they used a probe detection paradigm with ASD children. In this task, a small circle was presented in the horizontal centre of the face, either above the middle of the eyes or below the mouth. Participants had to identify when a probe appeared on the screen as quickly as possible. They found, in upright faces, both ASD and TD participants responded quicker to the probe that appeared above the eyes, compared to the one below the mouth. The authors conclude that that any face processing deficits seen in ASD are not as a result of abnormal allocation of attention across the face stimulus, away from the eye area and that there is a bias to look to the eyes in participants with ASD.

Overall, the previous behavioural research shows reduced accuracy for the eye region, when compared to the mouth region in ASD participants (Joseph & Tanaka, 2003; Riby et al., 2009; Rutherford et al., 2007; Wolf et al., 2008). However, it is important to note these studies all used similar methodology, a change detection task. In comparison, an alternative study using a probe detection paradigm did not find a deficit for eye processing (Bar-Haim et al., 2006). This suggests that the performance of autistic individuals might depend on task-specific constraints or demands. As a result of this, it is important to look at the eye tracking studies that have been conducted and allow further investigation of how attention is allocated on a face stimulus.

1.3.2. Studies of dwell time using eye tracking in ASD

There have been a large number of eye tracking studies aimed at understanding face processing in children and adults with ASD over the last decade, largely as a result of increased access to unobtrusive eye trackers (Sasson & Elison, 2012). In addition, eye tracking also allows a more direct measure of social attention, unlike some of the behavioural studies (Klin, Jones, Schultz, Volkmar, & Cohen, 2002a). Although there appears to be a clear pattern of eye preference in the NT eye tracking studies, the pattern in those with ASD is less clear. It was previously thought that individuals with ASD looked to the eyes less but the mouth more than NT control groups. However, this assumption does not generalise across the full range of tasks, contexts and participants (for reviews see Falck-Ytter & von Hofsten, 2011; Guillon, Hadjikhani, Baduel, & Roge, 2014). As a result of these mixed findings, Chita-Tegmark (2016) conducted a meta-analysis and concluded that there was a small but significant effect size for the eye region, with participants with ASD looking less to the eyes than the NT control groups across studies. Their meta-analysis also revealed a small but significant effect size for the mouth region, with the ASD participants looking less to the mouth than TD participants across the studies. In addition, the meta-analysis showed that ASD participants looked less to the face overall, but spent more time looking to the bodies than the TD controls. The author concludes that this shows atypical attention allocation by the participants with ASD, when compared to the control groups. However, the studies considered in the meta-analysis do show varying results, with some finding clear differences between the eye tracking patterns of the ASD and TD groups and some studies finding no differences at all. Therefore, it is important to look closer at some of these studies to understand the differences that occur.

A summary of studies that have investigated eye and mouth looking in ASD and NT groups are presented in Table 1.1 This table consists of studies from the meta-analysis conducted by Chita-Tegmark (2016) and additional studies that compared the amount of eye and mouth looking between ASD and control groups. This table highlights the range of methodologies, as well as the wide range of results found, allowing a more in-depth look at any emerging patterns. Within this table 33% of the studies found no significant difference in eye tracking patterns for the ASD participants compared to the control groups. In comparison, 33% of the experiments in Table 1.1 also showed a reduced amount of looking to the eye region in ASD (either as an isolated finding or in combination with differences in mouth looking patterns). In addition, 14% of the studies also showed a reduced amount of looking to the mouth in ASD compared to the control groups (again, either as an isolated finding or in combination with differences in eye looking patterns). There were also seven studies identified which only found differences in eye tracking patterns in different conditions of their experiments and not across all conditions. For example, Speer, Cook, McMahon, and Clark (2007) only found reduced eye looking in the social-dynamic stimuli condition, Birmingham, Cerf, and Adolphs (2011) only found reduced eye looking when the body was also visible, not just the head, and Nakano et al. (2010) found different effects for the children with ASD and the adults with ASD.

No clear patterns emerge from the table to suggest that differences in eye gaze are only seen in certain conditions, for example with a specific age group, a specific type of stimuli or a specific task type. For example, reduced eye looking in at least one part of the study was seen in 54% of freeviewing studies, 57% of identity recognition/ memory studies and 56% of emotional recognition studies. The pattern of significance was also investigated across other stimulus characteristics, including whether the face stimuli were static or dynamic, whether the face stimuli was isolated or embedded in a social context, and whether the presentation time was short (less than 500ms) or long. However, there was no suggestion of the findings varying by these characteristics. There were also no systematic differences depending on whether children or adults were tested.

Table 1.1: Summary of studies comparing eye and mouth looking in ASD and control groups

Authors	N	Ages	Matching criteria	ASD IQ/ ability	Task type	Stimuli type	Stimulus presentation time	Comparison of ASD and TD
Anderson et al. (2006)	ASD = 9 (8 male). TD = 9 (8 male).	ASD = 49.6 months. TD = 49.8 months	Age, gender	Mullen = 33.31 months	Freeviewing	Static, colour, photographs of faces.	15s	DT for core features combined: ASD = TD.
Asberg Johnels et al. (2014)	ASD = 11 (10 male). TD = 29 (21 male)	ASD = 52.5 months (9.8). TD = 28.7 months (2.5).	Language comprehension	NR	Freeviewing	Videos of a woman telling a story.	11s	Eye DT: ASD = TD. Mouth DT: ASD < TD.
Auyeung et al. (2015)	ASD = 32 (all male). TD = 34 (all male).	ASD = 36.04 (9.36). TD= 32.8 (9.4).	Age, IQ, gender	IQ = 116.84 (12.85)	Semi-structured interview via video	Real person	5mins	Eye fix: ASD < TD Mouth fix: ASD = TD
Bird et al. (2011)	ASD = 13 (10 male). TD = 13 (gender NR).	ASD = 40.5 (14.5). TD = 32.8 (10.8)	Age	IQ = 115 (14).	Freeviewing	Dynamic clips of social interaction or experimenter talking to camera.	20-98s	Eye DT: ASD < TD. Eye:mouth ratio looking: ASD = TD.
Birmingham et al. (2011)	ASD = 9 (8 male). TD = 5 (5 male).	ASD = 31.6 (12.2). TD = 32.6 (12.66).	Age, IQ	IQ = 108.8 (14.0)	Neutral task (what kind of room is this?), describe task (describe this picture), social attention task (where are people directing their attention?)	Colour photographs of social scenes	15s	Eye DT: ASD < TD (only when body not visible).

Boraston et al. (2008)	ASD = 11 (9 male). TD = 11 (8 male).	ASD = 34.6 (+-9.0). TD = 39.6 (+-11.1)	Age, VIQ, PIQ	VIQ = 118 (+-11.1). PIQ = 120 (+-9).	1. Genuine or fake smile? 2. Smile or neutral?	Colour static individual face images (neutral, genuine smile, fake smile).	2.5s	Eye DT: ASD < TD Eye fix: ASD < TD. Mouth DT: ASD = TD (trending towards ASD > TD). Mouth fix: ASD = TD (trending towards ASD > TD).
Chawarska et al. (2009)	ASD group 1 = 14. ASD group 2 = 30. TD group 1 = 15. TD group 2 = 15. (Genders NR).	ASD group 1 = 26.9 months (6.2). ASD group 2 = 46.4 months (6.4). TD group 1 = 26.3 months (6.5). TD group 2 = 46.3 months (4.3).	Age	NVMA (in months): Group 1 = 23 (9). Group 2 = 37 (12)	Face recognition	Colour static photographs of faces.	10s	Eye DT: ASD group 2 (older) < ASD group 1 & both TD groups. Mouth DT: both ASD groups < both TD groups.
Chawarska et al. (2013)	ASD= 12. High risk TD = 15. Low risk TD = 32. Atypical (non-ASD) = 35.	6 months	Age	N/A	Freeviewing	Dynamic – sometimes looking at camera, sometimes engaging in a task.	3mins	Eye DT: ASD = TD. Mouth DT: ASD = TD.
Corden et al. (2008)	ASD = 18 (13 male). TD = 17 (13 male).	ASD = 32.9 (13.4). TD = 31.9 (11.3).	Gender, age	IQ = 119.9 (11.1).	1. Freeviewing 2. Emotion recognition	Static emotional face images.	2.5s	Eye fix: ASD < TD. Mouth fix: ASD = TD (trending towards ASD > TD).
Dalton et al. (2005): Study 2	ASD = 16 (all male). TD = 16 (all male).	ASD = 14.5 (4.6). TD = 14.5 (4.6)	Age	IQ = 92.1 (27.7)	Identifying familiar photographs (family and friends)	Photographs	NR	Eye DT: ASD < TD. Mouth DT: ASD = TD.

Dalton et al. (2005): Study 1	ASD = 11 (all male). TD = 12 (all male).	ASD = 15.9 (4.71). TD = 17.1 (2.78).	Age	IQ = 94 (19.47)	Discrimination task – emotional or neutral?	Photos of a face with emotional expressions.	3s	Eye DT: ASD < TD. Mouth DT: ASD = TD.
Dapretto et al. (2006)	ASD = 10 (9 male). TD = 10 (9 male).	ASD = 12.38 (2.5). TD = 12.4 (2.2)	Age, IQ.	NR.	1. Freeviewing 2. Imitation of emotion seen	Emotional static single face images	2s	Eye DT: ASD = TD.
de Wit et al. (2008)	ASD = 13 (11 male). TD = 14 (10 male).	ASD = 5.2 (0.8). TD = 4.9 (0.1).	NR	NR	Freeviewing	Colour, static emotional images of one person.	10s	Eye DT: ASD = TD Mouth DT: ASD < TD (marginal).
Gillespie-Smith et al. (2014)	ASD = 21 (20 males). TD group 1 = 21 (15 male). TD group 2 = 21 (14 male). TD group 3 = 21 (18 male).	ASD = 13;7 (30 months). Group 1 = 13;6 (24 months). Group 2 = 8;4 (28). Group 3 = 10;4 (24 months).	Group 1: Age Group 2: Verbal ability Group 3: Non-verbal ability	Verbal ability = 74(27) – British picture ability scale. Non-verbal ability = 27(7) – Ravens coloured progressive matrices.	Freeviewing	Static photos – adults (familiar and unfamiliar)	3s	ASD: Eye DT > Mouth DT All controls: Eye DT > Mouth DT
Grossman et al. (2015)	ASD = 30 (28 male). TD = 3- (25 male).	ASD = 11;10 (1;4). TD = 12.5 (0;11).	Age, sex, IQ, receptive vocabulary	IQ = 107.8 (20.5)	Task 1: Freeviewing Task 2: Look at the person speaking	Dynamic, neutral background, speaking to the camera	4mins 37s	Eye DT: ASD = TD. Eye fix: ASD = TD. Mouth DT: ASD < TD. Mouth fix: ASD < TD.
Guillon et al. (2015)	ASD = 20 (16 male). TD = 21 (13 male).	ASD = 40.7 months (11.5). TD = 43.9 months (14.3).	Age, gender	NVMA = 33.6 months (SD = 12.6). VMA = 281. Months (SD	Freeviewing	Static face only images	3.5s	Right eye DT: ASD > TD. Left eye DT: ASD < TD (only marginal). Mouth DT: ASD = TD.

				= 13.6).				
Hanley et al. (2013)	ASD = 14. TD = 14 (gender NR).	ASD = 20;6 (13;10 – 24;10). TD = 20;4 (13;7 – 24;8).	Age, gender, VIQ, PIQ.	NR.	Freeviewing	Isolated faces: static images, just the face. Social scenes: static, 2 people per scene.	5s	Isolated faces eye DT: ASD = TD. Isolated faces mouth DT: ASD = TD. Social scenes eye DT: ASD < TD. Social scenes mouth DT: ASD = TD.
Hanley et al. (2014)	ASD = 17 (11 male). SLI = 14 (12 male). TD = 16 (6 male).	ASD = 10 (2.1). SLI = 9.6 (0.8). TD = 10 (0.7).	ASD and SLI: Age, verbal ability. ASD and TD: Age, non-verbal ability.	PIQ = 92.9 (13.8). British picture vocabulary scale = 84.5 (12.1).	1. Answering simple questions 2. Watching experimenter tell a story with a puppet	Live interaction with experimenter	1: Average 35s Part 2: NR.	Eye fix: ASD < SLI and TD. (SLI = TD). Mouth fix: ASD = SLI and TD.
Hanley et al. (2015)	ASD = 11 (7 male) TD = 11 (7 male)	ASD = 26 (8.1) TD = 24 (6.03)	Age, gender, VIQ, PIQ	PIQ = 111 (9) VIQ = 120 (14)	Conversation with experimenter	Liver interaction	Roughly 3.5 minutes	Eye DT: ASD > TD Mouth DT: ASD > TD
Hernandez et al. (2009)	ASD = 11 (all male). TD = 23 (all male).	24.09 (range 15-35)	Age, gender	NR.	Freeviewing	Neutral faces and emotional faces of adult males	4s	Eye DT: ASD < TD. Mouth DT: ASD = TD.
Horlin et al. (2013)	ASD = 19 (15 male). TD = 19 (15 male).	ASD = 10.9 (1.1). TD = 10.6 (1.0).	Gender, age.	At least average intelligence.	1. Identity recognition. 2. Emotional recognition. 3. Naturalistic conversation	1. Neutral static faces. 2. Emotional static faces. 3. Live interaction.	NR.	Eye fix: ASD = TD. Mouth fix: ASD = TD
Irwin and Brancazio (2014)	ASD = 10 (8 male). TD = 10 (8 male).	ASD = 10.2 (3.1). TD = 9.6 (2.4).	Sex, age, cognitive functioning and language	General conceptual ability = 92.1 (15.5). Core	Repeat the sounds heard.	Dynamic, single person, speaking facing the camera.	Short clips – exact time NR.	Face DT: ASD < TD. Proportional mouth DT mouth: ASD < TD. DT eyes: NR

			skill.	language index scores = 87.4 (17.3).				
Jones et al. (2008)	ASD = 15 (11 male). TD = 36 (24 male). DD = 15 (11 male).	ASD = 2.3 (0.6). TD = 2.0 (0.7). DD = 2.1 (0.7).	Age, NVMA.	Nonverbal function = 1.77 (0.47).	Freeviewing	Dynamic, actor looking straight into camera	10-38s	Eye DT: ASD < both control groups. Mouth DT: ASD = TD.
Jones and Klin (2013)	ASD = 11 (all male) – 10 from high risk and 1 from low risk groups. TD = 25 - all from low risk group)	2-24 months (longitudinal)	Age	N/A	Freeviewing	Dynamic – female adult looking into the camera and playing games with child	NR	ASD children's eye DT declines from 2-24 months (at 24 months they are half the level of TD)
Kirchner et al. (2011)	ASD = 20 (15 male). TD = 21 (15 male).	ASD = 31.9 (7.6). TD = 31.8 (7.4).	Age, years of education, IQ, gender.	IQ = 112.6 (11.6).	Emotion recognition and face identity.	Static, naturalistic photographs	4.5s	Eye DT: ASD = TD. Mouth DT: ASD = TD.
Klin et al. (2002b)	ASD = 15 (all male). TD = 15 (all male).	ASD = 15.4 (7.2). TD = 17.9 (5.6).	Age, VIQ.	VIQ = 101.3 (24.9).	Freeviewing	Dynamic: complex social interactions	30-60s	Eye DT: ASD < TD. Mouth DT: ASD > TD.
Moriuchi et al. (2017)	ASD = 26. TD = 38. DD = 22	All children = 24.9 months (7.5).	Sex, age, non-verbal cognitive ability matching to TD group.	N.R.	Freeviewing	Dynamic	N.R.	Eye DT: TD & DD > ASD

			Sex, age, verbal cognitive ability matching to DD group.					
Nakano et al. (2010)	ASD children = 25 (21 male). TD children = 25 (14 male). ASD adults = 27 (18 male). TD adults = 27 (16 male).	ASD children = 4;11 (2;8-9;0). TD children = 3;1 (1;2-7;9). ASD adults = 29.5 (sd = 7.4). TD adults = 32.1 (11.8).	TD children: chronological age matched to developmental age of ASD children. TD adults: matching NR.	Children: Mean developmental age = 3;1 (sd = 1;10). Adults: NR	Freeviewing	Dynamic, interactive, talking.	6s	Eye DT: ASD adults < TD adults; ASD children = TD children. Mouth DT: ASD adults = TD adults; ASD children < TD children.
Neumann et al. (2006)	ASD = 10 (all male). TD = 10 (all male).	ASD = 23 (+/- 2). TD = 28 (+/- 3).	IQ, age, gender	IQ = 104 (+/- 5).	Classifying the emotion	Static, emotional and neutral faces.	Until participant completed task (up to 10s).	Eye DT: ASD = TD. Mouth DT: ASD = TD.
Norbury et al. (2009)	ASD language impaired (LI) = 14. ASD language normal (LN) = 14. TD = 18.	ASD LI = 14.9 (1.2). ASD LN = 14.9 (1.4). TD = 14.5 (0.9).	Age, NVIQ.	ASD LI: NVIQ = 96.6 (15.7) VIQ = 81.9 (22.8). ASD LN: NVIQ = 99.7 (14.3) VIQ = 101.9 (16.3).	Freeviewing	Dynamic, social interaction.	20-36s	Eye DT: ASD LI = TD; ASD LN < TD Mouth DT: ASD = LI; ASD LN = TD.
Pelphrey et al.	ASD = 5 (all	ASD = 25.2	NR	IQ = 100.75	Phase 1: Freeviewing.	Greyscale static	2s	Across both tasks:

(2002)	male). TD = 5 (all male).	(19.1-30.2). TD = 28.2 (25.2-32.2).		(7.69).	Phase 2: emotion identification.	face images – Eckman (6 emotions).		Eye DT: ASD < TD. Mouth DT: ASD = TD.
Riby and Hancock (2008)	ASD = 20 (15 male). TD group 1 = 20 (14 male). TD group 2 = 20 (13 male).	ASD = 13;4 (48 months) Group 1 = 13;3 (48 months). Group 2 = 5;3 (17 months).	Group 1: Age matched Group 2: Non-verbal ability matched.	Ravens coloured progressive matrices = 13 (4).	Freeviewing	Static colour images of social scenes.	5s	Eye DT: ASD < both TD groups. Mouth DT: ASD = both TD groups.
Riby and Hancock (2009)	ASD = 20 (15 male). TD group 1 = 20 (14 male). TD group 2 = 20 (13 male).	ASD = 13;4 (48 months). Group 1 = 13;3 (48 months). Group 2 = 5;3 (48 months).	Group 1: Age matched. Group 2: Non-verbal ability matched	Ravens coloured progressive matrices = 13(3)	Freeviewing	1. Static colour images of social scenes. 2. Dynamic social scenes.	5s	Eye DT (dynamic stimuli): ASD < both TD groups. Eye DT (static stimuli): ASD = TD. Mouth DT (both stimuli): ASD = TD.
Rice et al. (2012)	ASD = 37 (30 male). TD = 26 (18 male).	ASD = 10.0 (2.3). TD = 9.5 (2.2).	Gender, age, FSIQ, NVIQ, VIQ.	IQ = 112 (15.2).	Freeviewing	Dynamic social scenarios	5-7s	DT eyes: ASD < TD. DT mouth: ASD < TD.
Rutherford and Towns (2008)	ASD = 11 (all male). TD = 11 (all male).	25;7 (range 19-38)	sex, age, IQ & education	NR.	Matching face with emotion	Photographs of single face	NR.	Eye DT: ASD = TD. FLs: ASD = TD
Sawyer et al. (2012)	ASD = 29. TD = 24 (genders NR).	ASD = 21.6 (9.8). TD = 24.0 (9.2)	Age, VIQ, NVIS, FSIQ	IQ = 108.1 (17.9).	1. Freeviewing 2. Emotional recognition	Static photographs of basic emotions and complex mental states.	1. 5s 2. Until decision was made	DT eyes: ASD = TD DT mouth: ASD = TD
Sepeta et al. (2012)	ASD = 20 (19 male).	ASD = 12.4 (2.5).	Age, PIQ	IQ = 106 (20)	Freeviewing	Static emotional face images.	2s	DT eyes: ASD = TD.

	TD = 18 (17 male).	TD = 13.7 2.7).						
Snow et al. (2011)	ASD = 22 (21 male). TD = 21 (17 male).	ASD = 15.96 (2.44). TD = 16.81 (1.9).	Age and IQ	IQ = 111.5 (17.57)	Identity memory task	Static images of black and white faces with facial features (hair, neck, ears) removed.	2.5s	Eye fix: ASD = TD Mouth fix: ASD = TD.
Speer et al. (2007)	ASD = 12 (all male). TD = 12 (all male).	13.6 (2.7)	Gender, age and verbal intelligence	VIQ = 96.3 (15). PIQ = 104.5 (17.66).	Memory questions at the end	Social dynamic, isolated-dynamic, social-static and isolated-static stimuli	Static = 10s. Dynamic = 21-69s	Social dynamic stimuli eye DT: ASD < TD. Other stimuli eye DT: ASD = TD.
Spezio et al. (2007a)	ASD = 8 (all male). TD = 5 (all male).	ASD = 23 (18-40). TD = 28 (20-40).	Age, PIQ, VIQ, FSIQ	IQ = 107 (83-133).	Emotional judgement	Cropped Ekman faces	Until the participant made a judgement (up to 10s).	Right eye DT: ASD < TD (when one outlier removed). Left eye DT: ASD = TD. Mouth DT: ASD > TD.
Spezio et al. (2007b)	ASD = 8 (all male). TD = 10 (all male).	ASD = 23 (18-40). TD = 28 (20-40).	Age, PIQ, VIQ, FSIQ	IQ = 104 (83-128).	Emotional judgement	Cropped Ekman faces	Until the participant made a judgement or 10s	ASD = Greater reliance on the mouth and decreased use of both eyes. More likely to saccade away from the eyes.
Sterling et al. (2008)	ASD = 17 (16 male). TD = 18 (27 male).	ASD = 23.5 (7.19). TD = 24.2 (6.86).	Age, FSIQ	IQ = 107.1 (13.3).	Freeviewing	Greyscale photographs of faces	8s	Eye fix: ASD < TD. Mouth fix: ASD < TD. Eye DT: ASD < TD. Mouth DT: ASD < TD.
van der Geest et al. (2002)	ASD = 17 (all male). TD = 17 (16 male).	ASD = 10.6 (2.1). TD = 10.1 (1.3).	FSIQ, VIQ, PIQ.	IQ = 95.1 (15.1).	Freeviewing	Colour photographs of emotional faces	10s	Eye fix: ASD = TD. Mouth fix: ASD = TD. Eye DT: ASD = TD. Mouth DT: ASD = TD.
Wagner et al. (2013)	ASD = 18 (all male).	ASD = 17 (2.2). TD = 17.9 (2.5)	Age, IQ.	IQ = 111.2 (18.1).	Freeviewing	Colour photographs of	5s	Eye DT: ASD = TD. Mouth DT: ASD = TD.

	TD = 20 (all male).					emotional faces.		
Wilson et al. (2012)	ASD = 11 (7 male). TD = 11 (6 male).	ASD = 10.2 (2.0). TD = 10.5 (2.0).	Age	WASI matrices = 45.7 (11.6).	Forced choice face recognition	Greyscale static images of adult faces.	3s	Eye DT: ASD = TD. Mouth DT: ASD = TD.
Yi et al. (2014)	ASD = 19 (14 male). TD = 28 (22 male). LD = 22 (18 male).	ASD = 20.84 (sd = 3.27). TD = 20.61 (sd = 2.90). LD = 23.59 (sd = 3.08).	TD matched on age. LD matched on IQ.	Combined Raven's test = 23.67	Memory test	Static, greyscale, front view, neutral expressions, elliptical shape (no hair, neck etc.)	Familiarization phase = 3s	DT right eye: ASD < TD and LD DT left eye: ASD = TD = LD. Proportional DT mouth: ASD = TD = LD.
Yi et al. (2013)	ASD = 20 (17 male). TD group 1 = 20 (18 male). Td group 2 = 20 (18 male).	ASD = 7.85 (1.51). TD group 1 = 7.73 (1.51). TD group 2 = 5.69 (0.83).	Group 1 = IQ. Group 2 = Age.	Combined Raven's test original = 21.53 (8.78), standardized = 77.16 (19.55)	Memory test	Photos of Chinese female adult	3s	Right eye DT: ASD < TD. Left eye DT: ASD = TD. Mouth DT: ASD = TD.
Zamzow et al. (2014)	ASD = 12 (9 male). TD = 14 (10 male).	ASD = 18.25 (SD = 2.66). TD = 19.36 (SD = 2.02).	Case wise matching for age, sex, IQ.	IQ = 103.5 (13.04).	Freeviewing	Dynamic – front on view of human faces	10s	Eye DT: ASD = TD. Mouth DT: ASD = TD.

DT = Dwell time; Fix = number of fixations; FSIQ = full scale IQ; VIQ = verbal IQ; PIQ = performance IQ; NVMA = non-verbal mental age; VMA = verbal mental age; WASI = Wechsler Abbreviated Scale of Intelligence; SLI = specific language impairment; DD = developmental delay; LD = learning disability

1.3.3. Combining behavioural and dwell time studies in ASD

As demonstrated above, many studies have investigated where autistic individuals look during face processing tasks. However, there is less investigation of how dwell time patterns may or may not influence the ability to successfully extract relevant information from a face (e.g. identity, emotion). One of the main limitations of pure eye tracking studies is that they only tell us the centre of someone's fixation and not the amount of information they are successfully extracting from that central fixation, as well as their peripheral vision. The obvious solution to this limitation is to combine measurement of eye gaze with measurement of some aspect of face processing ability and collect these measures simultaneously.

Limiting face processing studies to just investigating dwell time can be particularly restricting in studies with clinical populations. It is presumptive to assume that atypical looking is accompanied by impaired ability to extract relevant facial information, just as it is presumptive to assume that typical eye gaze reflects adequate ability to 'read' faces. One group of studies that often use both eye tracking and behavioural data together to better explore face processing in ASD are emotional recognition paradigms. For example, Rutherford and Towns (2008) found no difference in emotion recognition ability in ASD and TD adults and also found no significant difference in eye tracking patterns to the eye and mouth regions. However, Sawyer et al. (2012) and Pelphrey et al. (2002) found that autistic adults were less accurate at identifying emotions, compared to the TD controls, but as with the previous study did not show significantly different eye tracking patterns. This highlights the importance of collecting both behavioural and eye tracking data together, as the latter two studies suggest typical eye gaze is not sufficient to produce adequate emotion recognition. One interpretation is that these participants are not able to extract useful information from the facial regions they fixate on. Another group of studies that use eye tracking and behavioural measures simultaneously are those that study identity recognition and memory. However, the findings are mixed. For example, although Snow et al. (2011) and Wilson, Brock, and Palermo (2010) both found an impaired memory for faces in their ASD groups (adolescents and children respectively), Wilson et al. (2010) found comparable looking patterns across the face for the ASD and control groups while Snow et al. (2011) found subtle differences in the eye tracking patterns for areas outside of the key features.

As has been discussed, simultaneous data collection can be considered very important as it allows an understanding of both where people are looking and how successfully they are extracting the information from the stimuli. However, the findings from the limited number of studies that have collected these data simultaneously have been mixed, with one study finding no differences in either behaviour or eye tracking between the ASD and control groups, one finding differences in both eye tracking and behavioural measures, and the others all finding differences in behaviour, but not eye tracking. By continuing to collect behavioural and eye tracking data simultaneously it will help to build a more stable set of findings across a range of different samples and paradigms. As a result, in future it would enable more definitive conclusions to be drawn on how successfully people are extracting relevant information from the stimuli.

1.4 The use of alternative eye tracking measures

The most commonly used eye tracking measures in face processing tasks are dwell time and the number of fixations to ROIs. However, both the location of the first fixation on the face and how long it takes to fixate on key facial regions have also been used in some experimental paradigms. These measures enable us to move towards understanding some of the more complex patterns of face processing.

1.4.1 NT studies of first fixation locations

Some studies with NT participants have found that the first fixation on a face image is actually to the centre of the image and not to any of the features. In a recognition paradigm Bindemann, Scheepers, and Burton (2009) presented university students with face images in a variety of different orientations and found the first fixation was most often to the centre of the image, before participants moved their gaze to look towards features. Similar patterns have been seen in a paradigm presenting different sorts of figures (humans, humanoids and monsters; Levy et al., 2013). In addition, Birmingham, Visser, Snyder, and Kingstone (2007) found the second fixation of a complex scene made by undergraduate students was often to the eye area and the authors did not investigate first fixation location as they felt the first fixation was needed to orient to the unpredictable scene. Walker-Smith et al. (1977) speculate that this initial central fixation allows the participants to move their subsequent fixations to their preferred feature after they have identified the image as a face. This idea of a central orienting fixation fits with the other studies outlined above, as in each the stimuli presented were either unpredictable or in an unpredictable location and therefore a central fixation was necessary before the eyes moved to more meaningful areas of the image.

Although a central orienting fixation occurs in some paradigms, others have found that this is not always needed to successfully orientate to the meaningful regions of the face and sometimes the first fixation is a meaningful measure of looking (Peterson & Eckstein, 2012). Crucially, the face images presented by the researchers were consistently the same size, in the same location and with the same orientation, ensuring that the location of the different features was predictable. The authors found that in identity recognition and gender identification tasks, the first fixations ranged from between the eye and the nose area. However, the first fixations for the emotion recognition tasks were further down the face, which is in line with Smith, Cottrell, Gosselin, and Schyns (2005) findings of eye gaze patterns for an emotional recognition task. This suggests that the first fixation does not have to be a central orienting fixation when the images are predictable. In addition, when completing an identity recognition paradigm the first fixation is most often in the eye and nose area of the face, although it is important to note the different patterns seen across different task types.

These findings suggest that to use a meaningful measure of first fixation location it is important the stimuli used are predictable and consistent to avoid the need for an orienting fixation. When this need for an orienting fixation is removed this first fixation is then often to the eye area of the face, suggesting that there is an initial bias to look to the eyes in the NT population.

1.4.2 ASD studies of first fixations

As shown through the studies above, the use of the measure of first fixations can be useful in further explaining the bias to look to the eyes in NT populations, as long as an orienting fixation is not required. This measure is also useful to utilise in individuals with ASD to further understand whether this population look to the eyes as much, and in the same way, as NT populations. A bias for ASD participants to have their first fixation on social content in scenes has been shown in a variety of paradigms, including person present versus person absent scenes (Fletcher-Watson et al., 2009), looking at people in a scene before the objects in the scene (Wilson et al., 2010), and looking to the face of a magician completing a magic trick with the first or second fixation, rather than the trick (Kuhn, Kourkoulou, & Leekam, 2010). However, although all of these paradigms did result in the ASD participants looking to the social information in the scene initially, there are some important group differences to be aware of. In the study by Fletcher-Watson et al. (2009) a significant interaction was found, suggesting that although both groups did look to the person present scenes more than to the person absent scenes, there were significantly more first fixations to this scene for the NT adults and adolescents when compared to the ASD adults and adolescents. A similar group difference was found by Kuhn et al. (2010) with a magic trick paradigm as they found that the autistic young adults were less likely to attend to the face with their first fixation when compared to the NT control group.

The previous studies have outlined that there may be an initial bias to attend to a person or a face in ASD. However, it is important to also look more specifically at the different facial features, as the eyes appear to be the most important feature for social interaction, as has previously been discussed. A bias for first fixations to the eyes in ASD has been seen in studies that use both children with ASD (van der Geest et al., 2002) and adults with ASD (Rutherford & Towns, 2008; Sawyer et al., 2012). However, it is interesting to note that Rutherford and Towns (2008) also found a lot of within group variability for the ASD and NT groups, but each participant's patterns were relatively stable. This may suggest there are some individual differences within the preference of where to first fixate and this individual difference exists both in NT and ASD participants. It is also important to note the researchers drew quite large ROI boxes around both the eye and mouth regions and these boxes were the same size as each other, even though the eyes take up more room on a face. Subsequently, the mouth ROI included an area that was off the side of the face and therefore not representative of the mouth area.

The studies looking at first fixations in ASD suggest that individuals with ASD do orient towards social stimuli when initially viewing a stimuli, although it may be less than NT control groups. However, there does appear to be a bias to look at the eyes first when viewing an isolated face stimuli and this bias appears to be the same for the ASD and NT participants. These are surprising findings, especially considering the diagnostic criteria and personal experiences discussed in section 1.1 (see page 2). However, it is also true that there has been very limited investigation of first fixations compared to other measures of eye gaze. Therefore, it is important that further work is undertaken to understand first fixations to the eyes in a variety of paradigms in ASD.

1.4.3 Time to first fixate in NT and ASD participants

An even lesser used eye tracking measure to assess orientation to social stimuli is the amount of time it takes to first fixate on the ROI. As this measure is used so infrequently, studies for both NT and ASD participants will be considered together. The findings when using the measure of the time to first fixate on social stimuli are mixed. When using social scenes alongside geometric shapes, Shi et al. (2015) found no differences in the amount of time it took children to first fixate on either of these images. However, Wilson et al. (2010) found that TD children fixated quicker on the people in natural scenes than the autistic children. In addition, when presenting young adult participants with magic tricks Kuhn et al. (2010) found that NT participants fixated on the face area faster than the ASD participants.

The time to first fixate measure has also been used to examine how long it takes to look at specific features on the face. Studies have found no difference in the time to first fixate to the eye or mouth ROIs in groups of ASD children and adolescents when compared to a control group for both static (Gillespie-Smith et al., 2014) and dynamic stimuli (Grossman et al., 2015). In contrast, Freeth, Chapman, Ropar, and Mitchell (2010) used complex static social stimuli and found that their group of autistic adolescents were significantly slower to first fixate the face region. Notably, the ASD group were faster to first fixate one of the objects in the scene and, therefore, the authors concluded this slower time to first fixate the face was unlikely the result of a slower processing speed. Norbury et al. (2009) also found slowed first fixation to the eye ROI for dynamic stimuli but only for adolescents with ASD who did not have language impairment.

In summary, the findings for the time to first fixate on people or faces is mixed, with some studies suggesting a delay in orienting to the eye region in ASD and others suggesting there is no difference to the control groups. This suggests there may be a delay in orienting to the eyes in some participants with ASD, but this needs further investigation to understand whether this only occurs in certain paradigms or situations.

Considering the time to first fixate measure alongside the first fixation measure should enable a greater understanding of where both NT and ASD individuals look initially, and perhaps automatically, when viewing a social stimulus. The limited studies that have been conducted looking at first fixations on a face suggest that participants with ASD have a bias to initially fixate to the eye region, however the limited number of time to first fixate studies do not show such a clear pattern of results. The use of these measures in the same paradigm with the same participants would be useful to enable further understanding of the initial eye tracking patterns in ASD and how these two measures relate to each other.

1.4.4 Gaze following in NT and ASD participants

An alternative way to consider whether people look to the eye region and how this information is spontaneously attended to is through gaze following paradigms. These experiments typically present a face or whole person on the screen that moves their gaze in a certain direction or towards a specific object. Participant response to this gaze can be measured either by RT to respond to a target object or through the use of eye tracking. This ability to follow gaze direction is seen from a young age in TD individuals. For example, it has been found that children as young as twelve months old are able to respond to objects cued by an adult's gaze (Tatler, Hayhoe, Land, & Ballard, 2011). This effect is also consistently seen in adults, for example in one study participants would look to the actors eyes and then to the object that the actor was looking at to understand the scene that was presented to them (Castelhano, Wieth, & Henderson, 2007). In addition, in a real life interaction, adults were able to use the gaze cues given in conversation to fixate on the correct target piece when completing a construction task (Macdonald & Tatler, 2013).

Numerous studies have used different types of gaze cueing paradigms to compare performance of ASD and NT individuals to understand how those with ASD process the eye region. Although using very different methodology, these studies have all found no group differences between the ASD group and the NT control groups. Using a novel paradigm, Freeth, Ropar, Chapman, and Mitchell (2010) presented stimuli with either a person looking out towards the camera or gazing towards an object in the scene and asked the adolescent participants to draw a frame around the image so that the image made sense to them. When gaze was towards the camera both groups framed the person in the centre of the image, suggesting the person was the key element of the scene. However, interestingly when the person was gazing at an object both groups seemed to spontaneously attend to the eye gaze and include the gazed object as a central part of their framed image. In addition, a second experiment was conducted whereby the participants had to detect which item was missing on the second presentation of the image. Both the ASD and TD participants detected this change quicker when it was the object being gazed to by the actor in the scene. In a further study, Freeth, Ropar, Mitchell, Chapman, and Loher (2011) found no difference in the amount of gaze direction mentioned by the two groups of adolescents when they were asked to describe the scene in front of them. Comparable results have also been seen in an eye tracking study which found that there was no difference in gaze following between a group of ASD adolescents and a TD control group, suggesting they both spontaneously followed gaze to the same extent (Freeth, Chapman, et al., 2010).

Research involving the use of visual illusions within magic tricks can be important for understanding the role of gaze following, as magic tricks often use subtle social cues to misdirect attention. In one study the illusory ball trick was used to establish whether NT adult participants would automatically look to the experimenter’s eyes to infer information about the trick that was being performed (Kuhn & Land, 2006). In this trick the experimenter throws a ball up to catch it whilst following the ball with his eye gaze twice and then on the third trial pretends to throw the ball up whilst concealing it in his hands, either following the imaginary ball with the eyes (pro-illusion condition) or looking down to his hands (anti-illusion condition). More participants in the pro-illusion condition reported seeing the ball than in the anti-illusion condition and often stated they had seen the ball disappear off the top of the screen and the illusion was created by someone catching it above the screen. In addition, most of the participants claimed they spent the whole time looking at the ball, despite looking to the eyes most of the time. The same paradigm was later used to compare looking patterns and susceptibility to the illusion in young adults with ASD and a NT control group (Kuhn et al., 2010). In this study, it was found that there was no difference in the amount of time that the ASD and NT groups spent looking to the eyes and that the ASD group were even more susceptible to the illusion, than the NT group. This again suggests that both the ASD and NT participants were spontaneously looking to the eyes and extracting information from the gaze direction, without being instructed to do so.

Overall, the gaze following data presents a perhaps surprising picture considering the diagnostic criteria and common understanding that autistic individuals have atypical levels of eye contact. The previous studies suggest that both NT and ASD groups spontaneously attend to the eye region and then spontaneously follow the gaze from the eyes to look to other objects. Again, these findings suggest that it is important to further investigate how instinctively or automatically autistic individuals attend to the eye region in a range of different paradigms and using a range of different eye tracking measures.

1.5 Changing fixation patterns in line with an instruction

As has been described, social stimuli, especially the eyes, appear to capture attention and elicit greater recognition for NT individuals. In addition, although the findings are mixed in ASD, many studies suggest ASD individuals do look to the eye region and that their early fixations to the eyes are automatic. Understanding the orientation of automatic looking in autistic individuals is important as it helps us to understand any biases that exist in ASD and whether or not this is to social stimuli. Increased information on this automatic bias would enable further understanding of the symptom presentation in ASD and the drives behind these symptoms, i.e. having a bias to look to social stimuli but inhibiting this drive in daily life, or not having a bias to look at social stimuli in the first place. Therefore understanding whether or not there is an automatic bias to look to the eyes in autistic individuals would enable further understanding of those with autism and what drives any difficulties with social interaction they may experience in daily life. To enable further understanding of how automatic these fixation patterns are, a small number of studies have attempted to manipulate participants' gaze direction through a range of different paradigms to see if it is possible to change these face processing patterns.

1.5.1 Changing fixation patterns in NT individuals

A variety of paradigms have been used to investigate how successfully NT participants' gaze can be altered when viewing face stimuli in a range of different situations. One way of investigating this is by using magic tricks that normally rely on being able to predict where a person will automatically look. In an experimental manipulation, natural looking patterns, which typically lead to the viewer being tricked, can be compared to looking patterns when the individual is instructed on where to look. In one study it was found that an instruction to look to an alternative location, rather than the eyes, had some success, but the adult participants were unable to fully follow this instruction (Kuhn, Teszka, Tenaw, & Kingstone, 2016). In this paradigm participants watched a card trick and were told their task was to work out how it was done. Half of the participants were explicitly told to keep looking at the cards, as magicians often use misdirection, and the other half were not given any further instruction. Participants who were given this explicit instruction did fixate more on the cards and looked to the face less than those that received no instruction. However, despite this explicit instruction less than 5% of the participants instructed to only look at the cards managed not to look at the face at all during the interaction. This, therefore, suggests that the automatic and initial tendency to fixate on the face, is difficult to fully overcome and can only be partially moderated by explicit instruction.

The findings in this magic trick study are supported by the findings in a look/ don't look paradigm, which also found that adults had difficulty following instructions to not look at the eyes (Laidlaw et al., 2012). The participants completed a "don't look" (DL) task, where half were to avoid looking to the eyes (DL: eyes) and the other half the mouth (DL: mouth) for the five second presentation time. Although participants in both DL conditions reduced their fixation count and dwell time to the eyes and mouth respectively, those in the DL: eyes condition made significantly more errors (looked to the eyes significantly more) than those in the DL: mouth condition. In addition, when comparing the fixation count and dwell time to the amount of looking that would be expected if viewing was random across the screen, those in the DL: eyes condition looked more to the eyes than would be expected by chance, however, those in the DL: mouth condition looked to the mouth less than would be expected by chance. The authors also divided up the viewing time into the first second (early viewing period) and the remaining viewing time (late viewing period) to compare if inhibiting looking was easier to control with more time available to participants. They found that the amount of errors regarding DT for the DL: eyes condition, was significantly greater in the early viewing period, compared to the late viewing period, however both of these viewing periods resulted in more time viewing the eye region than would be expected by chance. This same effect was not seen in the DL: mouth condition, where there was no difference in the DT errors for the early and viewing periods.

Although the previous studies present a clear picture of the difficulties in not looking to the eyes, either when explicitly instructed not to or when instructed to look elsewhere, a study conducted by Itier et al. (2007) presents a slightly more complex picture. The authors attempted to manipulate adults' gaze patterns to a static face stimulus by providing the participants with two different tasks, one that required them to fixate the eyes and one that did not. Firstly, participants completed a gaze direction task, where they had to state whether the person in the image was looking at them or away. Secondly, they completed the head direction task where they had to distinguish between the images where the head was straight on and those where the head was in a ¾ view. In this second task participants were explicitly told they did not need to look at the eyes. It was found that there was significantly higher dwell time for the eye region in the gaze condition, compared to the head condition, however, there was more looking to the eye region than the lower face in both of these conditions. In addition, the authors used the measure of first fixations to understand whether participants would always look to the eye region first, and therefore that eye looking was reflexive and automatic, or whether this eye looking depended on the task being completed. They found that there were more initial saccades made to the eye area than the lower face area in the gaze task. However there were no differences between the number of eye and mouth first saccades in the head condition. The authors conclude that although there is a bias to look to the eyes in both tasks, this bias to initially saccade to the eye region appears to be task dependent.

These three different tasks all try to understand how successfully a NT adult's gaze can be changed in line with either a direct or an indirect instruction. They all show that, to some extent, there is a bias to look to the face or the eyes and that this looking still occurs even when participants are told not to or told it will not help them to complete the task. Laidlaw et al. (2012) propose that this difficulty to fully look away from the eyes even when told to do so represents an automatic component of eye looking, which is not under volitional control. These previous studies could also be considered within a top down and bottom up theoretical framework of attention. Top down attention is the process of voluntarily allocated attention to look to certain objects or features, whereas bottom up attention is not voluntarily directed and is the result of salient stimuli attracting attention (Carrasco, 2011; Corbetta & Shulman, 2002; Desimone & Duncan, 1995; Ungerleider & G, 2000). Therefore, these previous studies could suggest that although the majority of face looking is under volitional control, or with top down attention being dominant, there does appear to be a bottom up attention component that is more automatic. This is characterised by the difficulty in fully inhibiting looking to the eyes in the don't look paradigm (Laidlaw et al., 2012), the low number of participants who managed to not look to the eyes during the magic trick (Thomas & Didierjean, 2016) and the bias to look to the eyes in Itier et al.'s task.

These three previous paradigms considered together suggest that it is possible to reduce eye looking to some extent in line with an instruction, indicating there is some control over looking patterns, but the eyes do seem to draw attention and this is partly an automatic orientation that is not possible to fully overcome.

1.5.2 Changing fixation patterns in ASD individuals

As has been shown, some of the face processing fixation patterns in the NT population do appear to be difficult to change even when explicitly instructed to do so. This difficulty in consciously changing the way people look at faces may suggest that, to some extent, face processing patterns may be automatic, with people being drawn to the eye areas and struggling to change this even when explicitly told to do so. In ASD, however, there are many varied findings regarding face processing patterns in the previous research. This variation may suggest that the patterns of dwell time vary depending on the task and the paradigm in question. Subsequently, it could be argued that autistic individuals may not have such dominant automatic processing patterns and that their patterns of eye gaze may be easier to change. Alternatively, it could be that there are subgroups within ASD and that the variety seen is not as a result of task demand and if this is the case it is less clear how easy the face processing patterns of these groups would be to change.

There have been a limited number of studies investigating changing looking patterns towards faces in those with ASD and these studies use different paradigms and have drawn varying conclusions. One study used a gaze following task (as outlined in section 1.4.4, see page 26), but with a cued condition whereby children were instructed to identify the object being looked at (Riby, Hancock, Jones, & Hanley, 2013). The authors found that the ASD participants did not automatically look to the eyes and follow the gaze in the spontaneous condition, but the participants also did not change their gaze patterns to do this in the cued condition either. This suggests the ASD participants were not able to alter their looking patterns in line with an instruction in this paradigm. In contrast to this, Kikuchi et al. (2011), using a gap overlap task where a face is the central distractor, found that although ASD children did not look automatically to the eyes they were able to alter their looking patterns to look at the eyes when instructed. Different findings were found in a gaze cueing task where the eyes were looking at objects on either side of the screen (Rombough & Iarocci, 2013). The children were told whether they should look to the eyes to help them to complete the task or whether they should avoid looking to the eyes. In this task both the ASD and TD groups looked to the eyes regardless of the instruction and as a result showed poorer performance on the trials where the gaze direction was invalid and therefore the eyes were only being used as a distractor.

In summary, only a limited number of studies have investigated changing face gaze patterns and a wide range of methodologies have been used. The NT studies (Kuhn et al., 2016; Laidlaw et al., 2012) suggest that it is difficult for people to look away from the eyes even when explicitly instructed to do so. This may suggest that people automatically orient to the eye region and this may be out of their top down attentional control and is instead a bottom up process. However, the picture in the ASD studies is not as clear, with one study suggesting the participants were able to alter their looking patterns in line with a prompt (Kikuchi et al., 2011), but two suggesting difficulty altering face gaze patterns, either a difficulty in orienting to the eyes under instruction (Riby et al., 2013) or difficulty orienting away from the eyes under instruction (Rombough & Iarocci, 2013). There is not a clear picture across these studies of whether looking to the eyes is a bottom up or top down process for those participants with ASD, as the findings are contradictory. This again highlights the varied results seen in ASD research and the importance of trying to understand face gaze patterns further. This is especially important in ASD due to the social and communication difficulties experienced by those with a diagnosis. Further research to understand whether those with ASD can alter their looking patterns when looking at a face will help to establish whether there is an automatic bias to look to social stimuli (i.e. the eyes) which could result in further understanding of the behaviours of those with ASD and enable further understanding and support for the reasons behind these behaviours.

1.6 Summary and thesis outline

1.6.1: Summary of the literature

The social attention literature for the NT population of adults and children clearly demonstrates, across measures of dwell time, first fixation, time to first fixate and gaze following, that the eyes are the primary area of importance on the face. The behavioural presentation of ASD and theories of social attention in ASD would predict that a clear pattern of deficit in eye looking would be found in ASD. However, there are a mixture of findings regarding the amount of time looking to the eye and mouth regions on a face, with some finding no difference with NT groups, but others finding either a reduction of eye looking, mouth looking, or both. However, most literature does suggest some difficulty with face processing tasks in ASD, specifically those that rely on the eye region. Contrary to this, the limited amount of research that has been conducted on first fixations to the face regions suggest that autistic individuals look first to the face as much as the NT control groups. In addition, the research on whether looking patterns can be altered successfully in response to specific instructions in ASD is mixed; it is unclear whether those with ASD are able to alter their looking patterns in line with a prompt or whether they have a difficulty changing their automatic looking patterns. This suggests a complex picture of empirical evidence that warrants further investigation.

1.6.2: Thesis outline

This thesis will build on the previous literature with the aim of understanding more about face processing patterns in both the NT and autistic populations. Specifically, this thesis will use a novel prompting paradigm, embedded within a face recognition task, to investigate both unprompted and prompted looking patterns. The aim of this paradigm is to investigate whether aspects of face processing are automatic or under volitional control (as discussed by Laidlaw et al., 2012). It is important to understand automatic patterns of looking in ASD to aid further understanding of their profile of social communication difficulties.

Chapter 2 will involve secondary data analysis of a large sample of 14-16 year old adolescents with ASD and an age and IQ matched comparison group. This chapter will enable exploration of the behavioural data collected (accuracy and RT) on a large sample in a forced choice recognition task and explore any differences that may result from IQ or social communication measures.

Chapter 3 will demonstrate the use of the same paradigm with the addition of eye tracking measures in a sample of NT adults. This will enable the study of both where people are looking and how successfully they are completing the task (measured through accuracy and RT data). This chapter will allow the study of how successfully participants are able to follow an instruction to look to a certain ROI, or whether there is difficulty looking away from the eyes, as has been found previously in alternative paradigms.

Chapter 4 will then develop this combined eye tracking and behavioural paradigm for use in a large sample of TD children. This will enable investigation of whether the same eye tracking patterns are seen in TD children as in NT adults. The task will be adapted for use with children and a control task implemented, to aid interpretation of the data. In addition, the chapter will investigate individual differences, as previous research has suggested some person by person variation in where people look when viewing a face image.

Chapter 5 will use the eye tracking and behavioural paradigm developed in Chapter 4 in a group of matched ASD and TD children. This will allow a comparison of a range of eye tracking and behavioural measures across the two groups of children. This will be the first study to allow a comparison of three different eye tracking measures (dwell time, first fixation location and time to first fixate), as well as behavioural measures on one task between ASD and TD participants.

Finally, Chapter 6 will provide a summary of the key findings and the main implications. There will also be a discussion of the key strengths and limitations, as well as ideas for future research.

For ease of reference when reading this thesis a summary of the key findings from each chapter can be found in Table 6.1 (page 118).

Chapter 2: A comparison of face processing behaviour in young people with and without ASD

2.1 Introduction

Chapter 1 introduced the topic of face processing in ASD and focussed on the specific difficulties that may be seen in eye and mouth processing. The diagnostic criteria for ASD includes difficulties in social communication and social interaction (American Psychiatric Association, 2013) and this is often thought to be the result of difficulty orienting to important social stimuli, for example other people's eyes (e.g. Dawson et al., 2005; Sasson, 2006). However, as was seen in Chapter 1, the picture created by the empirical research is not clear cut and there are some mixed findings regarding the existence of a deficit of processing the eyes in ASD. This current chapter will focus on a behavioural paradigm of face processing that examines whether there is a deficit in eye processing in the ASD participants. This will provide an insight into the face processing patterns of participants with ASD in an alternative paradigm to those previously used. It is also the first step in developing an eye tracking paradigm (Chapters 3-5) which can be used to assess both behavioural and eye tracking patterns side by side to increase understanding of complex face processing, which in turn may relate to the social communication difficulties in ASD.

As was discussed in Chapter 1, the eyes appear to be an important region for enabling face recognition in the TD population. Various behavioural experiments have demonstrated that participants are less accurate in an identity recognition task when the eyes are masked (McKelvie, 1976), obscured from the screen (Haig, 1985) or blurred (Schyns et al., 2002). In addition, it has been found that in a change detection paradigms changes in the eyes are identified quicker than those in the mouth (Fraser et al., 1990).

However, as was discussed in Chapter 1, this bias to process the eyes that is consistently seen in TD participants is not the same pattern of results seen in ASD participants. In participants with ASD it appears there are difficulties with remembering and identifying faces when compared with a TD control group (e.g. Weigelt et al., 2012). This deficit in face processing may be considered as a result in difficulties processing the eye region, as some studies show deficits in processing the eyes, but no differences processing the mouth region (Riby et al., 2009; Rutherford et al., 2007; Wolf et al., 2008). However, this deficit to the eyes in behavioural studies has not been found in all paradigms, with Bar-Haim et al. (2006) finding the ASD participants could respond to changes in the eye region as quickly as TD controls using a probe detection task.

Moving on from previous work, the paradigm being developed in this chapter contributes the addition of a prompted condition. In this condition participants are explicitly told which region of the face to look to (eyes or mouth). This enabled investigation of both performance in an unprompted recognition task, as well as one in which they are told where to look. This should help to clarify whether ASD participants are able to alter where they are looking, regardless of natural bias. Previous studies suggest that it may be difficult for NT participants to look away from the eye region when instructed to do so, even for the benefit of task completion (Kuhn et al., 2016; Laidlaw et al., 2012). Less research has been done in this area in ASD populations, however, the limited research suggests that participants are able to change their looking patterns to the eyes when explicitly instructed to do so (Kikuchi et al., 2011) and may even struggle to look away from the eyes when instructed to not look to this region (Rombough & Iarocci, 2013). However, these two previous studies only focussed on gaze patterns and not task performance based on a prompt, e.g. whether identity recognition was improved with the addition of an instruction. Another previous study did look at task performance alongside changing eye gaze in line with an instruction. Riby et al. (2013) instructed participants to identify the object being looked at in the scene (therefore implicitly requiring the participants to look to the actor's eyes) and they found no changes in eye tracking patterns or task performance with the addition of this instruction. However, it should be noted that the instruction in this paradigm was not as explicit to look or not look to a certain ROI, instead they were instructed to identify the object being looked to, whereby they would need to look to the eyes although this was not explicitly instructed. To build on this previous research this study used a specific instruction to see how successfully participants with ASD were able to alter their behaviour to optimally complete a face recognition task when compared to a matched control group.

This study analysed a previously collected sample of adolescents, collected as part of the Special Needs in Autism Project (SNAP; Baird et al., 2006). A large sample of

ASD and non-ASD participants completed a face recognition task, focussing on the detection of changes to either the eye or mouth region. In addition, in the second half of the experiment there was the addition of a prompt, to instruct the participants where to look on the face image to enable them to perform optimally on the task. This prompt enabled investigation of whether both groups are able to successfully alter their looking patterns to enable them to improve their task performance. The analysis examined whether there are any differences in performance when the instruction was to look to the eye region, compared to the mouth region.

Based on the previous literature (e.g. Weigelt et al., 2012) it is hypothesised that the ASD group will have overall lower accuracy scores and slower RTs on the face processing tasks when compared to the non-ASD group. However, the previous literature is mixed so it is not clear whether there will be a deficit in processing the eye region compared to the mouth region in ASD. In the prompted condition I would expect the non-ASD group to show a greater improved performance when prompted to look to the eyes, compared to the mouth based on previous research showing it is difficult to look away from the eyes when instructed to do so (e.g. Laidlaw et al., 2012). In the ASD group the previous research in this area is more limited and it is not clear how this group will respond to the addition of a prompt and whether they will be able to shift their gaze appropriately and therefore improve their task performance in line with this. In addition, associations between recognition performance and IQ and age were explored to attempt to understand any individual differences in face processing patterns.

2.2 Method

2.2.1 Participants

The sample consisted of 100 adolescents with as ASD and 57 children without ASD. The participants were recruited as part of the SNAP project (Baird et al., 2006; Charman et al., 2011) and were tested entirely independently of the PhD. The analysis presented in the thesis represents the first analysis of this data and was conducted independently of the SNAP team but with their endorsement. Diagnosis of ASD was made with the Adult Diagnostic Interview (ADI-R: Lord et al., 1994) and the Adult Diagnostic Observation Schedule (ADOS-G: Lord et al., 2000) and a consensus research diagnosis was agreed upon (See Baird et al., 2006 for further information). Of the 57 without ASD, 26 children had a range of other diagnoses (3 specific reading/ spelling disorder, 1 expressive/ receptive language disorder, 16 mild learning disabilities, 3 moderate learning disabilities, 2 attention deficit hyperactivity disorder (ADHD), 1 no diagnosis). The remaining 31 non-ASD participants were recruited from mainstream schools and parents/ teachers confirmed none of the children had a psychiatric or developmental diagnosis, a statement of special education needs, or were taking any medication. In addition, the parents of 25 of these children completed the Social Communication Questionnaire (SCQ: Rutter, Bailey, & Lord, 2003) and all of these children scored below the cut-off for ASD. Eight participants did not complete the tasks (6 ASD and 2 non-ASD) due to time constraints, limited participant engagement or limited understanding of the task. Therefore, the final sample for this study was 95 ASD participants and 54 non-ASD participants (see table 2.1). IQ was assessed using the Wechsler Abbreviated Scale of Intelligence (WASI: Wechsler, 1999) and the participants in the two groups were not significantly different in age, full scale IQ (FSIQ), verbal IQ (VIQ) or performance IQ (PIQ) (all *p*s > 0.1).

Table 2.1: Participant information (SD in brackets)

	N	**Age (years; months) (SD in months)**	**Males:Females**	**FSIQ**	**VIQ**	**PIQ**
ASD	94	15;6 (5.6)	85:9	86.1 (17.0)	82.5 (17.3)	92.1 (17.7)
Non-ASD	54	15;6 (6.0)	52:2	89.1 (21.8)	87.2 (19.9)	92.6 (21.4)

FSIQ: full scale IQ, VIQ: verbal IQ, PIQ: performance IQ

2.2.2 Materials

Stimuli were created by Joseph and Tanaka (2003) and were greyscale digital photographs of 12 children's faces with a neutral expression (see Figure 2.1). The images were 21x14cm when displayed on the screen. The images were digitally altered images created from four original photographic images of four different children. Each of the four children provided eyes, nose, mouth and outline of the face to create 12 unique composites. There were twelve target images and each of these were paired with two foil images ('whole' images), each with either the eyes or mouth of the target image replaced with one from an unused photograph of different children. In addition, there were a further two images ('part' images) associated with target image, displaying just the eyes or just the mouth. Again, one of these was the eyes or mouth from the target image and the other was a foil image. These part images will not be analysed here, as they are beyond the scope of this thesis. In total, there were 48 pairs of images (12 targets x 2 foil types x 2 image types – whole face or part), which were divided into two sets of 24 trials (prompted and unprompted condition). The images were presented to the participants in one of six pseudo random orders.

In addition, colour photographs of cars and faces were used in the practice trials and were presented via Microsoft PowerPoint.

Figure 2.1: Example of the stimuli with the target image and the foil image where the mouth region has been changed

2.2.3 Design

Participants were divided into two groups (ASD and non-ASD) and completed a forced-choice face recognition paradigm, in which a target was presented followed by the target and a foil. Two variables were manipulated. Firstly, a region of the face was changed on the foil image, either the eyes, nose or mouth ('changed region'). Secondly, the first half of the trials were completed without a prompt and the second half of the trials involved a prompt to this changed region ('unprompted' and 'prompted'). This order was fixed, as having the prompted condition first would influence the free viewing in the unprompted condition. Behavioural data collected were accuracy (number of correct responses) and RT (average time of response, in milliseconds). In addition, correlations were performed between FSIQ, PIQ, VIQ, scores on the SCQ and age with the behavioural measures of accuracy and RT.

2.2.4 Procedure

The face recognition experiments were part of a large battery of tasks, which took place over two days. For this task participants sat in front of a computer screen and were approximately 75cm from the screen. First, the practice task was explained to participants. They were told they would be playing a game where they would see a picture in the middle of the screen and would then see two pictures and would have to choose the one that was "the same" as the first picture. The first trial used images of cars and the second used faces. Participants needed to pass both trials to progress to the testing phase. After completion of the practice task the participants moved on to complete the unprompted condition with the face stimuli. In this condition participants viewed the image of the face on the screen for 3.5 seconds and then had to make a choice between the two choice images by pressing the corresponding button. Participants were encouraged to give their best guess if they were not sure which one was the same. Participants were given 7 seconds to respond to each trial and after this time they moved onto the next trial, even if a response had not been given. If participants looked away from the screen they were encouraged to look back and engage in the task.

The prompted condition was run after the completion of the unprompted condition. In this condition, participants were told that they would be given a clue about where to look to help them decide if the face was the same. An instruction to either 'look at the eyes' or 'look at the mouth' was presented on the screen before the presentation of the target image. The instruction was read out loud if the participant had reading difficulties.

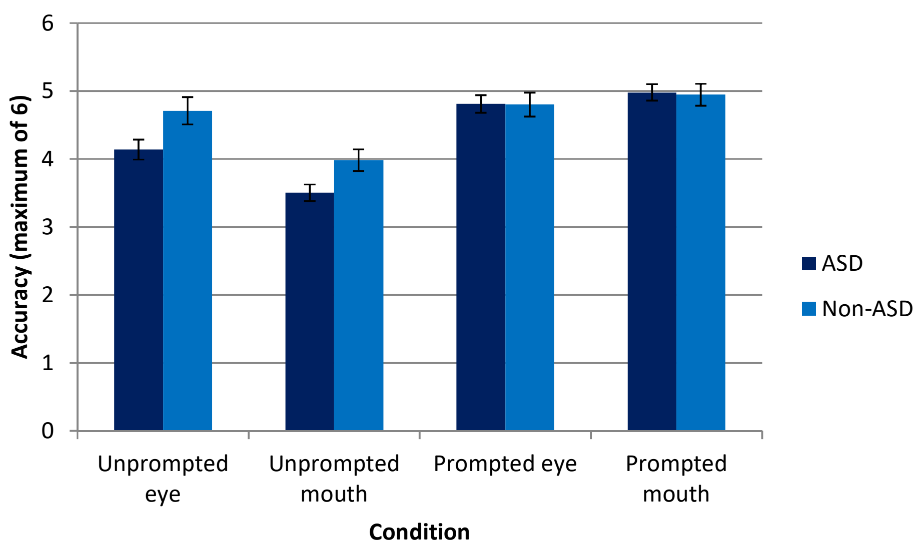
2.3 Results

The data were not normally distributed and the analyses were run with both non-parametric and parametric tests. As the patterns of significance were the same for both, the parametric tests are presented for ease of presentation.

2.3.1 Accuracy

To understand how well both groups of participants performed on the face recognition tasks in both an unprompted and prompted conditions a 2 (group: ASD or non-ASD) x 2 (Prompt: unprompted or promoted) x 2 (changed region: eyes or mouth) ANOVA was performed (see Figure 2.2). It was found that there was a significant effect of prompt, with participants improving their performance in the prompted condition, $F(1,147) = 69.75$, $p < 0.001$, $\eta_p^2 = 0.32$, a significant effect of the changed region with higher accuracy for the eye condition, $F(1,147) = 7.89$, $p = 0.01$, $\eta_p^2 = 0.05$, and no effect of group, $F(1,147) = 3.20$, $p = 0.76$, $\eta_p^2 = 0.02$. However, there were also significant interactions between prompt and group, $F(1,147) = 8.25$, $p = 0.01$, $\eta_p^2 = 0.05$, and between prompt and changed region, $F(1,147) = 23.44$, $p < 0.001$, $\eta_p^2 = 0.14$.

Figure 2.2: Accuracy data for ASD and non-ASD participants across conditions



On exploring these interactions it can be seen in Figure 2.3 that in the unprompted condition the non-ASD group were significantly more accurate than the ASD group, $t(1, 117.69) = 9.64$, $p < 0.001$, $d = 0.52$, however, in the prompted condition there was no longer a difference, $t(1, 103.34) = 0.14$, $p = 0.91$, $d = 0.02$, (Welch's t test used due to unequal sample sizes). In addition, as shown in Figure 2.4 when exploring the interaction between prompt and changed region it was found that in the unprompted condition participants performed better in the eye changed condition than the mouth change condition, $t(148) = 5.07$, $p < 0.001$, $d = 0.52$, however, in the prompted condition there was no longer a difference in performance, $t(148) = -1.41$, $p = 1.6$, $d = 0.13$.

Figure 2.3: Comparison of accuracy in the unprompted and prompted conditions for ASD and non-ASD participants

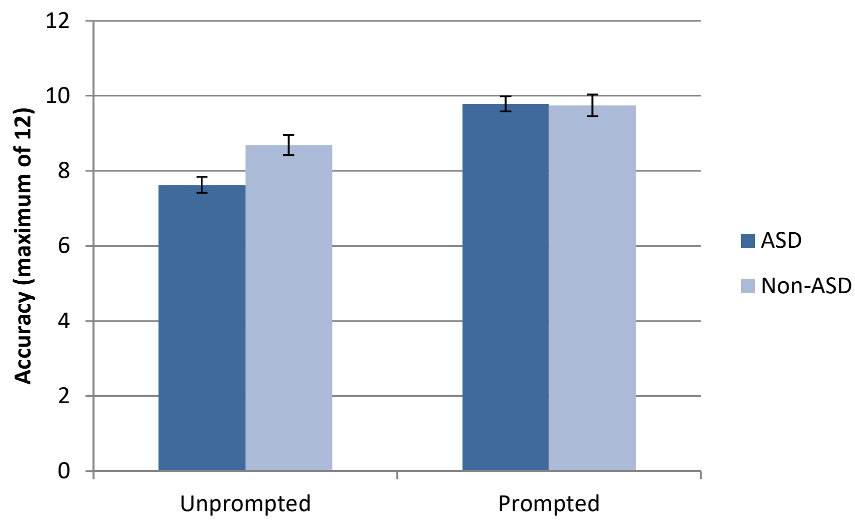
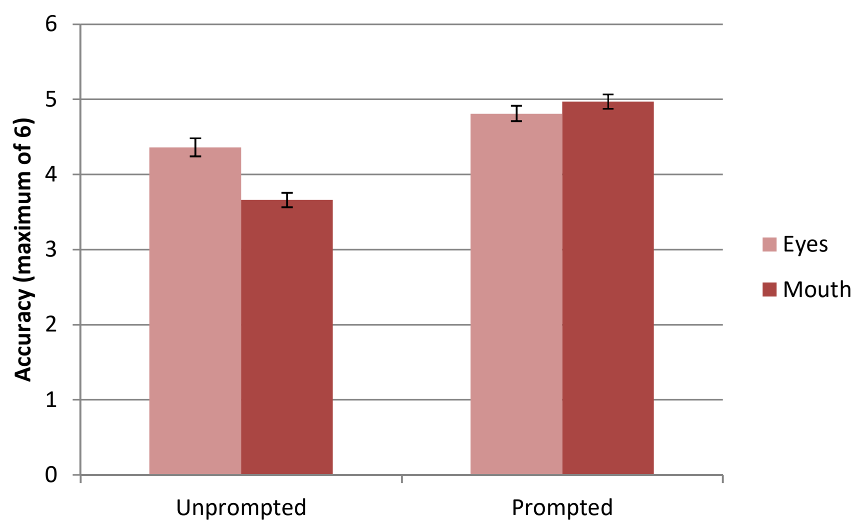


Figure 2.4: Comparison of accuracy for the eyes and mouth in the unprompted and prompted conditions for all participants

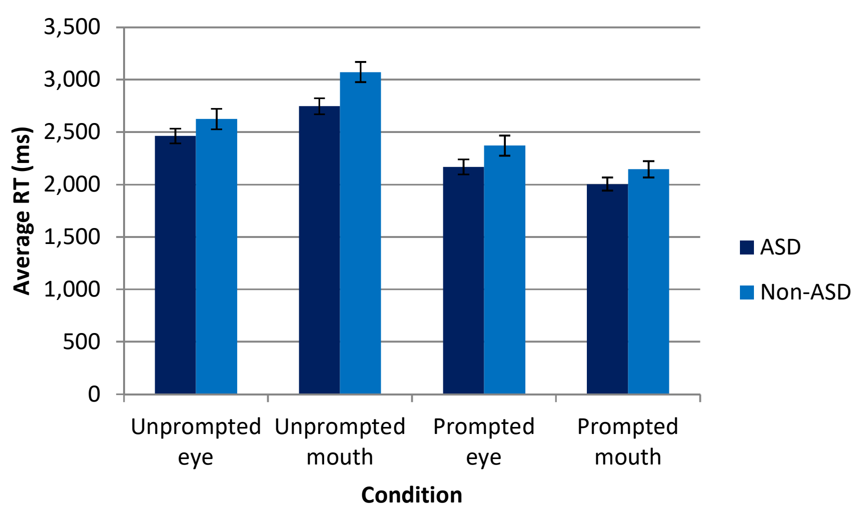


Overall, these results suggest that both groups were more accurate when the eye was the changed region, compared to when the mouth was the changed region. In addition, some group differences were observed with the non-ASD having higher accuracy in the unprompted condition, however in the prompted condition there was no longer a difference.

2.3.2 Reaction time

A 2 (group: ASD or non-ASD) x 2 (Prompt: unprompted or promoted) x 2 (changed region: eyes or mouth) ANOVA was performed (see Figure 2.5). There was a significant effect of prompt, with participants responding faster in the prompted condition, compared to the unprompted condition, $F(1,147) = 92.66$, $p < 0.001$, $\eta_p^2 = 0.39$. There was also an effect of the changed region, with shorter RTs when the eye was the changed region, compared to the mouth, $F(1,147) = 5.40$, $p = 0.02$, $\eta_p^2 = 0.03$. In addition, there was a significant effect of group with the ASD group having quicker RTs across conditions, when compared to the non-ASD group, $F(1,147) = 5.50$, $p = 0.02$, $\eta_p^2 = 0.36$. Finally, there was a significant two way interaction between prompt and changed region, $F(1,147) = 61.76$, $p < 0.001$, $\eta_p^2 = 0.30$. Post hoc *t* tests to investigate this interaction reveal that in the unprompted condition participants had a quicker RT when responding to the eye change condition, when compared to the mouth change condition, $t(148) = -6.73$, $p < 0.001$, $d = 0.48$. However, in contrast, in the prompted condition the participants had a shorter RT when responding to the mouth condition, compared to the eye condition, $t(148) = 3.88$, $p < 0.001$, $d = 0.28$. Overall, this pattern of data for RTs shows that a prompt decreases RT, but it appears to reduce the RT for the mouth more than the eye region. In addition, it shows that the ASD group show shorter RTs compared to the control group overall.

Figure 2.5: Average reaction time data across conditions



2.3.3 Individual differences in face processing

The large sample size enabled investigation of whether there were any individual differences in face processing performance associated with IQ or age. A Spearman's correlation (used due to the assumption of normality not being met) compared VIQ, PIQ and FSIQ with the accuracy and RT data for the unprompted and the prompted conditions. Due to the high number of correlations a more stringent p threshold of $p < .01$ was used. In the ASD group there were significant correlations between the prompted accuracy results and VIQ, $r_s = 0.32$, $p = 0.002$, PIQ, $r_s = 0.29$, $p = 0.005$, and FSIQ, $r_s = 0.33$, $p = 0.001$. All other correlations were not significant. In comparison, in the non-ASD group there was a significant relationship between unprompted accuracy and VIQ, $r_s = 0.52$, $p > 0.001$, PIQ, $r_s = 0.39$, $p = 0.003$, and FSIQ, $r_s = 0.47$, $p < 0.001$, as well as prompted accuracy and VIQ, $r_s = 0.58$, $p > 0.001$, PIQ, $r_s = 0.58$, $p < 0.001$, and FSIQ, $r_s = 0.58$, $p < 0.001$. Again, none of the RT measures correlated with any of the measures of IQ, all *p*s > 0.01.

Spearman's correlation was used to compare accuracy and RT in the unprompted and prompted conditions with the age of the ASD and non-ASD participants. No significant associations were found (all *p*s > 0.01).

2.4 Discussion

The primary aim of this study was to establish any differences in face recognition ability, specifically recognition of the eyes and mouth, between individuals with and without ASD and whether this could be altered by providing a specific instruction. To investigate this aim the performance of 14-16-year-old adolescents with and without ASD were compared on a forced choice face recognition task where either the eyes or the mouth were altered. This task was completed in both an unprompted and a prompted condition, allowing an investigation of how effectively the two groups responded to a prompt aimed to optimise their performance on the task.

A key difference between the performance of the two groups was lower accuracy for the ASD group compared to the non-ASD in the unprompted condition, although no difference was seen in the prompted condition. In addition, the ASD group showed shorter RTs than the non-ASD group across the whole task. These findings do not support the hypothesis that the ASD group would have lower accuracy and longer RTs than the non-ASD group, with only the unprompted accuracy data in support of this. It is possible that the increased speed and decreased accuracy in ASD is the result of a speed-accuracy trade off. One possible explanation for this is that the ASD participants' attention is not captured by the faces and therefore in the unprompted condition, without further instruction, their responses are quick and less focussed on the task. Alternatively, it is possible they find the faces, and particularly the eyes, aversive to look to and therefore respond quickly to terminate their engagement with the stimulus.

It was expected that it would be easier to orient to the eyes when instructed to do so and therefore performance in the prompted condition would be quicker and faster for the eye change trials in the non-ASD group. Due to the limited previous research in the area it was not predicted how the ASD group would respond to the prompt. Both groups showed the same pattern of data in the prompted condition, with both showing no difference in performance between the eye and mouth trials in the prompted condition. Notably, in the unprompted condition both groups showed greater accuracy for the eye trials than the mouth trials and therefore a greater improvement was seen in the mouth trials with the addition of the prompt. This suggests that without any specific instructions of where to look participants were preferentially processing the eye area, leading to better performance when unprompted. However, in the prompted condition participants demonstrated relatively greater improvement in the mouth trials and performed equally well in both the eye and mouth prompt condition. This suggests the mouth region is not fundamentally more difficult for participants but that they pay it less attention than the eye region, unless specifically instructed. Previous research reports that it is difficult to look away from the eyes even when instructed to do so (e.g. Laidlaw et al., 2012), which would predict difficulty with following the mouth prompt and therefore poorer performance. However, the stimuli in the current study were presented for 3.5 seconds, which may provide enough time to look elsewhere on the face even if the initial look was to the eyes. The eye tracking studies presented in Chapters 3-5 will enable us to investigate the specific pattern of looking directly.

These overall findings are broadly in line with previous research that shows that there are difficulties remembering and identifying faces in participants with ASD (e.g. Weigelt et al., 2012). However, previous research also suggests that this deficit may be as a specific result of difficulties processing the eye region (Riby et al., 2009; Rutherford et al., 2007; Wolf et al., 2008), however, performance on the eye change conditions was not different between the two groups in the current study. What was particularly notable was that the reduced accuracy in the ASD group was eliminated when the prompt was introduced and they were instructed where to look. This suggests that there may not be a fundamental impairment in recognising identity in ASD but that day-to-day challenges may reflect atypical looking styles in which relevant features are not processed.

It is of interest that the same pattern of results between the eye and mouth trials were seen for both the ASD and the non-ASD group, although there was a reduced overall accuracy for the ASD group, suggesting there were some face processing difficulties for this group. These findings are complementary to some previous eye tracking findings which suggest atypical looking patterns in ASD (Hernandez et al., 2009; Pelphrey et al., 2002; although see van der Geest et al., 2002 for a null effect). In these studies group effects appeared to be driven by the increased amount of time spent looking at non-core facial features or outside of the picture. When individuals with ASD were looking at core facial features they showed the same basic pattern of looking preferences as controls, spending more time looking at the eyes and starting gaze search with the eyes (Hernandez et al., 2009; Pelphrey et al., 2002). This seems to suggest that individuals with ASD collect the same pertinent perceptual information as those without ASD, but that the quality of this information is degraded due to overall reduced looking time, which is perhaps driven by a lack of interest in faces, avoidance of faces or difficulties with attention

A particular feature of the current study is that it was not limited to intellectually able participants. Approximately half of the autistic population has an IQ below 70 (Brugha et al., 2016) but these individuals are not well represented in the literature. Related to this, exploratory analyses into the relationship between performance on the face processing task with IQ and age were also conducted. Some associations between IQ and accuracy were found in both groups, however no relationships were found between RT and IQ. Notably, although there was no correlation between IQ and accuracy for the ASD group in the unprompted condition, all three IQ measures correlated with accuracy in the prompted condition. This suggests that general intellectual ability was not able to support performance in the unprompted condition, in contrast to the non-ASD group. Importantly, it suggests that the capacity of individuals with ASD to make use of constructive cues to improve social processing may be limited to, or more effective in, those with a higher intellectual ability. No relationships were found between age and accuracy or RT in either the ASD or the non-ASD group. However, the age range in this study was only 18 months, which provides very limited variability for detecting any effects of age. To investigate this further it would be necessary to investigate the effects with a wider age range. The association between IQ and accuracy on the task highlights the importance of using a matched sample when comparing an ASD sample to a control group, which will be maintained throughout the thesis.

Although the broad range of IQ included in the study was a strength the need for IQ matching meant that we included participants in the control group with a range of developmental diagnoses. This could be considered problematic as some in this group may have their own specific issues with face processing (e.g. ADHD: Uekermann et al., 2010). However, most had non-specific learning disabilities and there were a range of diagnoses, suggesting that there was no systematic bias within the group. Further, the standard deviations in the non-ASD group were not large and there were no outliers, which does not suggest a subgroup of atypical performers.

One limitation of the current study was the use of only behavioural data. By only collecting accuracy and RT data it only provides a limited understanding of what is happening during the task. The addition of eye tracking data, would allow for a more detailed understanding of both where participants are looking as well as how successfully they are competing the task. For example, the ASD group showed a benefit from the prompt and their performance was elevated to match the non-ASD group. Without eye tracking data it can only be indirectly inferred that this reflects a shift in looking patterns. Further, the pattern of accuracy across both groups indicates that the eyes are looked at more than the mouth when unprompted, but that looking can successfully be adjusted with a prompt as performance on the mouth task improves to match the eye task. However, this is extrapolation and not direct evidence.

This study used a novel prompting paradigm to enable an understanding of how successfully a large sample of adolescents with and without an ASD successfully completed a face recognition task with and without a prompt. In the next chapter this paradigm will be developed to include the addition of eye tracking measures (dwell time and the location of the first fixation). It is important to study both eye tracking and behavioural measures side by side wherever possible, as behavioural patterns alone do not tell us about exactly where people are looking and eye tracking data alone does not tell us how effectively people are extracting the information they are looking at in the scene. By collecting the measures of dwell time and first fixation location I will be able to further investigate where people automatically orient to the face (first fixation), where they look during a longer viewing period (dwell time) and how successfully they are able to change their looking patterns in line with a specific instruction (prompted condition).

Chapter 3: An investigation of eye and mouth looking patterns in Neurotypical adults

3.1 Introduction

In Chapter 2 a novel prompting paradigm was introduced, which enabled investigation of how adolescents with and without ASD performed on a face recognition task in either an unprompted or prompted condition. This task collected accuracy and RT data to allow an investigation of how successfully ASD and non-ASD adolescents processed the eye and mouth regions of face images. The ASD group performed as well as the non-ASD group when prompted where to look but were significantly less accurate when no prompt was provided. However, the two groups demonstrated the same eye bias effect, which was the primary focus of the study. In the unprompted condition both groups of participants were more accurate when processing the eyes than when processing the mouth, however, when given a prompt to look to the correct region to complete the task this eye advantage disappeared. Therefore, although the ASD group showed poorer performance in the unprompted condition than their non-ASD counterparts, they showed the same relative pattern of better performance for eye than mouth identity. One interpretation is that the ASD group spent less time than the non-ASD group looking in an optimal location in the unprompted condition, but showed the same relative pattern of looking. This reflects previous studies that have demonstrated groups with ASD spend less time looking at facial features but do bias the eyes when facial features are engaged (e.g. Hernandez et al., 2009; Pelphrey et al., 2002). Importantly, the improvement in the prompt condition suggests the ASD group were able to follow looking prompts that enabled better performance. This overall pattern was also reflected in a quicker RT for eye trials compared to mouth trials in the unprompted condition, a pattern that was reversed in the prompted condition.

The speculation over where the group with ASD were looking can be directly addressed by introducing eye tracking into the paradigm. This will enable an understanding of both how successfully people are completing a task, as well as where they are looking when completing the task. This paradigm will initially be developed in NT adults. Adults are experts in face processing (Bruce & Young, 1998) but this ability is still developing throughout childhood (e.g. Carey, Diamond, & Woods, 1980). Therefore, it is important to first use the paradigm and have an understanding of the results in a population with fully matured face processing patterns. In addition, there are increased difficulties when conducting an eye tracking paradigm with children (e.g. more prone to move their heads, less likely to remain seated throughout causing difficulties with the calibration procedures) and therefore to ensure the new paradigm is reliable it is important to develop this paradigm in a an adult sample. In later chapters, this paradigm will be adapted for use in children, initially establishing findings in a TD sample before assessing children with ASD. This task development will ultimately enable the results of Chapter 2 to develop by having direct rather than inferred understanding of where young people with ASD are looking when they complete the task.

As was outlined in Chapter 1, our preference for faces and face-like stimuli over other types of stimuli is a robust finding (e.g. Langton, Law, Burton, & Schweinberger, 2008; Nummenmaa, Hyona, & Calvo, 2006; Palermo & Rhodes, 2007). However, as well has having meaning as a whole, the face is comprised of constituent parts and it is the eyes specifically that appear to capture attention and have more importance in face processing. Early eye tracking studies identified the importance of looking to the eye region when viewing a face (e.g. Yarbus, 1967) and even infants appear to be able to process the eyes preferentially (e.g. Hood, Willen, & Driver, 1998). The bias to look to the eyes appears to be robust and remains even when the eyes are in an unexpected location. For example, Levy et al. (2013) used images of people, humanoids (human like cartoon images) and monsters (creatures that had the eyes on different parts of the body) and found participants would orientate to the eyes, even when located on unexpected parts of the monster body.

The measure of where first fixations fall on a face stimulus can be used to assess where people automatically look to when they are viewing a face. This will aide understanding of whether there are any areas of the face that automatically draw attention when the face is first presented. Various studies suggest that this initial fixation is often an orienting fixation, whereby the participant is looking towards the centre of the image to establish what they are looking at, before moving on to the key features of a face (e.g. Bindemann et al., 2009; Birmingham, Visser, et al., 2007). However, other studies suggest that when the face stimulus is more predictable, and therefore an orienting fixation to the centre of the image is not required, the first fixation for NT participants is more often to the eye area than to other areas of the face (van der Geest et al., 2002).

As discussed in Chapter 2, the paradigm used throughout this thesis involves a prompted condition, whereby participants are instructed where to look to enable them to complete a task. The addition of this prompt enables further understanding of whether looking patterns on a face are under volitional control or whether there is an automatic bias to look to certain areas that cannot be overcome with the addition of an instruction. The previous work in this area is minimal and has produced mixed results. Itier et al. (2007) used a paradigm where participants completed two tasks where one was beneficial to look to the eye region (determining gaze direction) and for the other it was not (determining head direction). They were explicitly told that when determining head direction it was not necessary to look at the eyes and gaze direction in this task was irrelevant. The authors found that, overall, participants were able to alter their gaze to some extent in line with the task they were completing. However, although they looked to the eyes less when determining head direction when compared to determining gaze direction, they still looked to the eyes more in both tasks when compared to other regions of the face. However, first fixation data showed a different pattern, with more first fixations landing in the eyes than the rest of the face for the gaze task, but in the head task there was no difference in the number of first fixations landing in the eyes and the lower face region. In a different paradigm, in which participants were explicitly told which region of the face to avoid looking at ("Don't look at the eyes" or "Don't look at the mouth"), Laidlaw et al. (2012) were able to investigate how participants responded to this direct instruction to alter looking patterns. They found that over the five seconds viewing period participants found it more difficult to follow the instruction to look away from the eyes than the mouth. The authors suggest that these findings indicate the existence of a bias to look to the eyes that is not entirely under the viewer's volitional control. These two studies therefore suggest a natural bias to look towards the eyes in typical adults, across different instruction types.

This chapter presents a study using a similar prompting paradigm to the one outlined in Chapter 2, but includes the addition of eye tracking measures. As well as the behavioural measures of accuracy and RT, the same as those collected in Chapter

2, the measures of overall looking time (dwell time) to the eyes and mouth and the location of the first fixation will be analysed. The use of the first fixation measure is particularly pertinent to the prompting paradigm, as it will allow an understanding of whether people are initially able to alter their looking patterns in line with an instruction, or whether any subconscious looking preferences are hard to control. The dwell time data will give an overall measure of how long participants look at the eyes and mouth over the duration of the stimuli presentation. Overall, this study will allow an understanding of where typical adults look on the face when completing a face recognition task and how looking patterns change in line with a prompt.

In line with the previous findings in this area, and the findings from Chapter 2, I hypothesise that in the unprompted condition participants will look more to the eye region than the mouth region and will perform better at face recognition when the eye region has changed, compared to when the mouth has changed. In addition, and reflecting the limited literature in this area (Itier et al., 2007; Laidlaw et al., 2012), in the prompted condition I hypothesis that participants will find it easier to follow the instruction to look to the eyes when completing the task, than looking to the mouth. As Laidlaw et al. (2012) showed that participants found it harder to look away from the eyes in the early viewing period, compared to the late viewing period, it is also possible that there may be difficulties altering looking patterns away from the eyes for the first fixation, but this difficulty may not sustain over the remaining dwell time.

3.2 Method

3.2.1 Participants

Forty-one participants (14 male, 27 female), aged between 20 and 37 (mean = 26.44 years, SD = 3.54) took part in this study. All participants reported either normal, or corrected to normal vision. Approval for this study was provided by the University of Essex ethics committee and the data were originally collected as part of a Master's in Psychology project. The current chapter presents a new focus and a completely new analysis of the data, which involved redrawing the ROIs and analysing the data in a new way that involved comparison across ROIs that were of different sizes.

3.2.2 Apparatus

Participants sat in an adjustable height chair with their chin on an adjustable height chin rest that was placed centrally 57cm in front of a screen. The stimuli were presented on a 19” PC screen, with a resolution of 1024x768 and a refresh rate of 60 Hz. A 1000hz eye tracker, the Eyelink 1000 system (SR Research), recorded eye movements, accuracy and RT for the 700ms when the target image was on the screen, and a button box was used for participants to make their responses.

3.2.3 Materials

The same stimuli were used as in Chapter 2, however with the addition of nose foil stimuli. Therefore, there were twelve target images and each of these were paired with three foil images, each with either the eyes, nose or mouth of the target image replaced with one from an unused photograph of different children. The nose foils were included to provide a more demanding task (i.e. three potential sources of change, rather than two). However, as looking to the nose region was not part of the hypotheses, performance on the nose trials were not analysed. In total, there were 36 pairs of images (12 targets x 3 foil types).

The pairs of images were separated into two groups of 18 (6 targets x 3 foil types). The group of images assigned to the unprompted or prompted condition was counterbalanced across participants. Further, each set of 18 images was repeated twice within the condition to enable more data collection, and the order of trials was randomised. In summary, each participant completed 72 trials, 36 in the unprompted condition (18 images x 2 repetitions) and 36 in the prompted condition (18 images x 2 repetitions).

3.2.4 Design

As in Chapter 2, the two main manipulations were for ‘changed region’ (eyes and mouth) and whether the trials were unprompted or prompted. Again, all unprompted trials were completed first. Behavioural data collected were accuracy (percentage of correct responses) and RT (average time of response, in milliseconds). Measures of eye gaze were taken during the initial presentation of the target image and were the location of the first look to the target image (percentage of first fixations to each ROI) and dwell time (average time dwelling in each ROI, in milliseconds).

3.2.5 Procedure

Participants were tested individually in an eye tracking laboratory. Before each set of 36 trials a nine-point calibration and validation procedure was completed. All validations had an average of 0.8 degrees of visual angle or below and a maximum of 2.0 degrees of visual angle or below. If validations were too high the calibration procedure was repeated until the desired set-up was established.

For the testing phase, each trial began with the presentation of a gaze contingent fixation point, consisting of a dot appearing randomly in one of the four corners of the screen, 50 pixels from each edge. Participants were required to look at the point and press a button on their button box. This manipulation ensured that the eye tracking data were not biased by systematic differences in starting eye positions. When this point was fixated the target stimulus was presented on the screen for 700ms (a reduced presentation time than in the previous chapter to make the task more demanding). Immediately afterwards the two choice images were presented on the screen side by side. Participants were informed their task was to select the face they thought was identical to the initial face image. Responses were recorded using the button box.

For the prompted condition, an additional instruction was included. Prior to each trial and before the gaze contingency was initiated, a word appeared in the centre of the screen saying either “eyes”, “nose” or “mouth”. Participants were informed that following this instruction would help them decide the target image. It was made clear to participants that this prompt would always be accurate, they would not be deceived and it would always be helpful to look at the area of the face indicated.

No breaks were provided throughout this task, as the average completion time was around 15-20minutes.

3.2.6 Normalisation of eye tracking data

ROIs were defined to enable analysis of fixations occurring in important regions of the target face. The eye ROI consisted of a rectangle incorporating the eyes, eyebrows and the region between the eyes, and the mouth ROI consisted of a rectangle around the mouth. The eye and mouth ROIs were different sizes, reflecting the different amount of space occupied by each region. In addition, the ROIs were drawn individually for each target image to best fit individual differences in morphology. As a larger ROI has a higher probability of acquiring fixations, the data were normalised to allow direct comparisons. The normalisation process was the same process used by Laidlaw et al. (2012) and the numbers reported throughout are the normalised values. To normalise, for each trial, the percentage of the total dwell time per ROI or the percentage of the total number of first fixations to that ROI were calculated and this figure was divided by the percentage pixel area of the screen taken up by that ROI (e.g. percentage eye dwell time/ percentage of the screen taken up by the eye ROI). These calculations created a ratio value, whereby a value of one indicates that a region was looked at as much as would be expected if looking across the whole screen was random. A value above one indicated that a participant looked to that ROI more than would be expected by chance and a value less than one indicated participants looked to the area less than would be expected by chance. A value of zero indicated that the ROI was not fixated at all.

3.3 Results

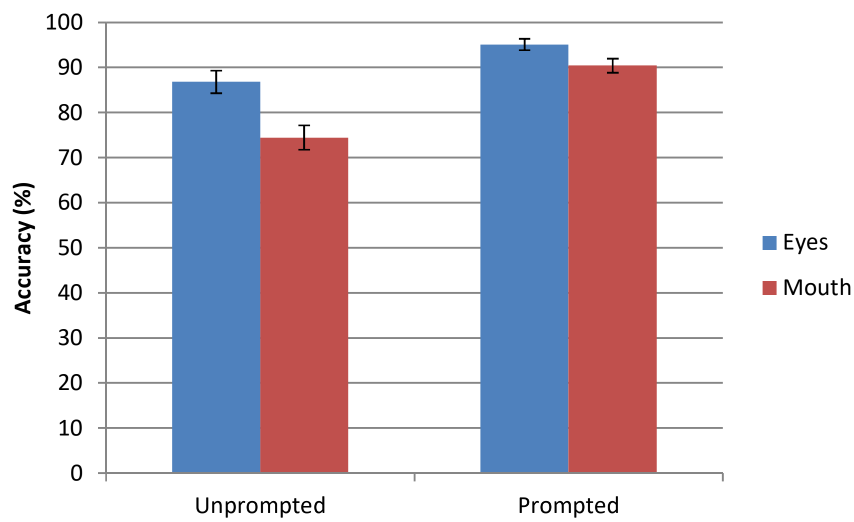
3.3.1 Data screening

The data were cleaned of invalid trials, based on atypical eye tracking responses. First, trials were removed where the participant did not look to the gaze contingent fixation point prior to the target image presentation. Second, trials were removed where no fixations were made to the target image (i.e. within the outline ROI) during initial presentation. In total 101 trials were removed (31 unprompted and 70 prompted), leaving 2851 trials for analysis (96.6% of the original trials).

3.3.2 Behavioural data

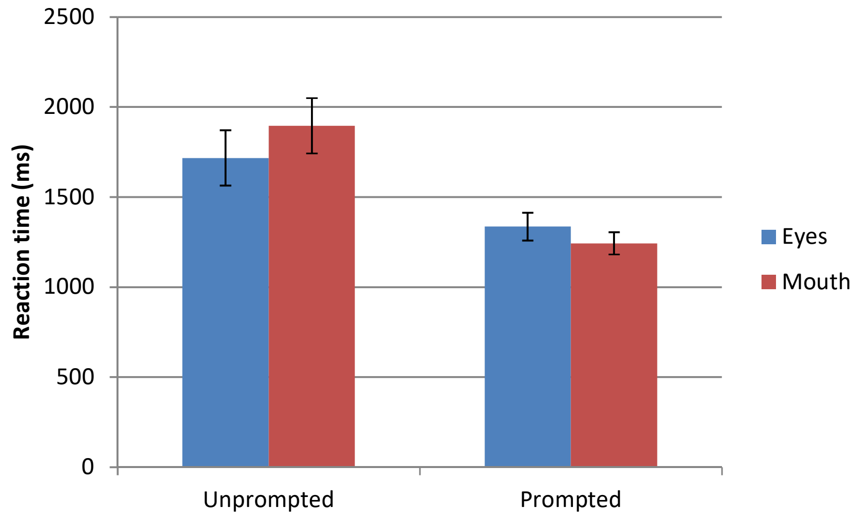
Data were not normally distributed so were log transformed; all statistical tests use the log transformed data. Accuracy data were analysed to allow a comparison of the success of the participant when the eyes and mouth were the changed region and how this differed in the unprompted and prompted conditions (see Figure 3.1). A repeated measures 2 (prompt: unprompted or prompted) x 2 (changed region: eye or mouth) ANOVA found people were significantly more accurate when prompted than when not prompted, $F(1,40) = 42.22$, $p < 0.001$, $\eta_p^2 = 0.51$ and accuracy was significantly higher when the eyes were the changed region than when the mouth was the changed region, $F(1,40) = 13.63$, $p = 0.001$, $\eta_p^2 = 0.25$. In addition, there was a significant interaction, $F(1,40) = 4.15$, $p = 0.048$, $\eta_p^2 = 0.09$. This interaction was explored with post hoc paired sample *t* tests (using Bonferroni corrected threshold of p < 0.025), showing participants were significantly more accurate when the eyes (vs. mouth) were the changed region in the unprompted condition, $t(40) = 3.16$, $p = 0.003$, $d = 0.67$, whereas this difference was smaller and did not reach Bonferroni corrected levels of significance in the prompted condition $t(40) = 2.32$, $p = 0.025$, $d = 0.48$.

Figure 3.1: Accuracy when the eyes and mouth were the changed region



RT data were also analysed as shown in Figure 3.2. A repeated measures 2 (prompt: unprompted or prompted) x 2 (changed region: eye or mouth) ANOVA was performed and found participants performed significantly faster in the prompted condition, $F(1,40) = 32.58$, $p < 0.001$, $\eta_p^2 = 0.50$, there was no significant difference in RT depending on whether the eyes or mouth were the changed region, $F(1,40) = 0.86$, $p = 0.36$, $\eta_p^2 = 0.02$, but there was a significant interaction, $F(1,40) = 13.68$, $p = 0.001$, $\eta_p^2 = 0.26$. Explorations with post-hoc paired sample *t* tests (Bonferroni threshold of p < .025) revealed that participants were significantly quicker at identifying changes to the eye region than the mouth region when no prompt was provided, $t(40) = -3.99$, $p < 0.001$, $d = 0.24$, but when the prompt was provided there was no longer a significant difference, $t(40) = 1.33$, $p = 0.19$, d = 0.19.

Figure 3.2: Mean reaction time when the eyes and mouth were the changed region



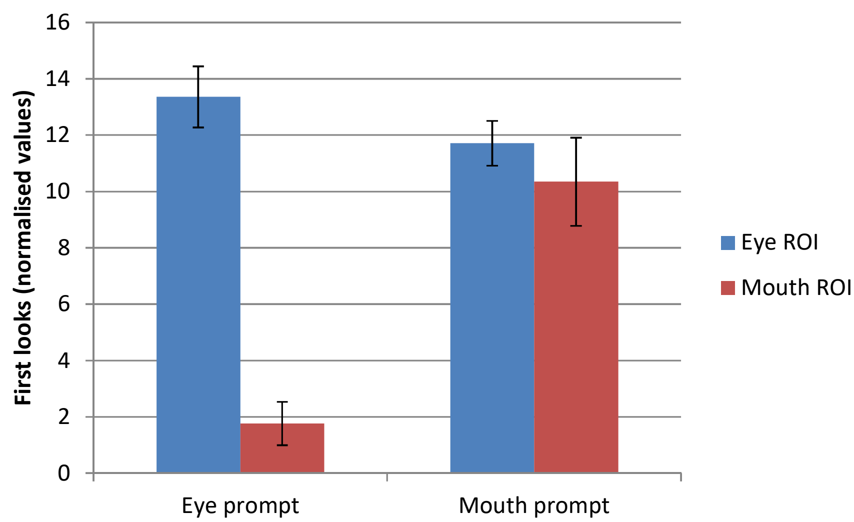
3.3.3 Natural (unprompted) looking patterns

The eye tracking data were significantly skewed and this could not be corrected by transforming the data. Non parametric and parametric tests produced the same pattern of results, so for ease of communication the parametric tests have been reported. The unprompted eye tracking data were used to analyse participants' natural looking patterns when viewing the target face image. A *t* test showed that participant's first looks were significantly more often to the eyes (mean = 13.83, sd = 6.22), than the mouth (mean = 0.85, sd = 2.11), $t(40) = 11.45$, $p < 0.001$, $d = 2.79$. In addition, total dwell time was significantly longer for the eyes (mean = 20.88, sd = 6.81), than the mouth (mean = 1.56, sd = 2.70), $t(40) = 14.68$, $p < 0.001$, $d = 3.73$.

3.3.4 Effects of prompting on looking patterns

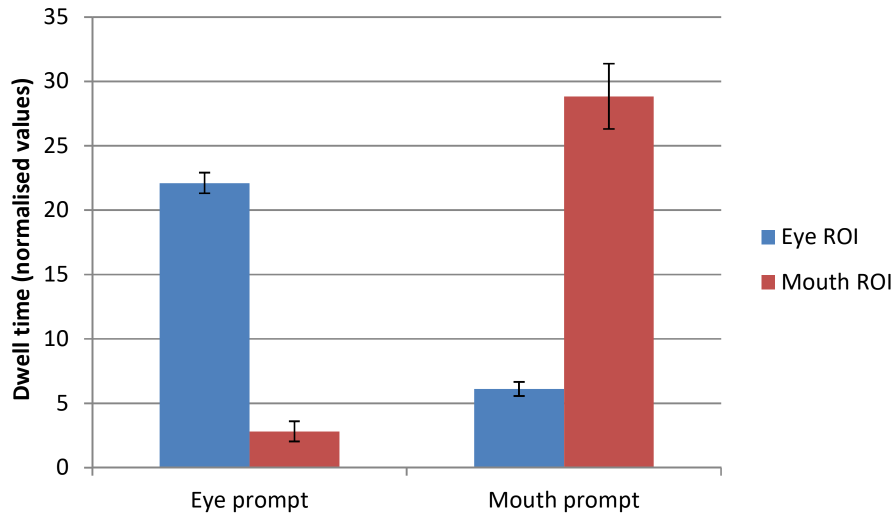
The effect of prompting on people's natural looking patterns is shown in Figures 3.3 and 3.4. A 2 (prompt location: eye or mouth) x 2 (ROI: eyes and mouth) repeated measures ANOVA conducted with the first look data. We found a significant main effect of prompt location, $F(1,40) = 17.53$, $p < 0.001$, $\eta_p^2 = 0.31$, a significant effect of ROI, $F(1,40) = 21.95$, $p < 0.001$, $\eta_p^2 = 0.35$, and a significant interaction, $F(1,40) = 21.53$, $p < 0.001$, $\eta_p^2 = 0.35$. Post hoc *t* tests (Bonferroni threshold of $p < .025$) revealed that when participants were prompted to look to the eyes their first look on the target image was significantly more often to the eyes (mean = 13.35, sd = 6.94) than the mouth (mean = 1.76, sd = 4.92), $t(40) = 7.70$, $p < 0.001$, $d = 1.93$. However, when prompted to look to the mouth there was no difference between first looks to the eyes (mean = 11.71, sd = 5.12) and the mouth (mean = 10.34, sd = 10.04), $t(40) = 0.68$, $p = 0.50$, $d = 0.17$. In addition, no difference was found between the number of first looks to the eyes in both the eye and mouth prompt conditions, $t(40) = 1.32$, $p = 0.19$, $d = 0.27$, however participants looked significantly more often to the mouth when prompted to do so, $t(40) = 5.72$, $p < 0.001$, $d = 1.09$. In summary, the data indicate participants had difficulty inhibiting first looks to the eyes in the mouth prompt condition.

Figure 3.3: First looks to each ROI when prompted to look to the eyes or mouth



Second, I examined the overall dwell time patterns during the prompted trials using a 2 (prompt location: eye or mouth) x 2 (ROI: eyes and mouth) repeated measures ANOVA with the dwell time data. We found a significant main effect of prompt location, $F(1,40) = 19.52$, $p < 0.001$, $\eta_p^2 = 0.32$, no significant effect of ROI, $F(1,40) = 1.22$, $p = 0.28$, $\eta_p^2 = 0.03$, and a significant interaction, $F(1,40) = 179.70$, $p < 0.001$, $\eta_p^2 = 0.82$. This significant interaction is the result of participants looking significantly more often to the eyes than to the mouth when prompted to look at the eyes, $t(40) = 14.06$, $p < 0.001$, $d = 3.77$, and significantly more often to the mouth than the eyes when prompted to look to the mouth, $t(40) = 8.12$, $p < 0.001$, $d = 1.93$. This suggests that, unlike the first look, over the whole viewing time participants were able to make adjustment their looking patterns in line with the prompt given.

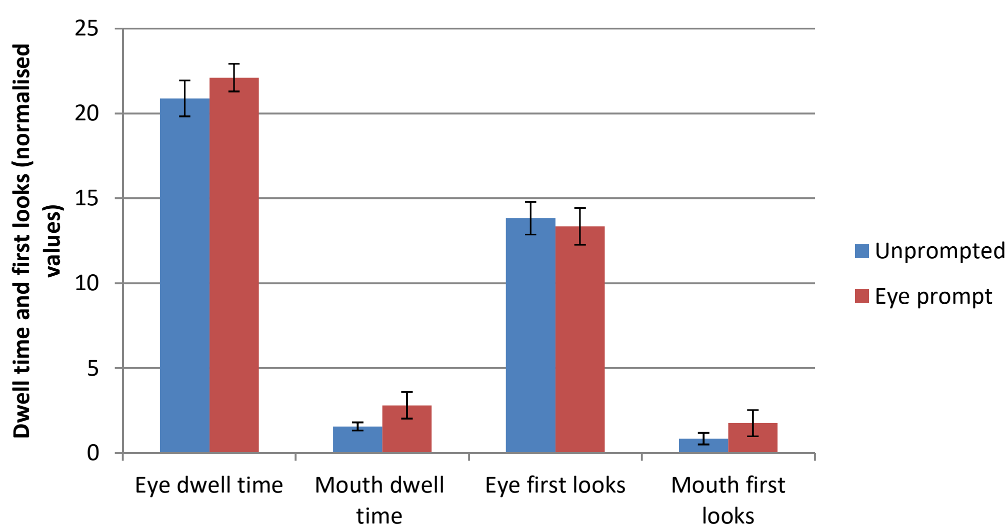
Figure 3.4: Mean dwell time for each ROI when prompted to look to the eyes or mouth



3.3.5 Comparison of unprompted and eye prompted conditions

I observed that the pattern of looking to the eyes was similar in the unprompted condition and prompt to the eyes condition (see Figure 3.5). Therefore, I was interested in whether prompting to the eyes significantly enhances looking in this region, or whether eye looking is already at a maximum level in a natural unprompted condition. Using *t* tests, it was found there were no differences between these two conditions, for both first fixations and dwell time (all *p*s < 0.05), suggesting eye looking is already at maximum capacity in the unprompted condition.

Figure 3.5: Comparison of means in unprompted and eye prompt conditions



3.4 Discussion

This study investigated where adults look during a face recognition task, comparing natural looking to a prompted looking condition that steered them to the eyes or mouth. The addition of eye tracking measures builds on the previous study (Chapter 2) by enabling a fuller understanding of both where people are looking and how successfully they are completing the task.

In line with my first hypothesis, it was found that in the unprompted condition participants looked more to the eye region than the mouth region. In addition, participants demonstrated greater accuracy and shorter RTs when the eye was the changed region, compared to the mouth. This finding is in line with the previous literature which shows that participants are better at processing the eye region than the mouth region (e.g. Haig, 1985; McKelvie, 1976) and that participants look to the eyes preferentially over other regions of the face (e.g. Janik et al., 1978; Laidlaw et al., 2012).

In support of my second hypothesis, in the prompted condition participants did not successfully alter their looking patterns away from the eye region when instructed to look to the mouth, as evidenced by the first look data. However, examination of the dwell time data suggests that over the 700ms viewing period participants were able to adjust their looking patterns in line with the prompt. Taking these findings together suggest an automatic preference to initially orient to the eye region that cannot easily be overcome, followed by the capacity for corrective behaviour and disengagement from the eyes. These findings complement the pattern of findings in previous studies using different paradigms. The initial difficulty orienting away from the eyes is in line with the findings of Laidlaw et al. (2012) and to some extent the findings of Itier et al. (2007). Laidlaw et al. (2012) argue that their findings suggest that looking to the eyes is not entirely under volitional control and that although participants did reduce their eye looking when instructed to do so, they did not reduce this as much as to the mouth region. My findings in this chapter add further support to these findings, but also add to them suggesting that this automatic eye looking exists specifically in the first fixation to the eyes and then is possible to control over the longer viewing period (as evidenced by dwell time). However, the comparison with the results found by Itier et al. (2007) are more complex. In the current study I found that this bias to look to the eyes seemed to exist only in the first fixation data, and not over the whole dwell time. However, Itier et al. (2007) found there was a bias to look to the eyes overall during the head direction task (where participants were told they did not need to look to the eyes), however, the first fixations in this task were no more likely to be to the eyes than to the lower face region.

Another interesting finding from this study was from the exploratory analysis comparing the unprompted condition with the eye prompt condition. This analysis was conducted as the two conditions appeared similar when inspecting the data. The comparison of these two conditions found no significant differences in the amount of eye dwell time, mouth dwell time, eye first looks and mouth first looks. This interesting finding suggests that participants reflexively looked to the eye region to such an extent that instruction to look to the eyes does not increase the amount of eye looking.

Overall, this study indicates not only that there is an unconscious bias to look to the eyes that it difficult to overcome, but that humans naturally orient to the eyes and prompting to the eyes does not increase this amount of orientation. However, the dwell time data suggests that after the first look adults do adjust their looking in line with the prompt. This chimes with the behavioural data, which shows that the ability to recognise identity based on the mouth region improves with the addition of the prompt. As discussed, these findings are similar to those of Laidlaw et al. (2012), but there are also important differences in the findings. In the current study the difficulty to orient to the prompted region only seems to exist in the first fixation. However Laidlaw et al. (2012) found this difficulty in not looking to the eyes throughout the five second viewing period of their task, albeit with stronger effects in their early viewing period (the first 1000ms of the task). There are a number of key differences between the paradigms which may explain the differences. For example, Laidlaw et al. (2012) gave the instruction, “Don’t look” to a certain region and is possible that an instruction not to look is more difficult to follow than a more active instruction of “Look”. In addition, the participants in Laidlaw et al.’s “Don’t look” task were not given a reason to look to certain regions of the face beyond the arbitrary task instructions. However, in the current study participants were provided with a reason to look elsewhere, as following the task instructions would enable them to more successfully recognise facial identity. It is possible that the contingency between following the instructions and doing well on the task provided additional motivation to the participants in the current study that was absent in the Laidlaw et al. (2012) paradigm. It is also important to note the different presentation times across the two studies. In the current study presentation time was only 700ms and as a result it was necessary to suppress the bias to look to the eyes as soon as possible. Participants only had time for two or three fixations throughout the whole presentation time. However, in the study conducted by Laidlaw et al. (2012) the presentation time was much longer (5 seconds). This longer period may have allowed for greater influence of the effects of waning attention. Difficulty maintaining adherence to the task instruction of not looking at the eyes could be established by looking at the final 1000 ms of the 5000 ms looking period. This would predict a U-shaped pattern, with more mistakes (eye looking) in the first 1000 ms due to a difficult-to-inhibit bias to the eyes and more mistakes in the last 1000 ms due to difficulty maintaining non-preferred looking.

The findings with the accuracy and RT data in this chapter are similar, but not identical, to those seen in Chapter 2. In both chapters it was found that participants were more accurate when the eyes were changed than when the mouth was changed in the unprompted condition, and this bias decreased (in this chapter) or disappeared completely (in Chapter 2) with the addition of the prompted condition. Across both studies, in the unprompted condition the eye change condition had a shorter RT than the mouth condition. In the current study RTs for the mouth and eye change conditions were not different in the prompted condition. However, in Chapter 2 the mouth change condition had shorter RTs than the eye change condition in the prompted condition. These minor behavioural differences do not diminish the overarching replication of the experimental effect and they possibly reflect minor differences in task design and participants. It should be remembered that the stimulus presentation times were different in the two studies, with the current study using a shorter presentation time to suitably challenge adults. Further, the current study used NT adults, whereas Chapter 2 used adolescents with and without ASD.

The previous literature on the location of first fixations was mixed, with some studies suggesting an orienting first fixation was needed when viewing an image, before participants were able to move on to look at the specific features (e.g. Bindemann et al., 2009). However, this study was in line with the previous findings by van der Geest et al. (2002) with the largest number of first fixations being to the eye area. The most likely explanation for the results in this study is that participants were informed that they would always be seeing face stimuli, which was in a predictable location. This negated the need for an orienting first fixation, meaning participants could orient directly to their preferred location on the target stimulus.

My data indicate that it is difficult not to initially orient to the eye region when instructed to look elsewhere. This is consistent with the findings of a number of paradigms, including participants being told not to look to the eyes (Laidlaw et al., 2012), indirect instructions to look to the eyes (Itier et al., 2007) and specific instructions to look at another part of the body (Kuhn et al., 2016). The current study extends this literature as it finds an eye bias when instructing participants to actively look at an alternative face region. In addition, the current study also suggests this pattern may not be consistent over time, as even though the first look was biased to the eyes in the prompt condition the overall dwell time was not similarly distorted. Therefore, this suggests instructions to look elsewhere can be adhered to over time when it benefits task success. This is a similar finding to Itier et al. (2007).

The addition of eye tracking into this paradigm was important as it enabled insight into looking patterns during the face processing task, which only partly reflected the behavioural task performance. Critically, although accuracy improved and RT decreased following the addition of the prompt for this sample of NT adults, this was not fully reflected in the eye tracking patterns because the first looks could not be completely modified in line with the prompt. Notably, the lack of appropriate orienting in the mouth prompt condition did not have a detrimental effect on task performance, arguably as the length of looking time overall dwell time aligned with prompt instructions.

This study has important implications as it adds to the growing body of knowledge that people struggle to look away from the eye region even when explicitly instructed to do so (Itier et al., 2007; Kuhn et al., 2016; Laidlaw et al., 2012). The use of first fixations also helps to create a greater understanding of the time course of this difficulty in changing viewing patterns. However, it should be remembered that this study has only used a recognition task and it is possible that pattern of fixations on the face may vary as a function of the purpose of the looking, for example, evaluating emotional expression compared to recognising someone (e.g. Peterson & Eckstein, 2012; Schyns et al., 2002).

Another possible limitation of this study is the improvement seen in the prompted condition (both accuracy and RT) may be as a result of practice, as the unprompted condition was always completed first. Although this seems unlikely, due to the different pattern of improvement across the eye and mouth conditions, this will be investigated in Chapter 4 by reversing the order of presentation, with prompted being presented first, for a subset of the participants. In addition, it is also possible that the bias to the eyes is not a face specific bias and is instead a generic effect of spatial preference. This will also be investigated in Chapter 4 with the addition of control stimuli to test whether this bias is specific to the eyes, as opposed to a bias to look towards the top of images.

A further consideration is the eye tracking data presented are for the encoding/ learning phase of the task, and the eye tracking data for the memory/ retrieval phase were not analysed. As the focus of this thesis includes initial looking it was decided to focus on this initial phase to allow investigation of any instinctive, or perhaps automatic, looking patterns immediately after the gaze contingent fixation point disappeared from the screen. In addition, this initial encoding phase was directly after the prompt in the prompted condition, which allowed investigation of how effectively participants were able to initially follow an instruction, or whether this top down processing took more time to deploy. This initial encoding stage of the task was also time limited, so participants would be more motivated to follow the instructions to look to the prompted region as quickly as possible to increase their chances of success in the task, whereas the memory phase was not time limited. This approach is similar to those used in gaze cueing tasks (e.g. Rombough & Iarocci, 2013) where it is important to investigate looking directly after the cue, as is also the case with the current paradigm. Although this was the focus for this thesis, it is important to be aware that eye tracking patterns may be different for the memory phase and a comparison of both initial looking patterns on faces and how successfully these can be changed should be conducted across a wide range of conditions in future research. Although, you would expect the initial bias to look to the eyes to remain the same if it does have an automatic component, it would be of interest to investigate this further across a range of task types and conditions. This focus on analysing the eye tracking data during the presentation of the target image only will be continued through the rest of the thesis.

The key finding of this chapter is the difficulty inhibiting initial looks to the eyes in adults. However, this does not inform us of how younger participants, who may have more difficulty following prompt instructions or a less established eye preference, may perform. It will be interesting to establish how children respond to instructions to change their looking patterns as the previous research in this area has been on NT adults. As face processing is still developing in children understanding whether this automatic initial bias to the eyes that is difficult to inhibit will provide further information on how this bias contributes to face processing patterns over the lifespan. In Chapter 4 a large sample of TD children will be studied to address these issues. This will also allow further investigation into whether IQ or age are important factors in the face recognition process, as was originally discussed in Chapter 2. In addition, by adapting the task for use in children, it will also enable the task to be used in Chapter 5 for assessing performance in children with ASD and to investigate any face processes biases in this group.

Chapter 4: An investigation of an automatic bias to look to the eyes in typically developing children

4.1 Introduction

Chapters 2 and 3 have introduced a new face processing paradigm to understand the effect of prompting on face processing patterns. Chapter 3 used this paradigm with NT adults and used eye tracking to collect measures of where people were looking. In addition, analysis of accuracy and RT allowed an understanding of how effectively people were able to extract the relevant information from the face stimuli. The most notable finding was the initial bias to look to the eye region, as evidenced by the first fixation data, even when explicitly instructed to look elsewhere on the face. This finding is novel and different to previous findings, which suggest there is a sustained bias to look to the eyes (e.g. Laidlaw et al., 2012). In contrast, Chapter 3 suggests this bias is stronger with initial viewing, therefore suggesting there is an automatic reflexive bias to look to the eyes initially. In this chapter a similar eye tracking paradigm will be used in TD children to enable an investigation of where children look throughout the task and whether they show a similar bias to adults. This is important to investigate as the previous research (e.g. Laidlaw et al., 2012) and the findings from the previous chapter have all been conducted with adults and so it is not clear if the patterns are the same in children. As discussed in Chapter 3, it was important to first establish this task in adults, who have fully developed face processing abilities (Carey et al., 1980) and are more easy to test in an eye tracking environment. Establishing the validity of the task in TD children enabled a final study (Chapter 5), which will assess performance of children with ASD on the task in comparison to a TD group. In addition, and in line with the limitations of the paradigm outlined in Chapter 3, a control task was introduced to enable an investigation of whether the findings were face specific. This will be particularly relevant when investigating this paradigm with a clinical sample in Chapter 5.

As previously discussed, it is established that people look to the eyes more than other features on the face in the TD population (e.g.Laidlaw et al., 2012; Walker-Smith et al., 1977) and that it seems to be difficult to inhibit looking to the eye region when told not to (e.g. Laidlaw et al., 2012). The data collected in Chapter 3, using a NT adult sample, was consistent with this finding and built on the previous research suggesting that the difficulty to inhibit looking to the eyes may be greater during the initial fixation when compared to the rest of the viewing period. The adaptation of this paradigm for use with children is important as face processing changes during development. For example, Ge et al. (2008) found that identity recognition improves dramatically between ages four and 11, but then is constant into adulthood. This suggests that younger children find it harder to process identity, which could be reflected in different looking patterns. Indeed, Roberson, Kikutani, Doge, Whitaker, and Majid (2012), found that using the eyes as the main part of the face to successfully complete an emotion recognition task changed over childhood. The authors used a paradigm where either the eyes or mouth were obscured and found that while older children and adults showed a decreased performance in an emotion recognition task when the eyes were obscured, compared to when they weren't, the younger children (under 9-years-old) did not show this same deficit in performance, suggesting a reduced reliance on the eye area. However, although there is clear evidence to show that face processing changes over childhood, it is also known that faces, and specifically the eyes, are salient from birth. For example, it has been shown that by two-month-old babies show a preference for looking to the eyes compared to other regions of the face (Hainline, 1978; Haith, 1977). In addition, by the age of 4 months infants are able respond preferentially to direct gaze as opposed to averted gaze (Vecera & Johnson, 1995) and from birth they prefer to look at faces that show direct rather than averted gaze (Farroni, Csibra, Simion, & Johnson, 2002) . Moreover, the preference for upright schematic faces in newborn babies has been attributed to the contrast polarity of the stimuli, which is consistent with sensitivity to direct eye gaze (Farroni et al., 2005). This evidence suggests that although face processing is developing and becoming more sophisticated over childhood, there is a preference to look to the eyes from infancy.

Another important element of this chapter is the addition of a control task to test whether the findings are specific to faces or whether, for example, children may have a general bias for looking at the top half of an image. This also helps to overcome a key limitation from Chapter 3, whereby it could not be established that the bias to look to the eyes in the adult population was specific to faces or a more generic effect of spatial preference. Houses will be used as control stimuli in this chapter. Tanaka and

Farah (1993) argue that houses make a good control condition to compare with faces as they both have internal features that can vary independently and the number of internal features in a house can be manipulated to match that of a face. Studies have previously used houses as a control condition to compare to with faces, for example in memory tasks (Tanaka & Farah, 1993) and recognition tasks (Bruce, Doyle, Dench, & Burton, 1991; Yin, 1969). These studies all show a different processing style for faces, with whole faces being processed more accurately than houses when upright, but no differences between inverted faces and houses. However, Donnelly and Davidoff (1999) also used houses as a control stimuli and did not replicate these previous findings that faces were processed differently to houses and suggested that the holistic face processing advantage outlined in the previous studies could also be found in houses. The inclusion of a house stimuli control condition will provide behavioural performance measures (e.g. to see if there is a bias to perform better on one region of the house), and also eye tracking data (e.g. to see if there is a general bias to look at the top half of houses) that will be important for determining the specificity of the patterns of performance found in face stimuli.

An additional eye tracking measure will be introduced in this study. The 'time to first fixate' measures how quickly participants look to the two ROIs of interest, the eyes and the mouth. As was discussed in Chapter 1, (section 1.4.3, page 25) people tend to fixate on the eyes faster than the other regions of the face (Freeth, Chapman, et al., 2010; Gillespie-Smith et al., 2014; Grossman et al., 2015). This measure provides additional information to dwell time, which is how long overall the feature is fixated, and first look, which is a categorical index of whether the eyes or mouth are preferred. The additional measure of time to first fixate therefore allows a more robust understanding of how quickly people look to the eyes and mouth. As a result, the data help provide a more complete picture of the eye preference established in the previous chapter. This will also be a useful measure to include in Chapter 5, when considering any differences between TD and ASD group looking patterns, as previous research suggests there may be subtle timing differences when looking at faces, even when first look patterns are comparable (e.g. Kuhn et al., 2010)

In addition to the other methodological changes, some alterations were made to ensure this task was suitable for the age of the children being studied in this task (8-11 years). Firstly, and similar to the approach with adolescents in Chapter 2, a practice task was introduced at the beginning of the eye tracking session. This included computerised images of faces and houses that were easy to discriminate, so participants' conceptual understanding of the task could be established. Secondly, the presentation time was increased from 700ms to 2000ms to enable the children to have a longer processing time when completing the task. This presentation time was established after a short pilot phase, which established that at 2000ms a ceiling effect had not been reached, yet the children appeared more comfortable completing the task compared to the shorter presentation time of 1500ms. This is a shorter presentation time than the one used with adolescents in Chapter 2. However, this earlier study included additional conditions (not analysed in this thesis) that were not part of the current design.

As discussed in Chapter 3, a limitation of the tasks presented in Chapters 2 and 3 is that the prompted condition always came last, meaning that the enhanced performance could be attributed to practice effects. To address this issue, a 'reversed condition' was included in this study as a control for order. An age and IQ-matched subsample of the participants completed the task in the alternative order, completing the prompted condition first. This task manipulation will enable exploration of whether the purported benefits of the prompt are a true reflection of the re-orienting of attention, or are an order effect.

Based on the findings from Chapter 2 and 3, alongside the previous evidence suggesting that the eyes are an important stimulus from a very young age (Hainline, 1978; Haith, 1977; Lasky & Klein, 1979; Vecera & Johnson, 1995), I would expect the patterns of data for the children in this study to reflect the findings seen in adolescents and adults. As a result, I would expect better accuracy in the eye conditions, alongside an eye preference in the eye tracking data, demonstrated by more first fixations and a shorter time to first fixate to the eyes even when prompted to look to the mouth. If the pattern of data is the same as adults, I would also expect an ability to overcome the initial bias to look to the eyes, which will be investigated with the measure of dwell time on the eye and mouth regions. Based on previous brain imaging studies that find faces have special status with dedicated and specific neural responses (e.g. Bentin, Allison, Puce, Perez, & McCarthy, 1996; Taylor, McCarthy, Saliba, & Degiovanni, 1999), I would not predict there would be any biases when viewing the house stimuli, and that any difficult to inhibit biases are specific to the faces.

4.2 Method

4.2.1 Participants

Eighty four participants took part in this study, aged between 8 and 11 years old. Two participants were excluded from the analysis as they were judged to have not understood the practice task (achieved 50% or lower) and 18 were excluded as adequate eye tracking data were not collected. This included participants who were unable to complete a useable eye tracking calibration at the start of the task, participants who were unable to sit in the same position for the whole task, and data lost due to equipment problems. The final sample consisted of 64 participants, who were divided into two groups to test for order effects. The standard order group (n = 50) completed the task in the same order as participants in Chapter 3 and the reversed order group (n = 14) completed the task in the reverse order with the prompted condition first. IQ data were collected, using the WASI (Wechsler, 1999), on all 14 participants in the reversed condition and on a sample of 30 participants in the standard order condition. There were no significant differences of age or IQ ($p > .05$) between the two groups. Participants were recruited through three mainstream schools, with no schools reporting a participant with a diagnosis of ASD or any other developmental or neurological problem. In addition, parents were asked to complete the SCQ (Rutter et al., 2003), which was returned for 36 of the 64 participants (27 from the standard order group and 9 from the reversed group, however one response from each group had multiple unanswered questions so could not be used in the analysis, leaving 34 responses). None of these children reached the cut-off score of 15 to suggest likelihood of ASD and there was no significant difference in SCQ scores between groups ($p > .05$). Participant information is

Table 4.1: Participant information

Group	n	Age (years)	Males: Females	FSIQ[a]	VIQ[a]	PIQ[a]	SCQ[b]
Standard order	50	10.40 (0.74)	27: 23	99.77 (12.32)	100.83 (12.50)	98.40 (15.55)	4.23 (3.02)
Reversed order	14	10.49 (0.73)	9: 5	99.57 (8.75)	103.00 (9.85)	96.21 (11.70)	3.63 (3.11)

FSIQ: Full scale IQ; VIQ: Verbal IQ; PIQ: Performance IQ; SCQ: social communication questionnaire

[a] n=30 for the standard order group;
[b] n=14 for the standard order group and n=8 for the reversed order group.

summarised in Table 4.1. Ethical approval for this study was granted by the School of Psychology Ethics Committee, Cardiff University.

4.2.2 Apparatus

Participants sat in a chair in front of a 21 inch monitor, with a resolution of 1920 x 1080, positioned on a table in front of the participant. A portable 60Hz eye tracker (Tobii) was used to record the eye tracker data. This consisted of a camera attached to the screen, so participants were not required to use a chin rest or wear any head gear. The same button box as used in Chapter 3 recorded the participants' responses. The task was programmed and run in Matlab (Mathworks).

4.2.3 Materials

The face stimuli used were the same as the stimuli used in Chapter 2 (see page 39). In addition, house images were created to act as a control task (see Figure 4.1). The procedure for creating the images followed the Joseph and Tanaka (2003) procedure for creating the face images, with each image being a composite of three original house images. These consisted of images of real houses acquired from the internet, which were edited in Adobe Photoshop. The target images were grey scaled and consisted of the main body of the house, including the outline, brick work and roof details, with the windows, door and additional features removed. Two upstairs windows of a second house and the door of a third house were added to this main body of the first house. Two foil images were also created for each target image, with either the door or upstairs windows replaced with one from an unused image.

In total there were 48 images (2 x task type (face or house) x 12 targets x 2 foils). For each task type, target-foil pairs were divided into two groups of 12 (6 targets x 2 foil types). The group of 12 images that was assigned to the unprompted or prompted condition was counterbalanced across participants.

In addition, four sets of practice stimuli were also created. Two grey scaled house drawings were each paired with two alternative house images (see Figure 4.2) and two grey scaled cartoon face images were each paired with two alternative face images (see Figure 4.3). The practice stimuli were the same size when presented on the screen as the experimental stimuli.

Figure 4.1: Example of house stimuli where the windows are the changed region

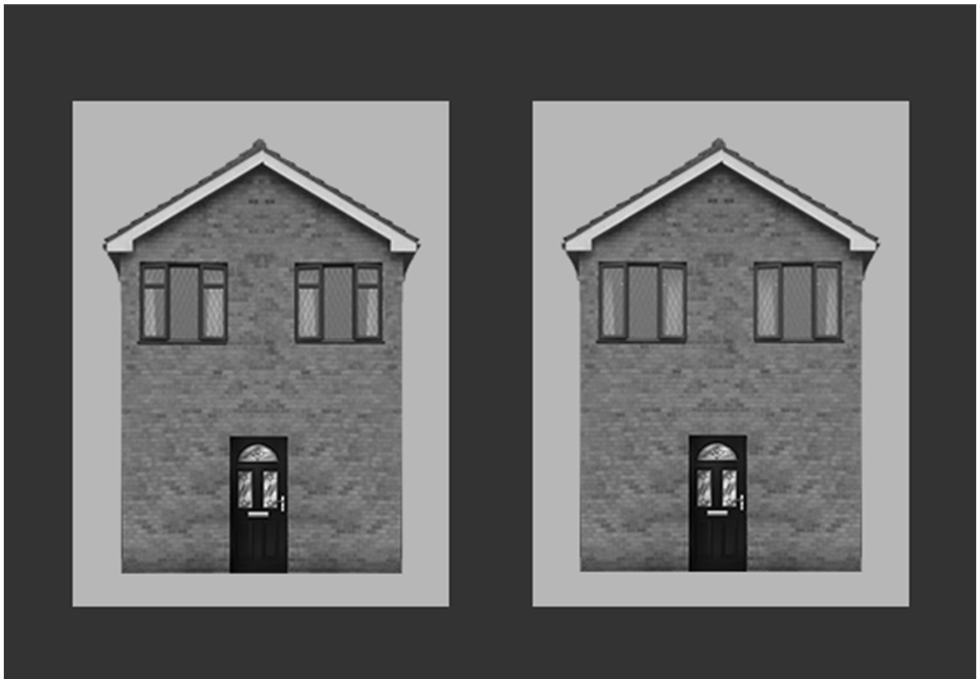
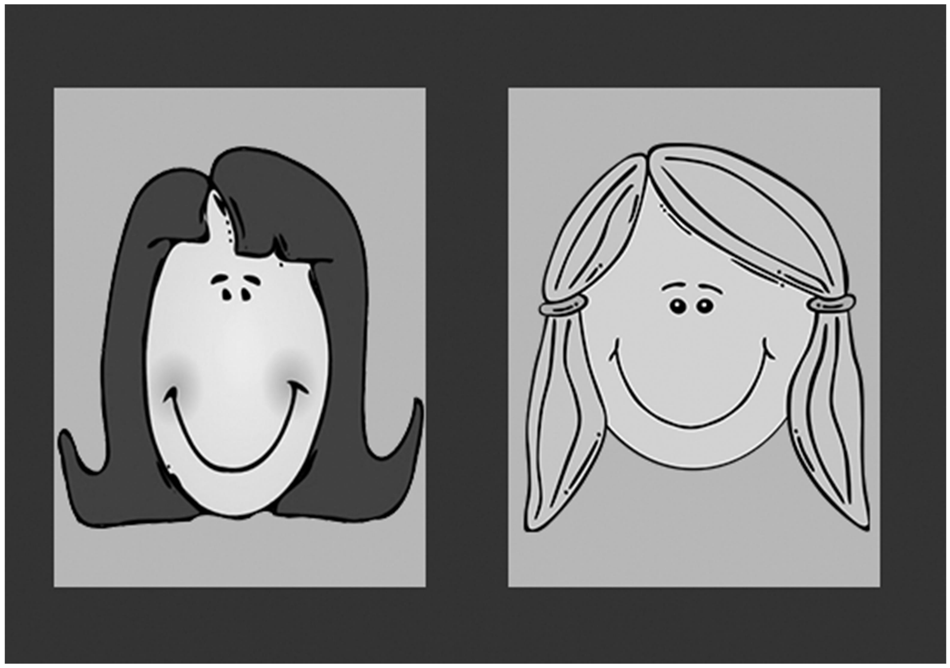


Figure 4.2: Example of practice stimuli for the house condition

Figure 4.3: Example of practice stimuli for the face condition



All participants completed the unprompted condition from one half of the face images and the prompted condition from the other half of the face images. The same process was used for the house images. The stimuli given to each participants, as well as the order of presentation (houses or faces first) was counterbalanced between participants. The order of presentation of the stimuli within each condition was random.

4.2.4 Design

Two variables were manipulated in this study. Firstly, a region of the face or house was changed on the foil image, either the eyes/mouth, or windows/door ('changed region'). Secondly, trials were completed either without a prompt or with a prompt to the changed region ('prompt'). To examine where participants looked when completing the task, dwell time (ms) to each ROI, percentage of first looks to each ROI, and the time to first fixate each ROI (ms) were recorded. In addition, accuracy (percentage of correct responses) and RT (average time of response, in ms) were recorded.

Completing the task either in the standard or reversed order was the between subject element of the design.

4.2.5 Procedure

The procedure was similar to the procedure in Chapter 3 (see page 54), however, there were some important adaptations made to ensure the task was suitable for children, as well as the addition on the control task (house stimuli). One important change was the presentation time of 2000ms. For three initial pilot participants the presentation time was 1500ms, but participants reported that they had found it stressful and difficult to complete in this time and were unmotivated to continue. As a result the time was increased to 2000ms for the participants included in the study.

Participants were tested individually in a room in their school. They sat on a chair in front of a screen with the eye tracker attached to the bottom centre of the screen. The participants were instructed to try to sit as still as possible during the task. A calibration procedure was completed at the start of the task, this was a five point calibration procedure and was different from the one completed with adults (Chapter 3) as images, rather than dots, were used to capture the attention for the children. The children were instructed to look very carefully at each image which it was on the screen. The calibration procedure was repeated until reasonable calibration was received on all five points.

The experimenter explained the tasks to participants and read out the instructions presented on the screen. It was explained that in each trial they would see a picture on the screen, it would then disappear and there would be two pictures on the screen. They were told it was their job to choose the one they thought was the same as the previous picture by using their button response box.

All participants completed the practice trials first. In these trials a small animated flower image appeared in one of the four corners of the screen. This was a child-friendly version of the gaze contingent fixation point used in Chapter 3. Fixation on the flower image prompted the target image to appear in the centre of the screen for 2000ms. Participants were reminded to look at the picture and to try and remember it. After this image had disappeared the target and foil images appeared on the screen and participants made their response using the button box.

After the completion of the practice trials, participants in the standard order group completed the unprompted trials first. The instructions were explained before both the block of house images and the block of face images. The procedure within each of these sets of trials was the same as the procedure during the practice trials and the same child-friendly gaze-contingent animated flowers were used.

After the completion of both sets of unprompted trials the participants then completed the prompted trials. Again the instructions were explained to the participants before both the house prompted condition and the face prompted condition. In this condition an additional instruction was given to pay attention to the prompt and the participants were informed that looking where the prompt told them to look would help them to complete the task. In this condition, before the appearance of the gaze contingent animated flower in each trial, a prompt was presented in the centre of the screen. This prompt said, 'eyes/ mouth/ windows/ door'. The location of this instruction was in line with the changed region on the images. As well as this prompt being written on the screen it was read out to each of the participants and they were encouraged to follow the instruction. The rest of the procedure was the same as for the unprompted and practice trials.

Throughout the task the children were able to take a break between the presentation of stimuli in each of the four blocks. The whole task took about 10 minutes to complete, without breaks.

The reverse order group completed the unprompted and prompted conditions in the reverse order. The procedure was identical apart from this one manipulation.

4.2.6 Normalisation of eye tracking data

ROIs for the faces were defined in the same way as in Chapter 3. For the house stimuli the door ROI consisted of a box drawn around the door on each house, and the window ROI consisted of a box drawn around each window and then these two boxes were summed together. It was decided to use individual boxes around each window, as opposed to one large box around both (as used for the eyes ROI), due to the large amount of space between the two windows. The same normalisation process was used as in Chapter 3 (see page 54 for a description) and once again ratio data is presented, as in Chapter 3.

4.3 Results

4.3.1 Data screening

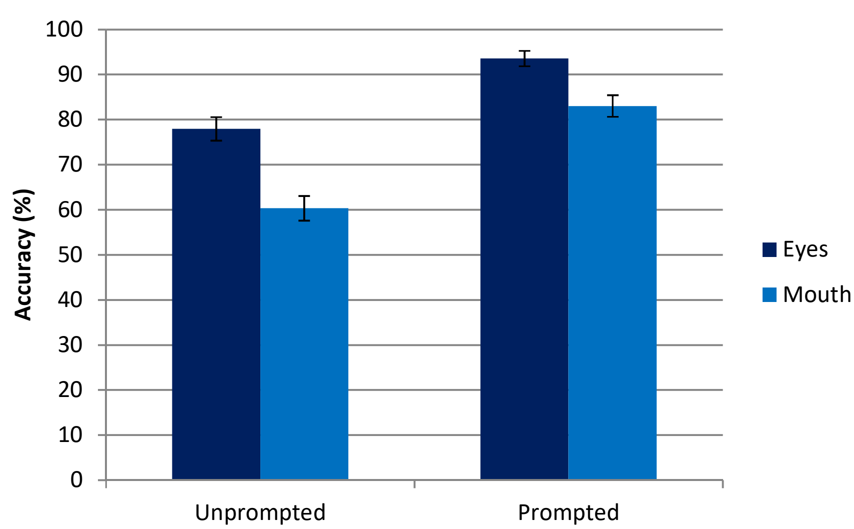
Trials were removed where the participants did not fixate the gaze contingent point to initiate the stimulus onset to the screen. This resulted in 54 trials being removed from analysis (25 face trials and 29 house trials). This represented 1.76% of all trials and the remaining 3018 trials were included in the analysis.

4.3.2 Behavioural data

The data presented throughout this section are an analysis of the standard order group only. Discussion of the reversed group data will occur in Section 4.3.6 (page 87). The data were not normally distributed and this was not resolved through transformation. Subsequently, both non-parametric and parametric tests were run, and as they both produced the same pattern of results the parametric tests will be presented throughout this results section.

Accuracy data were analysed to allow a comparison of the success of the participant when the eyes and mouth were the changed region and how this differed in the unprompted and prompted conditions (see Figure 4.4). A repeated measures 2 (prompt: unprompted or prompted) x 2 (changed region: eye or mouth) ANOVA found participants were significantly more accurate when prompted than when not

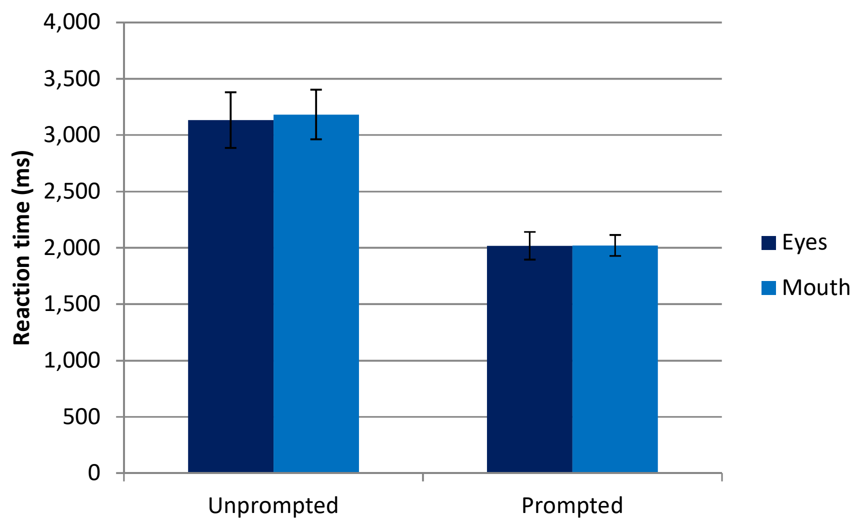
Figure 4.4: Accuracy in the unprompted and prompted conditions (faces)



prompted, $F(1,49) = 73.08$, $p < 0.001$, $\eta_p^2 = 0.60$ and accuracy was significantly higher when the eyes were the changed region than when the mouth was the changed region, $F(1,49) = 35.51$, $p < 0.001$, $\eta_p^2 = 0.42$ and there was no interaction , $F(1,49) = 2.32$, $p = 0.13$, $\eta_p^2 = 0.05$.

RT data were also analysed to allow a comparison of the speed of response when the eyes and mouth were the changed region and how this differed in the unprompted and prompted conditions (see Figure 4.5). A repeated measures 2 (prompt: unprompted or prompted) x 2 (changed region: eye or mouth) ANOVA found participants were significantly faster when prompted than when not prompted, $F(1,49) = 40.29$, $p < 0.001$, $\eta_p^2 = 0.45$. However, there was no difference in RTs when the eyes and mouth were the changed regions, $F(1,49) = 0.04$, $p = 0.85$, $\eta_p^2 = 0.001$, and in addition there was no interaction, $F(1,49) = 0.09$, $p = 0.76$, $\eta_p^2 = 0.002$.

Figure 4.5: RT in the unprompted and prompted conditions (faces)



In addition, the house data were analysed to understand if the effects seen were specific to faces, or could be generalised to other tasks (see Figures 4.6 and 4.7). Firstly, the accuracy data were analysed using a repeated measures 2 (prompt: unprompted or prompted) x 2 (changed region: windows or door) ANOVA. It was found that participants were significantly more accurate when prompted than when not prompted, $F(1,49) = 172.93$, $p < 0.001$, $\eta_p^2 = 0.78$. However, there was no effect of ROI, $F(1,49) = 0.42$, $p = 0.52$, $\eta_p^2 = 0.008$, and no interaction, $F(1,49) = 2.53$, $p = 0.12$, η_p^2

= 0.05. This shows there was not a bias to perform better with one of the ROIs, as was seen with the eyes in the face stimuli.

Figure 4.6: Accuracy in the unprompted and prompted conditions (houses)

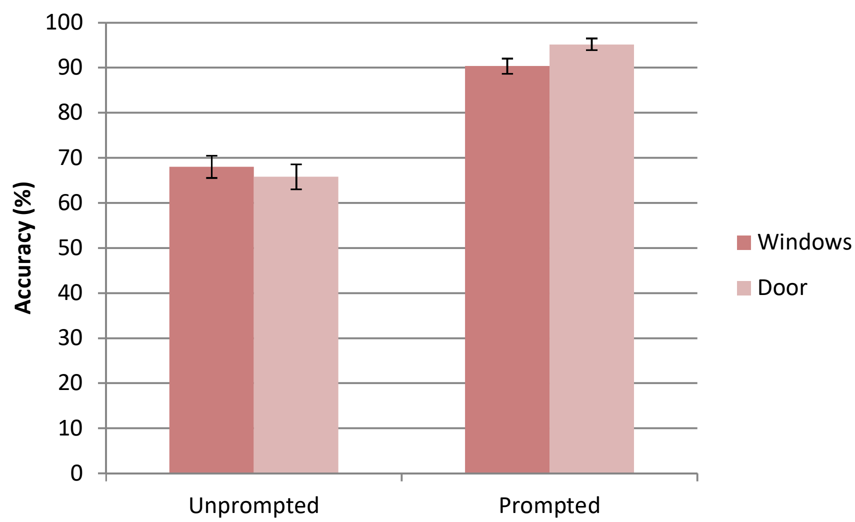
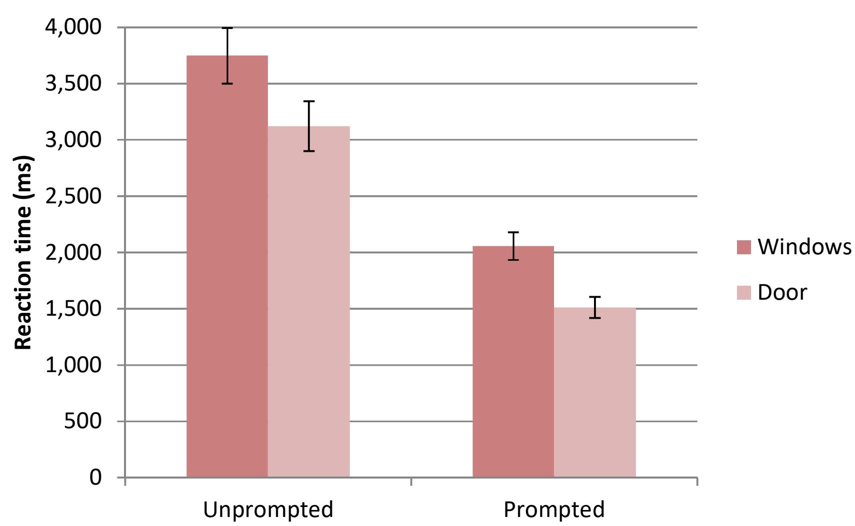


Figure 4.7: RT in the unprompted and prompted conditions (houses)

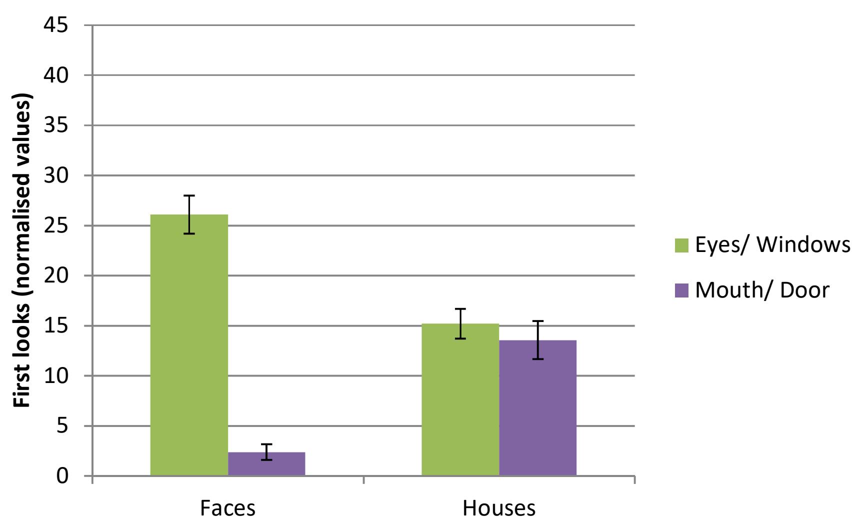


Finally, the RT data for the houses were analysed with a repeated measures 2 (prompt: unprompted or prompted) x 2 (changed region: windows or door) ANOVA. It was found that participants were significantly faster to respond when prompted than when not prompted, $F(1,49) = 92.96$, $p < 0.001$, $\eta_p^2 = 0.66$ and when the doors were the changed region, $F(1,49) = 50.18$, $p < 0.001$, $\eta_p^2 = 0.51$. However, there was no interaction, $F(1,49) = 0.16$, $p = 0.69$, $\eta_p^2 = 0.003$. This suggests that doors are processed faster than the windows.

4.3.3 Unprompted eye tracking patterns

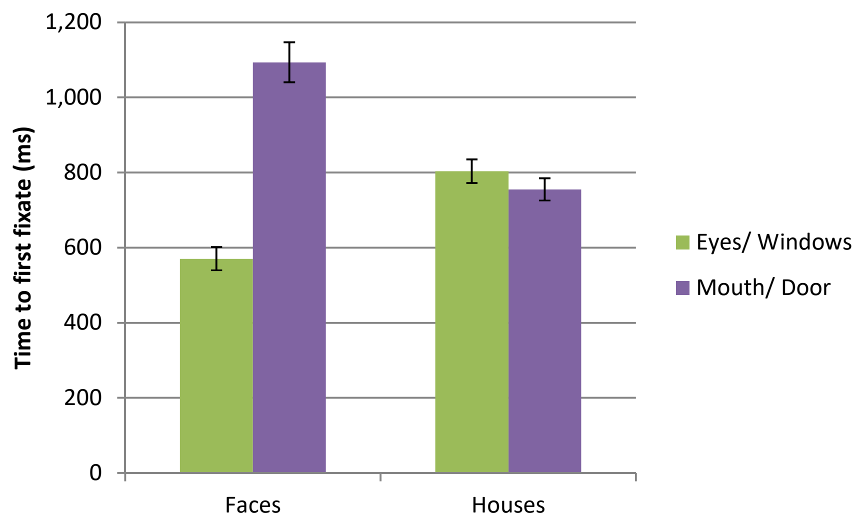
The unprompted eye tracking data were used to analyse participants' natural looking patterns when viewing the target face and house images, using the measures of first looks (Figure 4.8), time to first fixate (Figure 4.9), and dwell time (Figure 4.10). Firstly, a 2 (condition: faces or houses) x 2 (changed region: eye/ windows or mouth/ door) repeated measures ANOVA was conducted with the first look data. This showed no main effect of condition, $F(1,49) = 0.01$, $p = 0.91$, $\eta_p^2 < 0.01$, a significant effect of changed region, $F(1,49) = 44.97$, $p < 0.001$, $\eta_p^2 = 0.48$ and a significant interaction, $F(1,49) = 47.65$, $p < 0.001$, $\eta_p^2 = 0.49$. Post hoc *t* tests (Bonferroni threshold of $p < .025$) showed that within the face condition participants looked first to the eyes more than they looked to the mouth first, $t(49) = 11.01$, $p < 0.001$, $d = 2.31$. However, in the house condition there was no significant difference between the amount the windows and door were fixated first, $t(49) = 0.59$, $p = 0.56$, $d = 0.13$.

Figure 4.8: First fixations in the unprompted condition



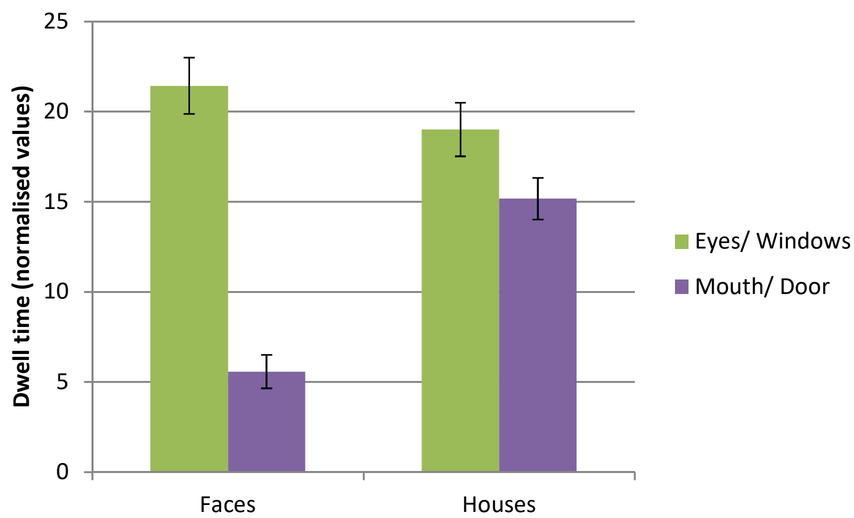
Next, a 2 (condition: faces or houses) x 2 (changed region: eye/ windows or mouth/ door) repeated measures ANOVA was conducted with the time to first fixate data. This found a main effect of condition, $F(1,35) = 8.02$, $p = 0.01$, $\eta_p^2 = 0.19$, a significant effect of changed region, $F(1,35) = 18.48$, $p < 0.001$, $\eta_p^2 = 0.35$ and a significant interaction, $F(1,35) = 78.02$, $p < 0.001$, $\eta_p^2 = 0.69$. Post hoc *t* tests (Bonferroni threshold of $p < .025$) revealed that within the face condition participants took less time to fixate the eye region than the mouth region, $t(35) = 7.24$, $p < 0.001$, $d = 1.82$, however in the house condition there was no significant difference between the length of time to first fixate the windows or the doors, $t(49) = 1.13$, $p = 0.27$, $d = 0.23$. An additional relevant observation is the number of participants that did not fixate on at least one region and were therefore excluded from the analysis. In the face condition, 14 participants did not fixate on the mouth region at all during this unprompted condition, however all participants looked to the eyes, windows and doors at least once.

Figure 4.9: Time to first fixate in the unprompted condition



Finally, a 2 (condition: faces or houses) x 2 (changed region: eye/ windows or mouth/ door) repeated measures ANOVA was conducted with the dwell time data. This revealed a main effect of condition, $F(1,49) = 17.10$, $p < 0.001$, $\eta_p^2 = 0.26$, a significant effect of changed region, $F(1,49) = 39.77$, $p < 0.001$, $\eta_p^2 = 0.45$ and a significant interaction, $F(1,49) = 29.56$, $p < 0.001$, $\eta_p^2 = 0.38$. Post hoc *t* tests (Bonferroni threshold of $p < .025$) showed that within the face condition participants looked to the eyes more than they looked to the mouth, $t(49) = 7.61$, $p < 0.001$, $d = 1.74$. In the house condition participants looked more to the windows than doors but the difference was not significant following Bonferroni adjustment $t(49) = 2.23$, $p = 0.03$, $d = 0.41$.

Figure 4.10: Dwell time in the unprompted conditions



In summary, there is an unprompted bias to look to the eyes of faces. However, the control task shows that this bias is specific to faces, as there was no systematic and significant bias to the windows or doors.

4.3.4 Prompted eye tracking patterns

The prompted eye tracking data were analysed to see what effect a prompt to look to the different ROIs had on the first look locations (Figures 4.11 & 4.12), the time to first fixate on each region (Figures 4.13 & 4.14), and dwell time on each ROI (Figures 4.15 & 4.16). Firstly, a 2 (prompt location: eye or mouth) x 2 (ROI: eyes and mouth) repeated measures ANOVA was conducted with the first look data and there was no effect prompt location, $F(1,49) = 1.39$, $p = 0.24$, $\eta_p^2 = 0.03$. However, there was a significant effect of ROI, $F(1,49) = 26.41$, $p < 0.001$, $\eta_p^2 = 0.35$ and a significant interaction, $F(1,49) = 33.28$, $p < 0.001$, $\eta_p^2 = 0.40$. Post hoc *t* tests (Bonferroni threshold of p < .025) revealed that when participants were prompted to look to the eyes they looked to the eyes first significantly more often than the mouth, $t(49) = 11.22$, $p < 0.001$, $d = 2.50$, but when prompted to look to the mouth there was no significant difference in where they looked to first, $t(49) = 0.05$, $p = 0.96$, $d = 0.01$. This suggests difficulty inhibiting first looking to the eyes when instructed to look to the mouth. This point can be further illustrated by considering that 55 out of 64 participants looked to the eyes first at least once in the mouth prompt condition; however, in the eye prompt condition only six participants looked to the mouth first.

Figure 4.11: First look locations in the prompted condition (faces)

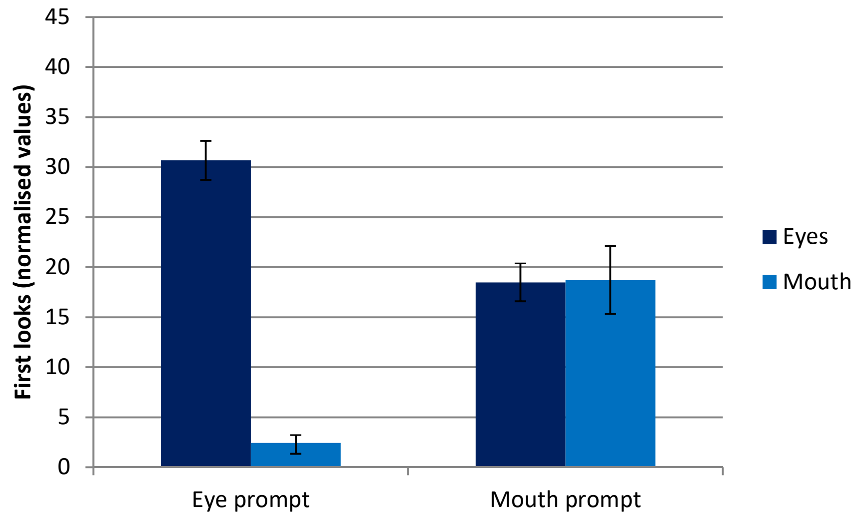
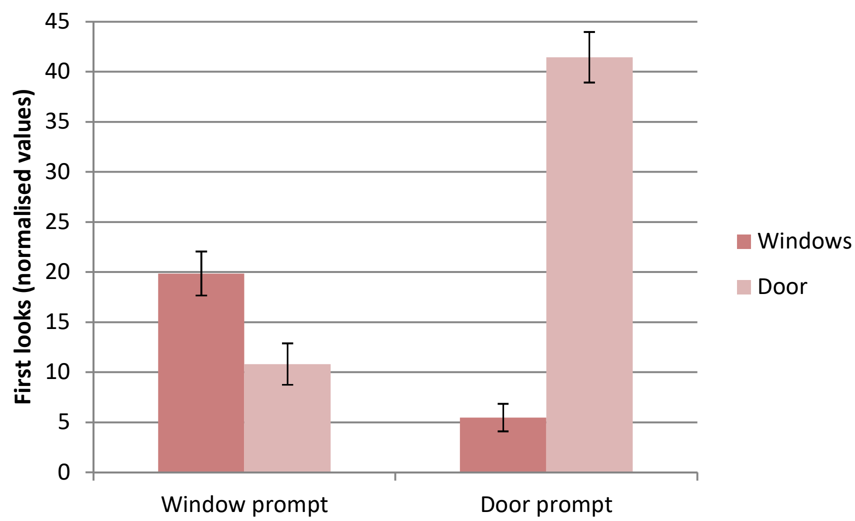


Figure 4.12: First look locations for the prompted condition (houses)



In the control task there was a main effect of prompt location, $F(1,49) = 36.39$, $p < 0.001$, $\eta_p^2 = 0.43$, a significant effect of ROI, $F(1,49) = 26.48$, $p < 0.001$, $\eta_p^2 = 0.35$ and a significant interaction, $F(1,40) = 103.47$, $p < 0.001$, $\eta_p^2 = 0.68$. Post hoc *t* tests (Bonferroni threshold of $p < .025$) revealed that when participants were prompted to look to the windows they looked to the windows first more than the door, $t(49) = 2.51$, $p = 0.015$, $d = 0.60$ and when prompted to look to the door they looked to the door more than the windows, $t(49) = 11.11$, $p < 0.001$, $d = 2.50$. This suggests that the difficult to inhibit bias to look to the eyes is not a non-specific consequence of a bias to look at the top half of an image.

Next, a 2 (prompt location: eye or mouth) x 2 (ROI: eyes and mouth) repeated measures ANOVA was conducted with the time to first fixate data and there was no effect of prompt location, $F(1,49) = 1.70$, $p = 0.20$, $\eta_p^2 = 0.06$ and no significant interaction, $F(1,49) = 1.78$, $p = 0.19$, $\eta_p^2 = 0.07$. However, there was a significant effect of ROI, $F(1,49) = 14.60$, $p = 0.001$, $\eta_p^2 = 0.37$. This data shows that over both conditions participants were faster to fixate the eye region than the mouth region, even when prompted to look to the mouth. In the control task there was no effect of prompt location, $F(1,49) = 0.33$, $p = 0.57$, $\eta_p^2 = 0.01$. However, there was a significant effect of ROI, $F(1,49) = 5.89$, $p = 0.02$, $\eta_p^2 = 0.18$ and a significant interaction, $F(1,40) = 5.54$, $p = 0.03$, $\eta_p^2 = 0.17$. Post hoc *t* tests (Bonferroni threshold of $p < .025$) revealed that when participants were prompted to look to the windows there was no difference in the amount of time to first fixate on the windows and the doors, $t(49) = 0.28$, $p = 0.79$, $d = 0.07$, but when prompted to look to the door they looked to the door faster than the windows, $t(49) = 3.23$, $p = 0.003$, $d = 0.81$. This shows there was no bias to look faster to one region over the whole task in the control task, as was seen in the eyes in the faces condition. However, it does suggest that the door prompt resulted in faster looking to the door and the same pattern was not seen in the windows condition.

Figure 4.13: Time to first fixate on each ROI in the prompted condition (faces)

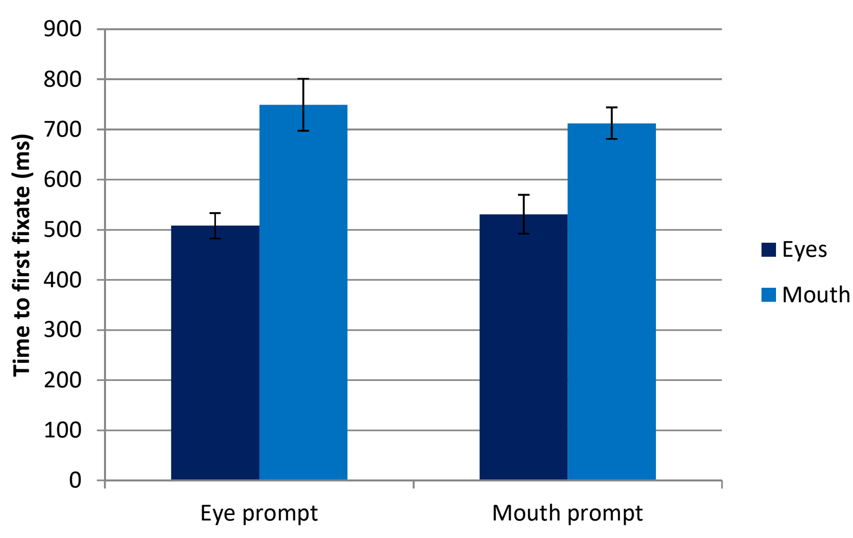
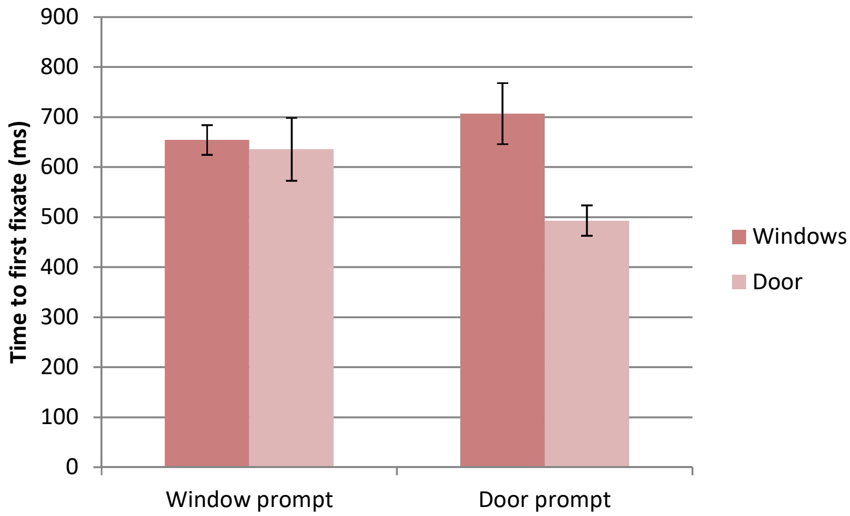


Figure 4.14: Time to first fixate on each ROI in the prompted condition (houses)



Finally, a 2 (prompt location: eye or mouth) x 2 (ROI: eyes and mouth) repeated measures ANOVA was conducted with the dwell time data and there was a main effect of prompt location, $F(1,49) = 85.47$, $p < 0.001$, $\eta_p^2 = 0.64$ and a significant effect of ROI, $F(1,49) = 16.05$, $p < 0.001$, $\eta_p^2 = 0.25$. In addition, there was a significant interaction, $F(1,49) = 255.43$, $p < 0.001$, $\eta_p^2 = 0.84$. Post hoc *t* tests (Bonferroni threshold of p < .025) revealed that when participants were prompted to look to the eyes they looked to the eyes more than the mouth, $t(49) = 17.04$, $p < 0.001$, $d = 3.41$ and when prompted to look to the mouth they looked to the mouth more than the eyes, $t(49) = 11.45$, $p < 0.001$, $d = 2.37$. This suggests that over the whole 2000ms viewing period participants were able to alter their viewing patterns in line with the prompt. The same pattern of results was seen in the control task, with a main effect of prompt location, $F(1,49) = 44.15$, $p < 0.001$, $\eta_p^2 = 0.47$, a significant effect of ROI, $F(1,49) = 39.08$, $p < 0.001$, $\eta_p^2 = 0.44$ and a significant interaction, $F(1,40) = 330.44$, $p < 0.001$, $\eta_p^2 = 0.87$. Post hoc *t* tests (Bonferroni threshold of p < .025) revealed that when participants were prompted to look to the windows they looked to the windows more than the door, t(49) = 15.79, p < 0.001, d = 3.10 and when prompted to look to the door they looked to the door more than the windows, t(49) = 17.43, p < 0.001, d = 3.50.

Figure 4.15: Dwell time in the prompted conditions (faces)

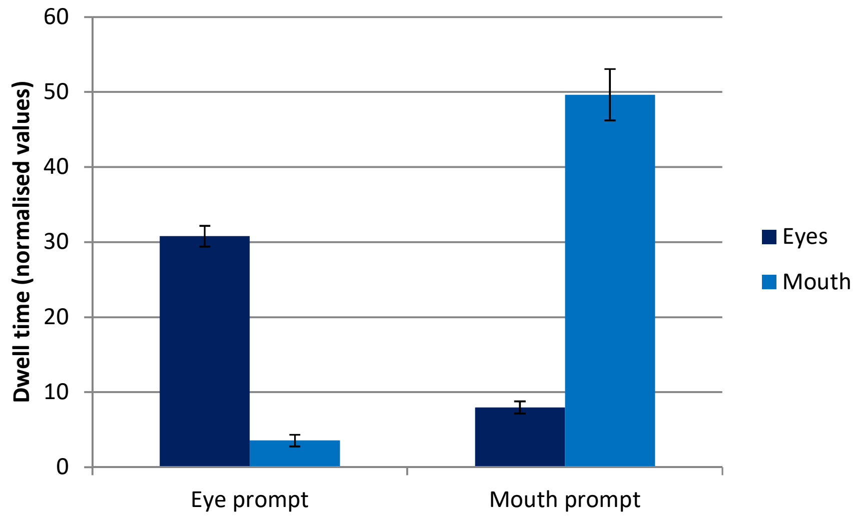
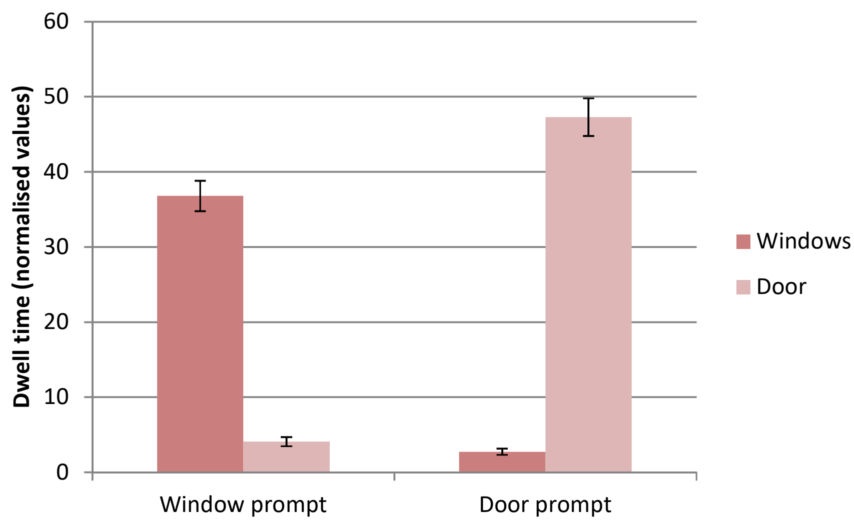


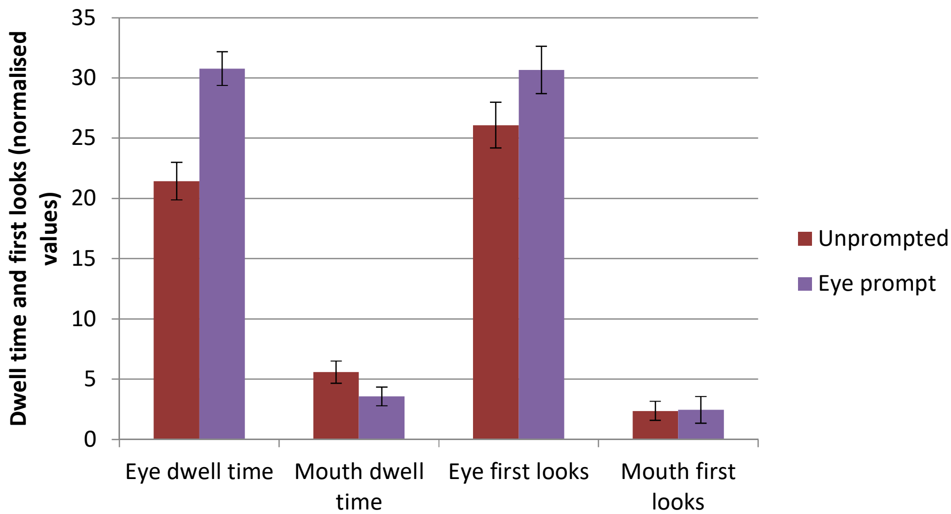
Figure 4.16 Dwell time in the prompted conditions (houses)



4.4.4 Comparison of unprompted and eye prompt conditions

In Chapter 3 there were no significant differences between the unprompted and eye prompt eye tracking data, therefore the same comparisons were run with this sample (see Figure 4.14). Using *t* tests it was found that there was no significant difference between the mouth dwell times in the two conditions, $t(49) = 7.02$, $p = 0.11$, $d = 0.33$ or the mouth first looks, $t(49) = 0.06$, $p = 0.96$, $d = 0.01$. However, unlike the findings in Chapter 3, there was a significant difference in the amount of eye dwell time in the two conditions, $t(49) = 7.02$, $p < 0.001$, $d = 0.89$, with significantly more eye looking in the eye prompt condition, than the unprompted condition. In addition, there was a significant difference between the eye first look data, $t(49) = 2.19$, $p = 0.03$, $d = 0.34$, again with more first looks to the eye in the eye prompt condition, when compared to the unprompted condition.

Figure 4.17: Comparison of unprompted and eye prompt data



4.3.5 The effects of individual differences on task performance

There was a lot of variation in the participants' eye tracking patterns. For example, in the eye prompt condition 32 out of the 64 participants (including both the standard order and reversed order groups) did not look to the mouth at all during the 2000ms display period. In addition, in the mouth prompt condition 33 of the 64 participants did not look to the mouth first at all, even when instructed to do so. In contrast, the remaining 31 participants to manage to inhibit this bias and look to the mouth first at least once.

To allow an understanding of the extent to which participants exhibited an eye preference and how this correlated with various individual difference measures, difference scores were calculated. In the unprompted, eye prompt and mouth prompt conditions, the amount of mouth dwell time was subtracted from the amount of eye dwell time to give a difference measure that shows the preference to look to the eyes. This was repeated for the first looks to the eyes and the mouth, the time to first fixate on the eyes and the mouth, accuracy for eye and mouth changed regions and RT for eye and mouth changed regions. Correlations were then run on these difference scores with age, IQ and SCQ data to investigate any individual difference (significance threshold set to $p < 0.01$ due to multiple tests). Firstly, in both the unprompted and prompted conditions age did not significantly correlate with any of the behavioural or eye tracking measures, *r*s = 0.03-0.26, all *p*s > 0.01. Second, full scale, verbal and performance IQ did not significantly correlate with any of the behavioural or eye tracking difference scores in both the unprompted and prompted conditions, rs = 0.01-0.33 all ps > 0.01. Lastly, the scores from the SCQ did not significantly correlate with any of the behavioural or eye tracking measures in either the unprompted or prompted conditions, rs = 0.002-0.32, all *p*s > 0.01. This suggests that although there is individual difference in the sample, this cannot be explained by the measures of IQ, age or levels of social communication difficulty.

4.3.6 Reversed group

To assess whether performing the prompt condition last introduced practice effects, comparisons were conducted between the standard order group and the reversed order group. Welch's *t* tests (due to uneven group sizes) were conducted on the accuracy and RT data in both the unprompted and prompted conditions and showed there were no significant differences between the two groups on any of the measures, all *p*s > 0.1. In addition, the eye tracking data for the face conditions were compared, to ensure there were no significant differences in eye tracking patterns between groups which could explain these differences. Welch's *t* tests were conducted on the dwell time, first fixation and time to first fixate data and again found no significant differences between groups, all *p*s > 0.1. Again, this suggests that differences seen are as a result of task manipulations, not merely order or practice effects.

4.4 Discussion

In this chapter I reported on how the paradigm developed in previous chapters has been adapted for use with 8-11-year-old children. Further, it has been expanded to include a stimulus control task and an additional index of eye gaze has been included in the analysis. I was also able to address the potential confound of order effects by using a reverse order control group. Assessing 8-11-year-old TD children, the key finding was a very similar pattern of results across both the behavioural and eye tracking data to those found in the previous chapters, in line with my hypotheses. First, there was a bias for children to look more to the eyes than the mouth and they demonstrated better identity recognition when the eyes changed. Second, this bias to look was difficult to inhibit, as indexed by both the location of the first fixations and the time to first fixate on the eyes and mouth.

The accuracy and RT data collected in this study support my hypothesis that children would behave similarly to adults and perform better when the eyes were the changed region compared to the mouth. In addition, the house condition revealed no bias to recognise the door or windows better in either the unprompted and prompted conditions, which suggests the eye effect was not a non-specific preference for looking to the upper half on an image. The use of a control task will be particularly important in the next chapter, where children with ASD will be compared to a TD group. Here, it will be important to establish whether any atypical looking or responses in ASD are specific to faces or whether they represent a general processing impairment (e.g. poor attention or working memory) or perceptual preference (e.g. general bias for the bottom half of the image). Across both the face and house conditions there was an improvement in performance in the prompted conditions, when compared to the unprompted conditions, showing that children aged 8-11 years were able to use the prompt information successfully to complete the task.

The unprompted eye tracking data supports the findings in Chapter 3 and extensive previous literature (e.g. Laidlaw et al., 2012; Yarbus, 1967) that people look to the eyes more than the mouth, and this was shown across the dwell time, first fixations and time to first fixate measures. There was no bias shown to look at either the windows or the door in the house condition, suggesting the bias for one feature over others is not a general property of stimuli.

Reflecting Chapter 3 and in line with predictions, the first look data showed that there is a bias to look to the eyes in 8-11-year-old children that is initially difficult to inhibit. Once again, when prompted to look to the mouth there was no difference in the first looks between the two regions. Further, this study also used the additional measure of the time taken to first fixate on each ROI. It was found that across both the eye prompt and mouth prompt conditions participants were significantly quicker at looking to the eyes than the mouth. In line with the findings from Chapter 3, it was found that the dwell time over the whole looking period was greater to the prompted region. This suggests that, like adults, children do not show a sustained eye bias over a longer looking period, which was 2000ms in the current study. Once again this suggests that there is automatic looking to the eyes in the early viewing period, as evidenced by the first fixation and time to first fixate data, but after this initial looking period there appears to be more top down control, meaning the participant is able to alter their looking pattern in line with the prompt. The house condition was not characterised by a systematic looking bias, with participants following the prompt successfully for their overall dwell time and first look locations. However, the time to first fixate data was less clear, with participants only looking to the door faster in the door prompt condition and there being no difference in the time to first fixate times in the window prompt condition. Possible reasons for this will be discussed later on.

This key finding of a difficult to inhibit eye bias, even when specifically instructed elsewhere, is once again consistent with the alternative paradigms found in the literature (Itier et al., 2007; Laidlaw et al., 2012). However, it is important to remember that these previous findings, as well as the findings from Chapter 3, have been conducted with adults while the current study establishes that the bias to look to the eyes occurs in children too. This finding may be expected when considering research with babies that shows they have a preference to look to the eyes before they are 6 months old (Farroni et al., 2002; Hainline, 1978; Haith, 1977; Lasky & Klein, 1979; Vecera & Johnson, 1995). However, face processing patterns are not fully developed in childhood and the reliance on the eye region to complete a recognition task is not fully developed until adulthood (Roberson et al., 2012). The current study suggests that even though top-down face processing strategies that enable optimal discrimination may not be fully developed, the difficult to inhibit bias to look to the eyes is present in 8-11-year-old children.

The investigation of individual differences within the sample did not find any significant associations between age, IQ or levels of social communication across any of the eye tracking or behavioural measures. These results are in line with a previous study which found no correlations between the time spent looking at different ROIs and the measures of age, verbal IQ and performance IQ in high functioning university students both with and without a diagnosis of ASD (Hanley et al., 2015). These findings provide support that the preference to look to the eyes seen in young children (Farroni et al., 2002; Hainline, 1978; Haith, 1977; Lasky & Klein, 1979; Vecera & Johnson, 1995) remains throughout childhood and does not change as a result of age, or vary with other measures such as IQ or levels of social communication. It is important to remember that only a small age range was used for this study and investigation is required with a wider age range. For example, children under 8 years may have more difficulty in inhibiting the bias; this latency of inhibition would be indicated in longer dwell times to the eyes in the mouth condition. The lack of significant correlations between the eye bias and parent-reported social communication is notable as this would predict individuals with ASD, who will be tested in the next chapter, will show the eye bias effect. Caution should be taken, however, as the number participants with SCQ data was low.

The addition of the time to first fixate measure enabled an understanding of how quickly the children looked to the eyes or mouth. As well as providing additional evidence for the robustness and reliability of the eye bias effect, it also enabled an additional understanding of how quickly children looked to the eyes. Participants in this study took on average 570ms to first fixate the eye region, compared to 855ms to first fixate the mouth region. This shows that on average across all conditions the children fixated the eye region faster than the mouth region. This is in line with the limited previous research using the measure of time to first fixate which have previously shown that people look to the eyes quicker than to the mouth in both static (Gillespie-Smith et al., 2014) and dynamic stimuli (Grossman et al., 2015). This measure will be particularly useful in the following chapter, as a direct comparison can be made between the amount of time to fixate these regions for the TD and ASD groups.

The addition of a house condition helps to add support that the effects seen were specific to faces and not as a result of general looking to the top of an image, or an inability to follow certain prompts. Finding a control task for face stimuli is challenging and the current data suggests there are some issues with the use of houses as a control task. Ideally, there should be no differences in accuracy or RT between the trials with the windows as the changed region and the trials with the doors as the changed region, as this would demonstrate that there is no bias to respond to one over the other. However, the RT data shows that the participants responded quicker to the images where the doors were the changed region, in comparison to those where the windows was the changed region in both the unprompted and prompted conditions. It is possible these findings reflect the door covering a substantially smaller area of the screen than the windows. As a result, the windows make take longer to scan before a decision can be made. In addition, when participants were prompted to look to the windows they did not look to the windows any faster than they looked to the doors. Speculatively, it is also possible that the changes to the doors may have been more salient than the changes made to the windows, for example it is possible that changes to a letterbox or design of a door may have been easier for participants to recognise than changes to a window frame. Critically, considering the eye tracking measures together there is no evidence to suggest that there is an overall bias to look to the top of house image over the bottom half of the image. This helps to provide support that the bias to look to the eyes found in this chapter and in Chapter 3 is a genuine bias to look to the eyes and not a non-specific effect of looking to the top half of the screen.

As well as the addition of the control task, a group of participants were included who completed the task in a reversed order of prompted condition followed by unprompted condition. This sub group did not perform significantly different to the main participants. This supports my interpretation that the effects of the prompt condition are not a consequence of order effects.

In conclusion, the key finding of this chapter is that there is an initial and difficult to inhibit bias to look to the eyes in 8-11 year old children, which reflects previous findings (Chapter 3) in an adult population. Following the findings in Chapter 2, showing participants with ASD had reduced accuracy, faster RTs, but a similar bias to processing the eyes more accurately when compared to the non-ASD participants, Chapter 5 will investigate the pattern of looking to the face in ASD using the paradigm established here. If looking biases exist in ASD then this may provide further understanding to the inconsistent face processing findings in ASD (see Chapter 1, page 8).

Chapter 5: An investigation of a bias to look to the eyes in ASD and TD children

5.1 Introduction

As has been shown throughout this thesis, there is a bias to look to the eyes and process the eyes preferentially. In Chapter 2, using a novel behavioural forced choice face recognition task, it was found that overall adolescents without ASD were more accurate that adolescents with ASD. However, perhaps surprisingly considering the behavioural presentation of ASD, both groups performed better when the task requirement was to process the eyes, compared to the mouth. Chapters 3 and 4 developed an eye tracking paradigm to capture the patterns of looking on this task. These chapters established the existence of a difficult to inhibit initial bias to look to the eyes in NT adult and child populations during face recognition, as shown by the use of first look and time to first fixate data. Notably, participants were able to correct this initial bias, as demonstrated by the overall dwell times. Chapter 4 also demonstrated that the looking bias did not exist in an alternative control task, using house stimuli instead of faces, therefore suggesting the bias is eye specific. In this chapter the paradigm will be used in group of children with ASD and compared with a matched TD control group. This will enable a greater understanding of where on the face children with ASD look during face recognition and whether they can successfully follow a prompt. Critically, it will establish whether the difficulty to inhibit first look to the eyes is seen in ASD as well as in the NT population.

As was discussed in Chapter 1 (see page 8), studies of where people with ASD look when viewing a face has produced very mixed findings. Table 1.1 (page 12) highlights the breadth of studies and the wide variety of results found across a range of participants, stimuli and task types. However, looking more specifically at where participants with ASD first look when viewing face stimuli gives a clearer picture. Here, most of studies found that participants were more likely to look to the eyes before the mouth (Rutherford & Towns, 2008; van der Geest et al., 2002), and that there were no differences in the amount of eye looking between the ASD participants and the TD control group (Sawyer et al., 2012). What these studies have not investigated is the dominance of the tendency to first look to the eyes in ASD. A key question is whether the autistic children in the current study will be able overcome their eye bias with the use of a prompt. Their atypical eye gaze, including a tendency by some to look less to the eyes, may be reflected in a stronger ability to override an eye bias. Alternatively, they may perform similarly to TD children and find their initial looks to the eyes difficult to suppress.

As was also discussed in Chapter 1 (see page 31), how successfully autistic participants' looking patterns can be altered when viewing a face has received limited investigation. One study, which gave the instruction to identify what object was being looked at by an actor, found that the addition of this specific instruction did not improve looking to the eyes or object (Riby et al., 2013). However, in an alternative methodology, where a more explicit and direct instruction to look to the eyes and mouth was provided, it was found that autistic participants were able to alter their looking patterns in line with the prompt (Kikuchi et al., 2011). Perhaps the most relevant previous study is the work of Moriuchi et al. (2017), who found that 2 year old children with a diagnosis of ASD looked to the eyes when cued to look there, and did not look away any faster than the TD and developmentally delayed control groups. In summary, these studies suggest that our participants with ASD should be able to follow explicit instructions to look to the eyes or mouth.

This study will use the paradigm outlined in previous chapters to enable a greater understanding of the looking patterns of participants with ASD. This will be the first study in the field to use all of the measures of dwell time, first look location and the time to first fixate on each ROI in both an unprompted and prompted condition. This will enable further understanding of where ASD participants look at an image when trying to remember it for a recognition task, but also how successfully they are able to change any dominant face processing patterns they have in line with a prompt given.

Consistent with the findings from Chapter 2, where behavioural performance on the task was measured in adolescents with and without ASD, I would not hypothesise any overall group differences in the patterns of response (accuracy and RT to the eye and mouth regions) between the ASD and TD groups. In addition, the previous research on first look locations suggests that a dominant bias to look to the eyes may exist in ASD (Rutherford & Towns, 2008; Sawyer et al., 2012; van der Geest et al., 2002), despite the behavioural presentation of ASD of often consisting of poorly modulated eye gaze. However, whether children with ASD find it as difficult as non-autistic children and adults to overcome this bias remains to be established.

5.2 Method

5.2.1 Participants

Twenty-six participants with an ASD were recruited for this study, but as a result of technical problems with the eye tracker, lack of participant understanding of the task, or difficulties in participant attention, only 14 completed the task. The final 14 participants were not significantly different from the 12 excluded participants in age, full scale IQ, verbal IQ (both measured by the Wechsler Abbreviated Scale of Intelligence) or ADOS-2 scores, all *p*s > 0.05, but the included participants did have a significantly higher performance IQ than the excluded participants, $t(1,24) = 5.40$, $p = 0.03$ (Welch's *t* test used due to unequal sample size). Data from 14 TD participants were used as a matched control group and these were selected from the TD participants in the standard order group from Chapter 4, matching according to age and ability. The ASD participants were recruited through their school or through an online participant register at the Wales Autism Research Centre, Cardiff University. All participants with ASD had a clinical diagnosis of an ASD. Behavioural presentation was further investigated using the ADOS-2 module 3 (Lord et al., 2012). Four of the participants were below the threshold for an ASD diagnosis (between one and three comparison points below the cut off for ASD). However, analyses were completed with and without these participants and the patterns observed were the same. Therefore, the reported analyses include these participants. In addition, SCQs were sent to all parents to complete and 12 were returned (7 in the TD group and 5 in the ASD group). All of the TD children were below the score of 15 usually used to indicate the existence of ASD and all of the ASD children were above this cut off. Participants in the ASD and TD groups were matched at the group level on age, $t(16.79) = 0.66$, $p = 0.52$, full scale IQ, $t(26) = 0.98$, $p = 0.34$, performance IQ, $t(26) = 0.50$, $p = 0.62$, and verbal IQ, $t(26) = 1.84$, $p = 0.08$ (see table 5.1). All participants reported either normal, or corrected to normal vision.

Table 5.1: Participant information

	n	Age (in years)	Males: Females	FSIQ	VIQ	PIQ	ADOS
ASD	14	10.5 (1.9)	13: 1	95.7 (13.1)	88.1 (16.4)	104.3 (14.8)	8.00 (2.01)
TD	14	10.2 (0.7)	6: 8	100.1 (10.3)	97.4 (9.2)	101.6 (12.9)	N/A

FSIQ: Full scale IQ, VIQ: Verbal IQ, PIQ: Performance IQ, SCQ: ADOS: Autism Diagnostic Observation Schedule

5.2.2 Apparatus

The same eye tracker and experimental set up was used as was explained in Chapter 4 (see page 71).

5.2.3 Materials

All stimuli used in this study were the same as those used in Chapter 4 (see page 71).

5.2.4 Design

The design of the study was the same as for Chapter 4 (see page 73), but with the addition of a between groups component to allow a comparison of the ASD and TD groups. Given the null effect of condition order (prompted, unprompted) on performance, all participants completed the tasks with the unprompted condition first.

5.2.5 Procedure

The procedure used was the same as in Chapter 4 (see page 74), although some ASD participants were tested in a room at Cardiff University and others were tested in a private room in their school. In addition, the ASD participants underwent the ADOS-2 assessment. All participants tested in schools undertook each of the tasks (eye tracking paradigm, WASI and ADOS) on different days, however the children tested at Cardiff University undertook all tasks on the same day with long breaks in between each task.

5.2.6 Normalisation of eye tracking data

The same normalisation process was conducted as in Chapters 3 and 4 (see page 54), with ratio values presented throughout this analysis.

5.3 Results

5.3.1 Data screening

Trials were removed where the participants did not fixate the gaze contingent point to initiate the stimulus onset to the screen. This resulted in 38 trials being removed from analysis (17 ASD trials and 21 TD trials). This represented 2.83% of all trials and the remaining 1306 trials were included in the analysis.

5.3.2 Behavioural Results

The data were not normally distributed and this was not resolved through transformation. Subsequently, both non-parametric and parametric tests were run, and as they both produced the same pattern of results the parametric tests will be presented throughout this results section.

Firstly, the accuracy data were analysed to see how successfully both groups of participants were able to complete the tasks in the different conditions (Figures 5.1 & 5.2). A 2 (prompt: unprompted or prompted) x 2 (Changed region: eye or mouth) x 2 (Group: ASD or TD) mixed ANOVA was performed on the accuracy data. This revealed a significant effect of prompting with participants being more accurate in the prompted condition than the unprompted condition, $F(1,26) = 15.25$, $p = 0.001$, $\eta_p^2 = 0.37$ and a near significant effect of changed region, with higher accuracy in the eyes condition than the mouth condition, $F(1,26) = 4.01$, $p = 0.06$, $\eta_p^2 = 0.13$. In addition, there was no effect of group, $F(1,26) = 0.871$, $p = 0.36$, $\eta_p^2 = 0.03$, with both groups showing a similar pattern of results. In addition, there were no significant interactions, all *p*s > 0.05. This suggests there was an improvement in both groups in prompted condition and the bias to perform better in the eye changed condition was at the borderline of significance, with a medium to large effect size.

Figure 5.1: ASD face accuracy in the unprompted and prompted conditions

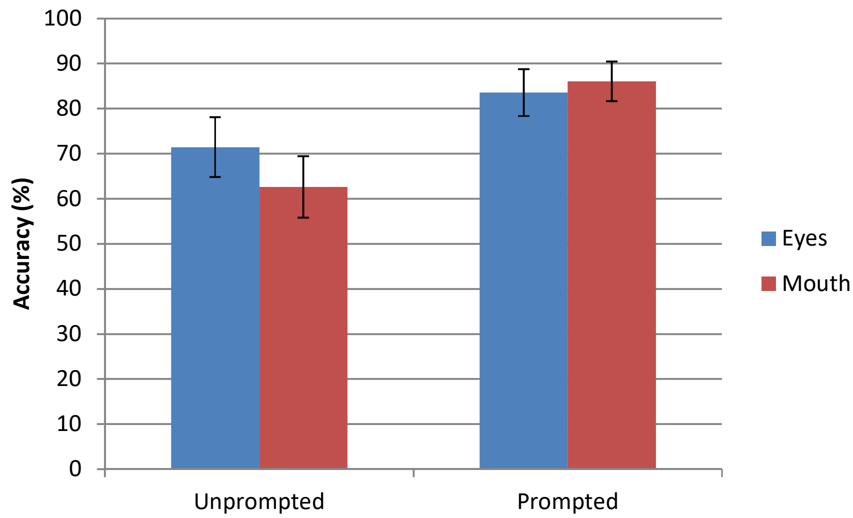
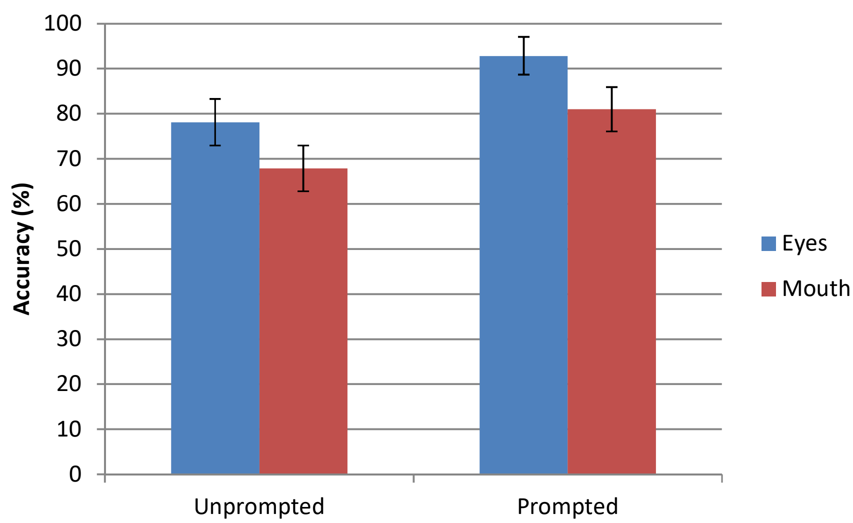


Figure 5.2: TD face accuracy in the unprompted and prompted conditions



In comparison, in the control task (Figures 5.3 & 5.4) there was a significant effect of prompting, with increased accuracy in the prompted condition when compared to the unprompted condition, $F(1,26) = 77.62$, $p < 0.001$, $\eta_p^2 = 0.75$, no significant effect of changed region (window or door), $F(1,26) = 0.14$, $p = 0.71$, $\eta_p^2 = 0.01$ and no effect of group, $F(1,26) = 0.001$, $p = 0.72$, $\eta_p^2 < 0.001$. However, there were significant interactions between changed region and group, $F(1,26) = 6.28$, $p = 0.02$, $\eta_p^2 = 0.20$, and between prompting and group, $F(1,26) = 4.30$, $p = 0.048$, $\eta_p^2 = 0.14$. These interactions seem to be driven by the ASD participants showing a smaller improvement in the prompted condition compared to the unprompted condition, whereas the TD group show a greater overall improvement with the addition of a prompt.

Figure 5.3: ASD house accuracy in the unprompted and prompted conditions

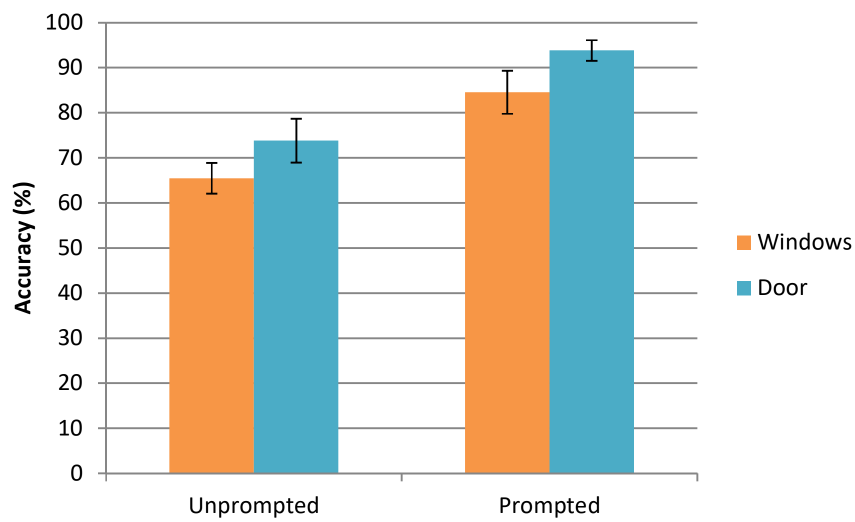
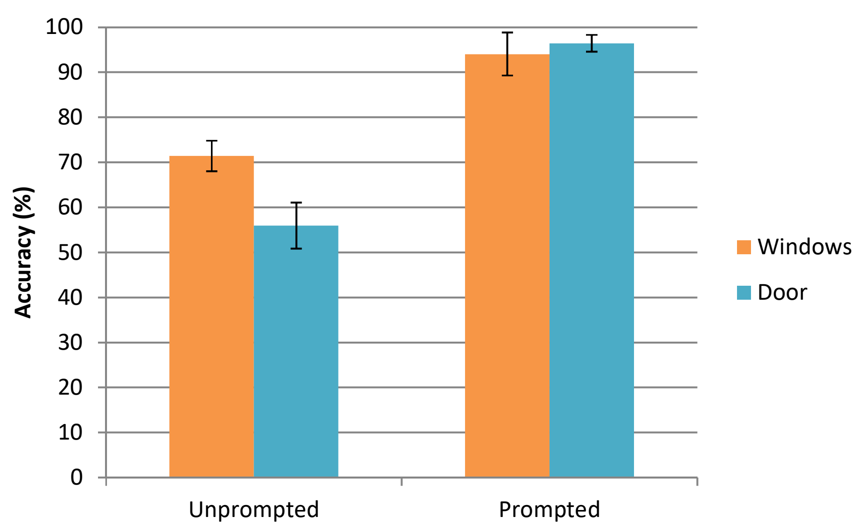


Figure 5.4: TD house accuracy in the unprompted and prompted conditions



Next, a 2 (prompt: unprompted or prompted) x 2 (Changed region: eye or mouth) x 2 (Group: ASD or TD) mixed ANOVA was performed on the RT data (Figures 5.5 & 5.6). This revealed a significant effect of prompting with the prompted condition having quicker RTs, $F(1,26) = 15.64$, $p = 0.001$, $\eta_p^2 = 0.38$, no significant effect of changed region, $F(1,26) = 0.02$, $p = 0.90$, $\eta_p^2 = 0.001$, and a significant effect of group with the TD group displaying quicker RTs, $F(1,26) = 4.56$, $p = 0.04$, $\eta_p^2 = 0.15$. In addition, a three way interaction was found, $F(1,26) = 6.96$, $p = 0.01$, $\eta_p^2 = 0.21$. This interaction appears to be driven by the ASD group responding to the eyes quicker than the mouth in the unprompted condition and the mouth quicker than the eyes in the prompted condition, but with the TD group showing less differentiation between ROIs, particularly in the prompted condition.

Figure 5.5: ASD face reaction time in the unprompted and prompted conditions

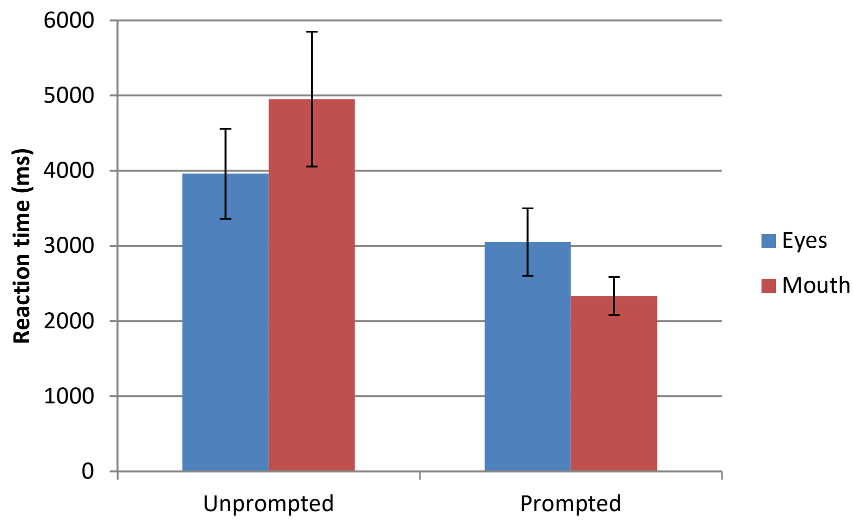
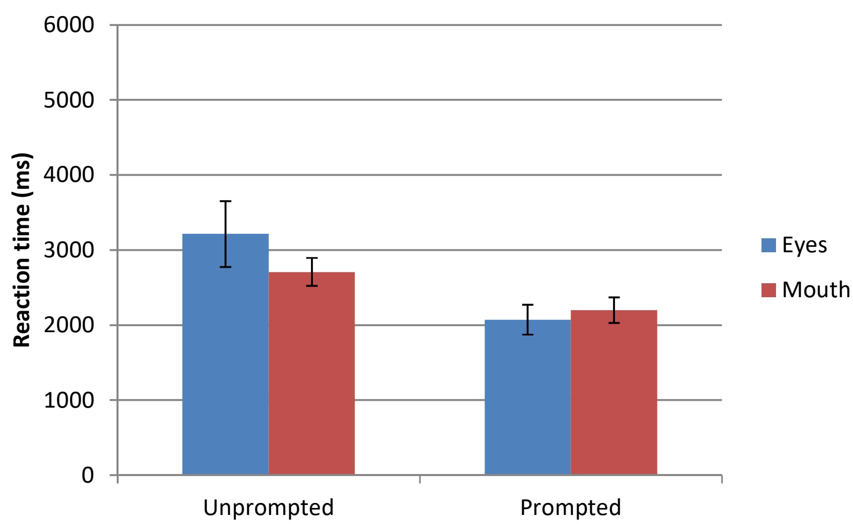


Figure 5.6: TD face reaction time in the unprompted and prompted conditions



In comparison, in the control task (Figures 5.7 & 5.8) there was a significant effect of prompting, with shorter RTs in the prompted condition when compared to the unprompted condition, $F(1,26) = 77.92$, $p < 0.001$, $\eta_p^2 = 0.75$, a significant effect of changed region, with shorter RTs for the doors than the windows, $F(1,26) = 43.87$, $p <$

0.001, $\eta_p^2 = 0.63$, no effect of group, $F(1,26) = 1.75$, $p = 0.20$, $\eta_p^2 = 0.06$ and no significant interactions, all $ps > 0.05$. Therefore, with the house stimuli participants in both groups were quicker to respond to the doors and when a prompt was provided. In summary, in both the faces and houses a prompt improved response time, but in the face condition this was more complex with the ASD group responding to the eyes quicker than the mouth in the unprompted condition and the mouth quicker than the eyes in the prompted condition.

Figure 5.7: ASD house reaction time in the unprompted and prompted conditions

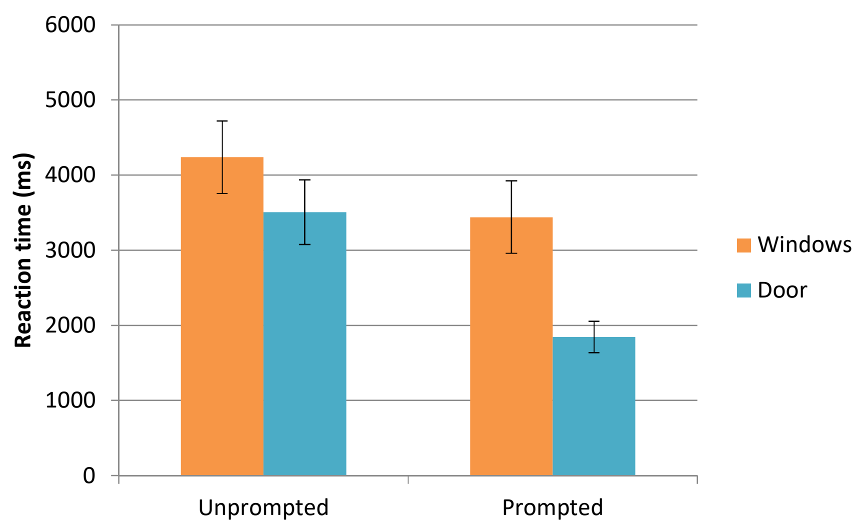
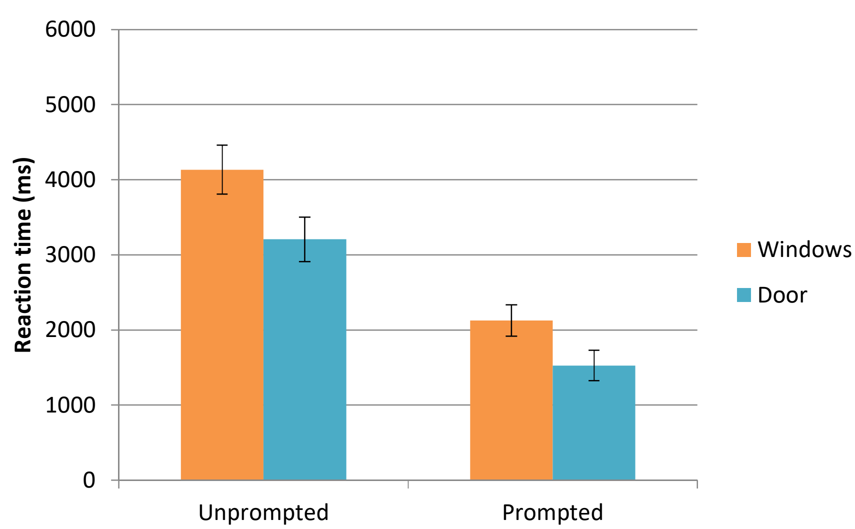


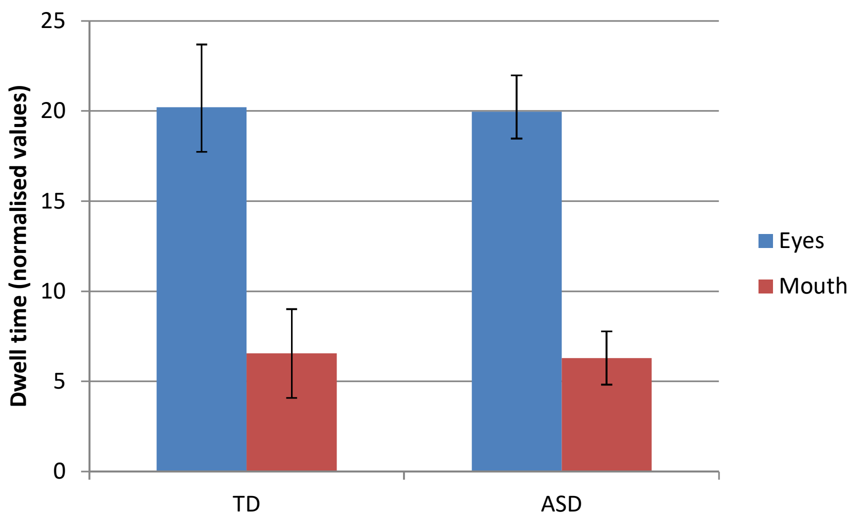
Figure 5.8: TD house reaction time in the unprompted and prompted conditions



5.3.3 Unprompted eye tracking data

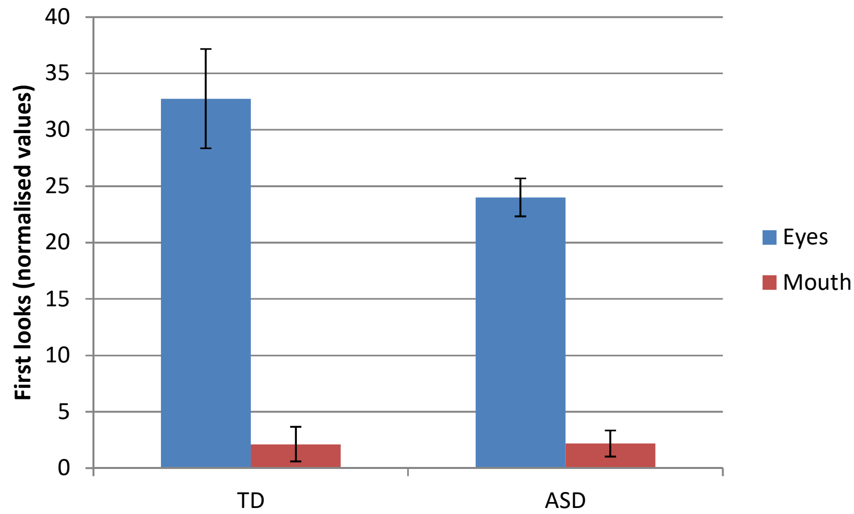
The unprompted dwell time, first look and time to first fixate data were analysed to understand how both groups look at the images without a prompt. Firstly, a 2 (ROI looking: eye or mouth) x 2 (Group: ASD or TD) mixed ANOVA was conducted on the dwell time face data (Figure 5.9). This showed a significant effect of ROI, $F(1,26) = 22.38$, $p < 0.001$, $\eta_p^2 = 0.46$, with participants looking more overall to the eyes than the mouth. In addition, there was no significant effect of group, $F(1,26) = 0.02$, $p = 0.90$, $\eta_p^2 < 0.001$, and no significant interaction, $F(1,26) < 0.00$, $p = 0.988$, $\eta_p^2 < 0.001$.

Figure 5.9: Unprompted face dwell times



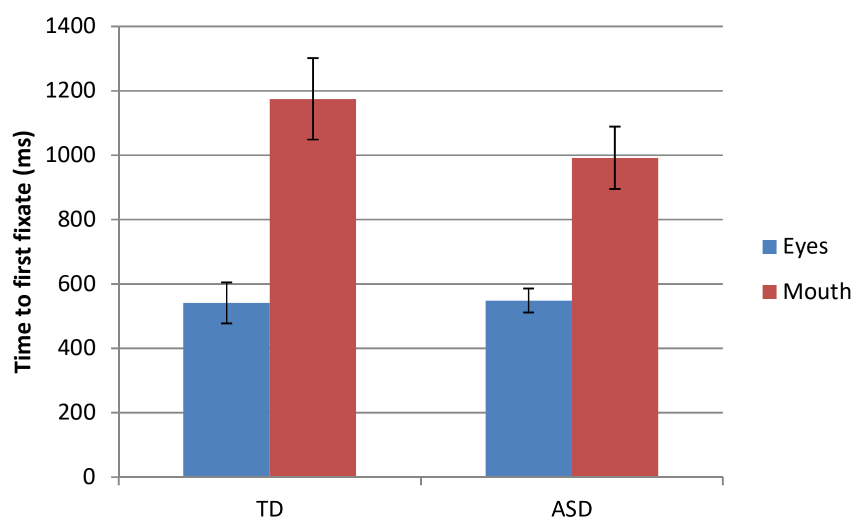
Next, a 2 (ROI looking: eye or mouth) x 2 (Group: ASD or TD) mixed ANOVA was conducted on the first look location data (Figure 5.10). This showed a significant effect of ROI, $F(1,26) = 86.13$, $p < 0.001$, $\eta_p^2 = 0.77$, with participants looking more first to the eyes than the mouth ROI. There was also a close to significant effect of group, $F(1,26) = 3.78$, $p = 0.06$, $\eta_p^2 < 0.13$ and no significant interaction, $F(1,26) = 2.44$, $p = 0.13$, $\eta_p^2 = 0.09$. These data suggest that overall the patterns of results were the same for both groups, with more first fixations to the eyes than to the mouths. However, the effect of group was close to significant and had a medium-large effect size, and this suggests that overall there were fewer first fixations to either of the two key features for the ASD participants, than the TD control group.

Figure 5.10: Unprompted face first fixations



Finally, a 2 (ROI looking: eye or mouth) x 2 (Group: ASD or TD) mixed ANOVA was conducted on the time it look participants to first fixate on either the eye or mouth ROI (Figure 5.11). This showed no significant effect of ROI, $F(1,16) = 2.41$, $p = 0.13$, $\eta_p^2 = 0.09$, no significant effect of group, $F(1,16) = 0.26$, $p = 0.61$, $\eta_p^2 = 0.01$, and no significant interaction, $F(1,16) = 0.65$, $p = 0.43$, $\eta_p^2 = 0.02$. Although, there was no significant difference between the time to first fixate on the eyes and the mouth there was a medium effect size with it taking on average 545ms for the two groups to look to the eyes and 1073ms for them to look to the mouth. It also should also be noted that

Figure 5.11: Unprompted face time to first fixate per ROI



ten participants (six TD, 4 ASD) did not look to the mouth at all in the unprompted condition and are therefore not included in this time to first fixate analysis, thus the analysis was relatively underpowered. Taken together, these eye tracking data suggest that there is a bias to look to the eyes in the unprompted condition and that it is present for both ASD and TD participants.

In the control condition (Figures 5.12, 5.13 & 5.14), there were no significant effects of region or group across all three measures (all *p*s > 0.05), indicating that in the unprompted condition there was no viewing preference for either the windows or the doors in either the ASD or TD participants.

Figure 5.12: Unprompted house dwell times

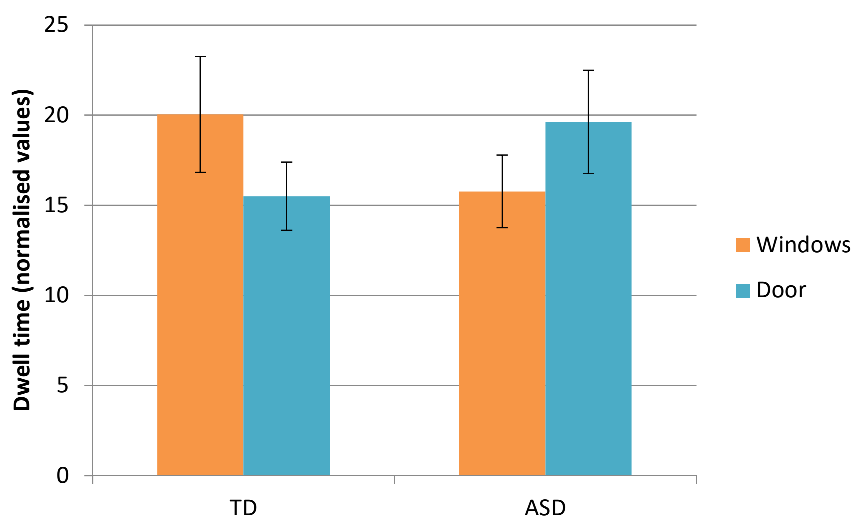


Figure 5.13: Unprompted house first looks

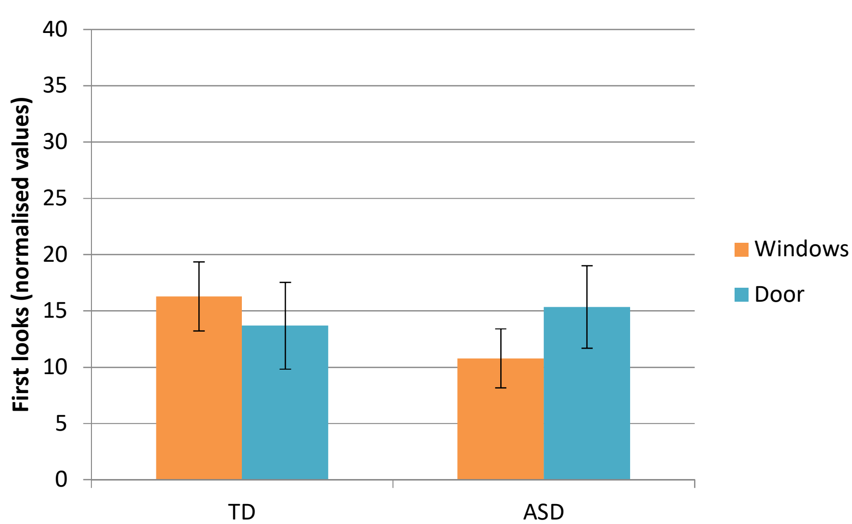
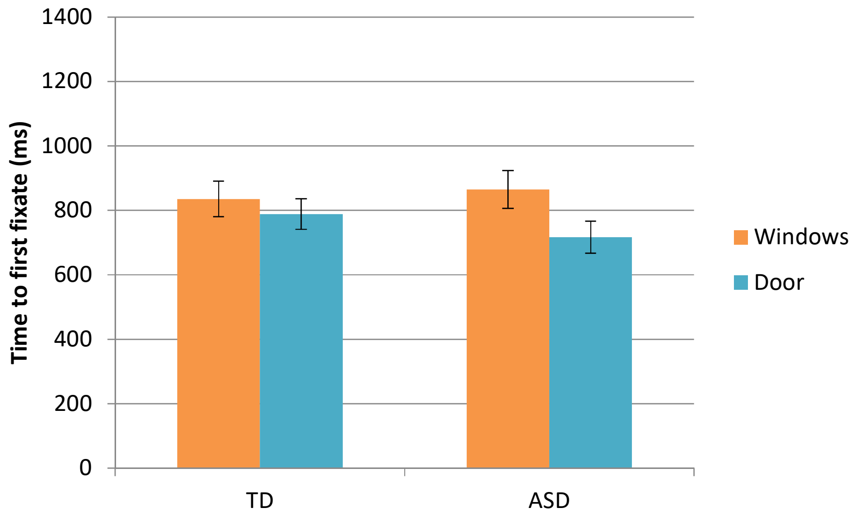


Figure 5.14: Unprompted house time to first fixate per ROI



5.3.4 Prompted eye tracking results

To understand the effects of prompting on the looking patterns of both groups I analysed measures of dwell time, first fixation location and time taken to fixate on each ROI. A 2 (prompt location: eye or mouth) x 2 (ROI: eye or mouth) x 2 (Group: ASD or TD) mixed ANOVA was performed on the face dwell time data (Figures 5.15 & 5.16). This revealed a significant effect of prompt location, $F(1,26) = 12.66$, $p = 0.001$, $\eta_p^2 = 0.33$, no effect of ROI, $F(1,26) = 0.44$, $p = 0.52$, $\eta_p^2 = 0.02$, and no effect of group, $F(1,26) = 0.76$, $p = 0.39$, $\eta_p^2 = 0.03$. In addition, there was a significant interaction of prompt location and ROI, $F(1,26) = 86.38$, $p < 0.001$, $\eta_p^2 = 0.77$. Post hoc *t* tests (Bonferroni threshold of $p < .025$) showed that when prompted to look to the eyes participants looked more to the eyes than the mouth, $t(27) = 11.99$, $p < 0.001$, $d = 3.41$, and when they were prompted to look to the mouth they looked to the mouth more than eyes, $t(49) = 5.58$, $p < 0.001$, $d = 1.61$.

Figure 5.15: ASD prompted dwell time to faces

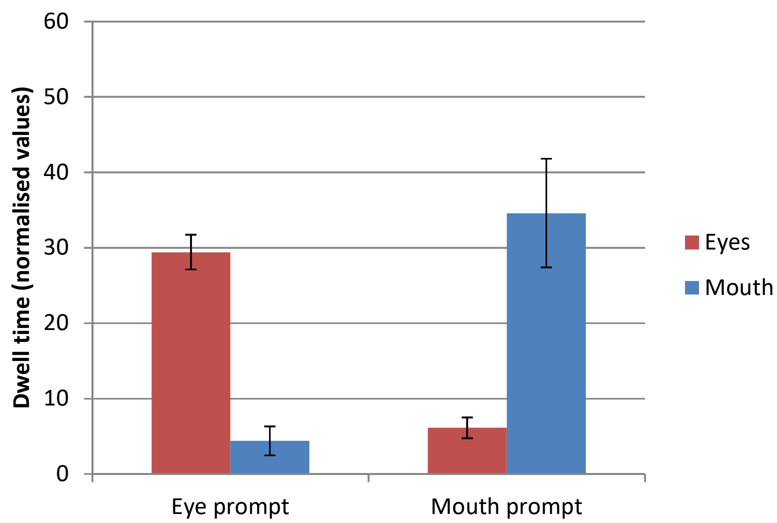
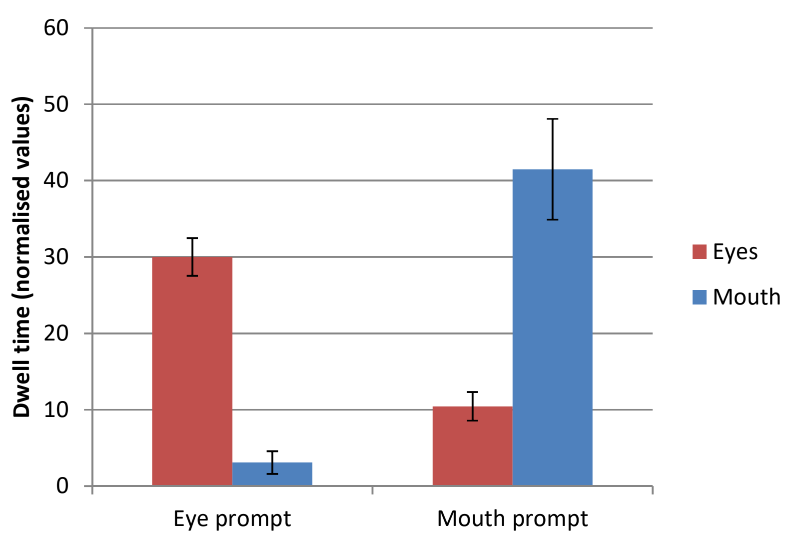


Figure 5.16: TD prompted dwell time to faces



A similar pattern of results was seen in the house condition (Figures 5.17 & 5.18), with a significant effect of prompt location, $F(1,26) = 23.52$, $p < 0.001$, $\eta_p^2 = 0.46$, a significant effect of ROI, $F(1,26) = 46.21$, $p < 0.001$, $\eta_p^2 = 0.64$, and no effect of group, $F(1,26) = 0.45$, $p = 0.51$, $\eta_p^2 = 0.02$. In addition, there was a significant interaction of prompt location and ROI, $F(1,26) = 213.14$, $p < 0.001$, $\eta_p^2 = 0.89$. Post hoc *t* tests (Bonferroni threshold of $p < .025$) showed that when prompted to look to the windows participants looked more to the windows than the door, $t(27) = 10.60$, $p < 0.001$, $d = 3.09$, and when they were prompted to look to the door they looked to the door more than windows, $t(49) = 14.80$, $p < 0.001$, $d = 4.16$. Therefore, in both the face and house conditions, participants' dwell time over the 2000ms was in line with the prompt given.

Figure 5.17: ASD prompted dwell time to houses

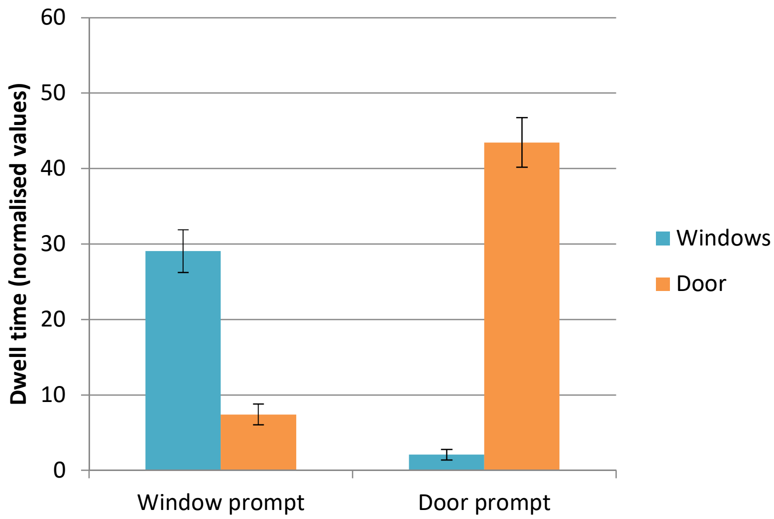
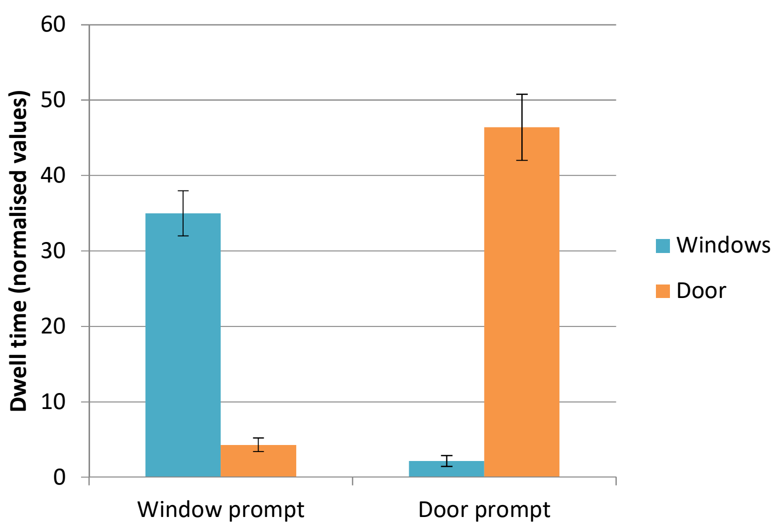


Figure 5.18: TD prompted dwell time to houses



Next, a 2 (prompt location: eye or mouth) x 2 (ROI: eye or mouth) x 2 (Group: ASD or TD) mixed ANOVA was performed on the first fixation face data (Figures 5.19 & 5.20). This revealed no significant effect of prompt location, $F(1,26) = 0.25$, $p = 0.62$, $\eta_p^2 = 0.01$, a significant effect of ROI, $F(1,26) = 18.31$, $p < 0.001$, $\eta_p^2 = 0.41$, and no effect of group, $F(1,26) = 0.31$, $p = 0.58$, $\eta_p^2 = 0.01$. In addition, there was a significant interaction of prompt location and ROI, $F(1,26) = 23.74$, $p < 0.001$, $\eta_p^2 = 0.47$. Post hoc *t* tests (Bonferroni threshold of p < .025) showed that when prompted to look to the eyes participants' first fixations were more often to the eyes than the mouth, $t(27) = 9.41$, $p < 0.001$, $d = 2.65$, but when they were prompted to look to the mouth there was no difference in their first fixation locations, $t(49) = 0.28$, $p = 0.78$, $d = 0.08$.

Figure 5.19: ASD prompted first looks to faces

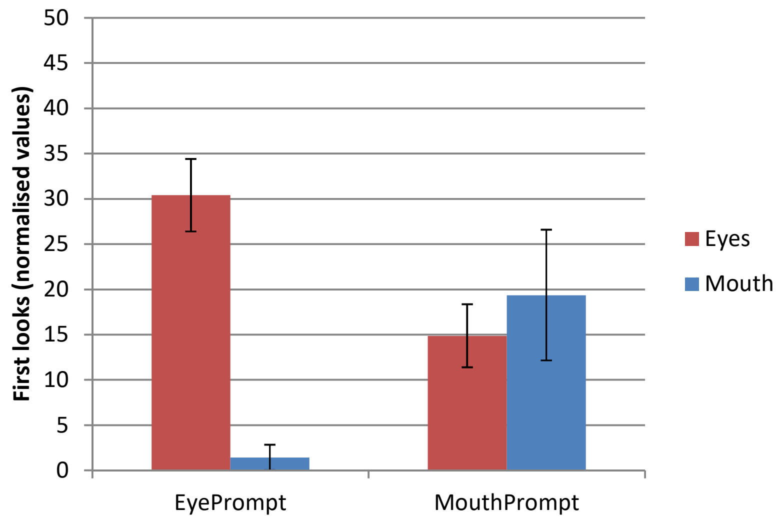
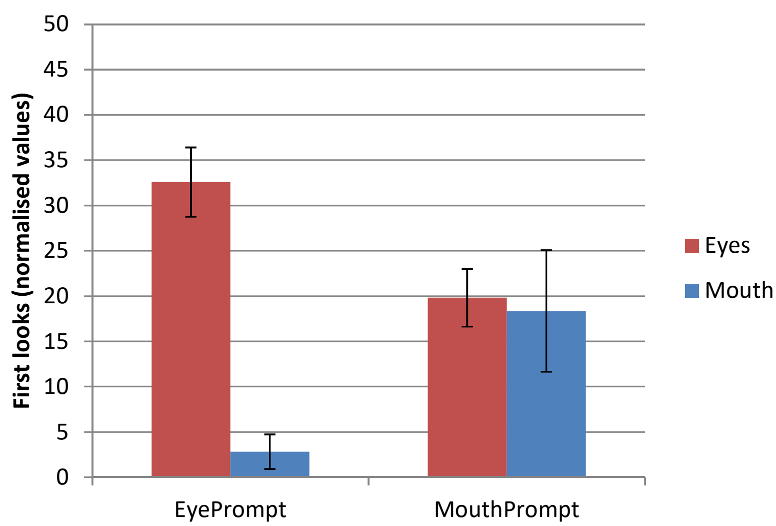


Figure 5.20: TD prompted first looks to faces



In comparison, in the house condition (Figures 5.21 & 5.22) there was significant effect of prompt location, $F(1,26) = 23.65$, $p < 0.001$, $\eta_p^2 = 0.48$, a significant effect of ROI, $F(1,26) = 28.85$, $p < 0.001$, $\eta_p^2 = 0.53$, and no significant effect of group, $F(1,26) = 0.31$, $p = 0.58$, $\eta_p^2 = 0.11$. In addition, there was a significant interaction of prompt location and ROI, $F(1,26) = 59.92$, $p < 0.001$, $\eta_p^2 = 0.69$. Post hoc *t* tests

(Bonferroni threshold of $p < .025$) showed that when prompted to look to the windows there was no significant difference in the amount of first looks to the window and to the door, $t(27) = 0.91$, $p = 0.37$, $d = 0.27$, but when they were prompted to look to the door they looked to the door first more often than the windows, $t(49) = 10.86$, $p < 0.001$, $d = 3.12$.

Figure 5.21: ASD prompted first looks to houses

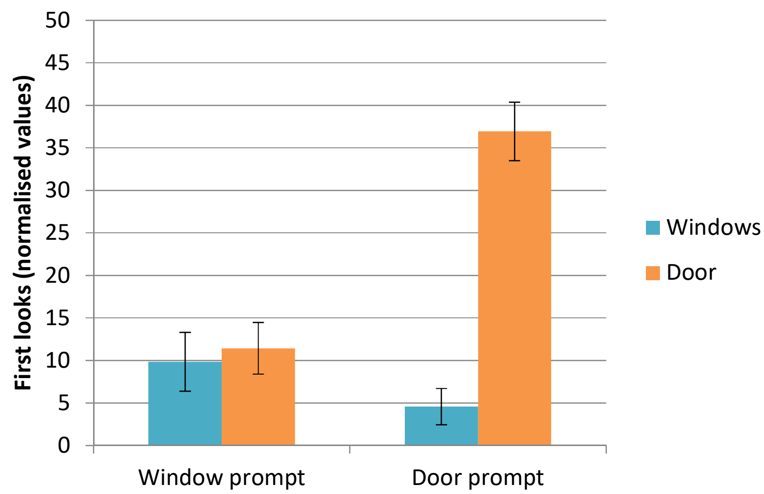
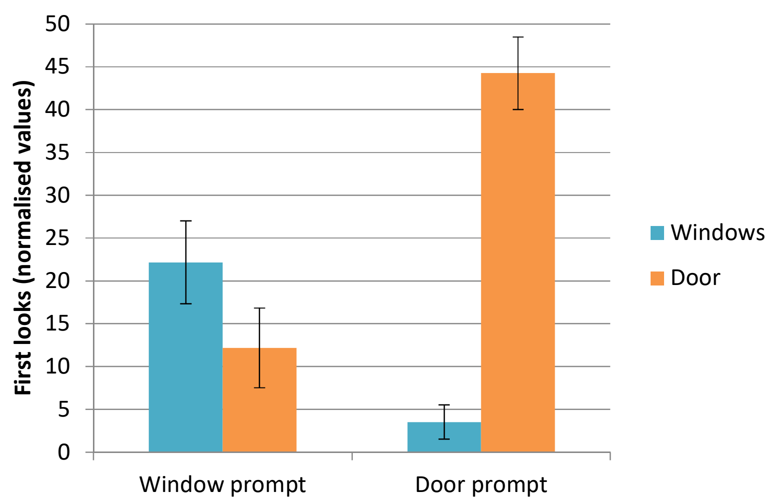


Figure 5.22: TD prompted first looks to houses



These data suggest that there is a bias to look to the eyes that is difficult to inhibit in both the TD and ASD groups. However, it also suggests it is easier to follow the door prompts initially, when compared to the window prompts.

When examining the data it was found in the TD group eight out of the 14 participants did not fixate the mouth at all when prompted to look to the mouth and in the ASD group seven out of the fourteen did not fixate the mouth in this condition. As a result of this there was not enough information to run analysis on the time to first fixate data. Notably, all participants showed fixations to the eyes when prompted to look at the eyes.

5.4 Discussion

This chapter set out to understand the eye gaze patterns of children with ASD during a face recognition task and whether or not these changed with the addition of a prompt to look at either the eyes or mouth.

I first hypothesised that there would be no overall differences in the patterns of behavioural data between groups. The data in this study support this hypothesis with both groups of participants showing greater accuracy in the eye change condition, than the mouth change condition and no group differences. This is similar to findings in Chapter 2, where both the ASD and control groups also showed greater accuracy in the eye change condition when compared to the mouth change condition. However, in Chapter 2 the control group showed greater overall accuracy (when collapsed across the eye and mouth conditions) when compared to the ASD group and this finding was not replicated in the current study.

As in Chapter 2, the pattern of results for RT was more complex. Although there was no significant main effect of group, there was a significant three-way interaction. Notably, the ASD group had quicker RTs when responding to the eyes than the mouth in the unprompted condition, whereas differences for the TD group were more subtle. This is compatible with the ASD group processing information in the eyes efficiently. This is different, however, to the pattern of data seen in Chapter 2. In Chapter 2 the ASD participants exhibited faster average RTs across the whole task than the non-ASD control group, but the patterns of RTs to the eyes and mouth across the two groups was similar. This difference may be as a result of the different control groups used, as in Chapter 2 the control group included children with intellectual disabilities, who may therefore have slower processing speeds.

The eye gaze data are in line with the hypothesis that there would be no differences in the pattern of results between and the ASD and TD groups. In the unprompted condition, both groups showed a bias to look to the eyes, with both groups showing greater dwell time, more first fixations and looked more quickly to the eyes than to the mouth. The only substantive difference, although this did not reach the significance threshold, was that the ASD group made fewer first fixations overall to the eye and mouth, when compared to the TD control group. This suggests a greater tendency in the ASD group to look at either alternative regions of the face or outside of the face when first fixating. This corresponds with previous eye tracking research that has found an increased tendency to look at non-core facial features or away from the face in ASD, despite a similar pattern of looking to the eyes when the face is engaged (e.g. Hernandez et al., 2009; Pelphrey et al., 2002).

The key question in this chapter was whether the children with ASD would find it as difficult as TD children to look away from the eyes when prompted to look at the mouth i.e. does being autistic reduce the strength of the eye bias? The findings were clear in demonstrating that the ASD group did not perform differently to the TD children and showed similar difficulty in disengaging from the eyes. The first look and time to first fixate data show that even when prompted to look to the mouth both the TD and ASD groups look first more often and look more quickly to the eye region than to the mouth region. However, as was seen in both Chapters 3 and 4 with NT adults and TD children, this bias appears to be specific for the early viewing period. The dwell time data shows that both groups of participants were able to follow the prompt instruction when the whole 2000ms viewing period was considered, with more looking to the eyes when prompted to look to the eyes and more looking to the mouth when prompted to look to the mouth. The lack of group difference found in the current chapter is in line with the finding from Chapter 4, that none of the eye tracking or behavioural measures correlated with a measure of social communication. The current chapter extends this with the finding that no differences were found in the group with a social communication disorder. The findings of this chapter replicate the findings from the previous chapters that over a longer viewing period participants can alter their looking patterns, but the initial bias to look to the eyes is the most difficult to inhibit. Importantly, this bias exists in ASD participants as well.

The lack of differences between the ASD and TD groups in their looking patterns is perhaps the most interesting and striking finding of this study. However, similar performance in autistic and non-autistic populations is not new. For example, like in the current study, Rutherford and Towns (2008) and van der Geest et al. (2002) found that autistic participants looked first more often to the eye region than to the mouth region and Sawyer et al. (2012) also found no differences between the ASD and control groups. However, where the current study is novel is that it extends these findings to consider the ability to suppress the eye bias.

The ability to follow an instruction to look to different face regions is an area that has received minimal investigation in ASD and therefore this current study helps to increase the understanding of this process. By considering the whole viewing period (dwell time over 2000ms) it can be seen that autistic children, as well as TD children, were able to successfully follow the instruction to look to the eye or mouth region, which is line with the previous findings by Kikuchi et al. (2011) in children and adolescents and Moriuchi et al. (2017) in toddlers. In addition, the first look and time to first fixate data suggest children both with and without ASD experience initial difficulties in following an instruction to look to the mouth due to a bias to look to the eyes. This finding is in line with the findings by Rombough and Iarocci (2013) who also found that participants with ASD had some difficulty looking away from the eyes even when explicitly told to do so. The paradigm developed in this thesis is very different to the previous paradigms used and helps to increase knowledge of this eye bias. For example, the study by Rombough and Iarocci (2013) is a gaze cueing study, whereby participants are told whether looking to the eyes will help them or not, which is a very different paradigm than the prompted forced choice recognition paradigm developed throughout this thesis. The study conducted by Moriuchi et al. (2017) is conducted on children around the age of 2-years-old. As a result the manipulation that can occur is minimal due to the children's understanding of the task. In addition, Kikuchi et al. (2011) showed that in a gap overlap task autistic participants can alter their gaze to look to the eyes when instructed to do so and then the eyes are distracting from the task. However, the paradigm developed through this thesis is the first to explicitly instruct ASD participants to look to a certain face area (with a verbal instruction) to be able to complete the task. By adding this specific manipulation it allows a greater understanding of the first fixation pattern of eye tracking data that appears to be automatic and cannot be changed in ASD participants, as well as the TD group.

The findings from the current study may be considered surprising alongside the behavioural presentation of ASD, which often includes poorly modulated eye contact.

However, the stimuli used in this study were black and white static images, as opposed to the complex, dynamic contexts in which faces are perceived in daily life. Although the paradigm is therefore limited in its ecological validity it does allow for a controlled experiment that can focus on understanding basic looking mechanisms. These data suggest that when looking demands are stripped back to controlled face images, children with ASD are able to show the same looking patterns as their TD peers. Moriuchi et al. (2017) suggest that individuals with ASD may show gaze indifference in real life and look to the eyes less as they are seen as less engaging or informative. They suggest that the elevated anxiety and autonomic responses to eye contact reported in ASD (Kylliainen & Hietanen, 2006) may be a developmental consequence of ASD and not a cause of social communication difficulties per se. The current study suggests that those with ASD do still have those same biases to look to the eyes, and therefore, perhaps it is the anxiety of real life social situations that result in reduced or abnormal eye looking for some people with ASD.

Caution should be taken when interpreting the time to first fixate data as 50% of the TD group and one third of the ASD group did not look to the mouth at any point during the unprompted trials, and therefore could not be included in the analysis. This left an underpowered analysis of a biased sample of participants, excluding participants who showed the strongest eye bias effect. The fact that so many participants did not look to the mouth at all when unprompted supports the strong evidence in this thesis of an automatic eye bias effect. For future research, the findings suggest that first look data, alongside an examination of how many do not look to regions at all, may be a more meaningful analysis than considering the time to first fixate each region.

As in Chapter 4, for the house control condition there was no bias to look to either the windows or the door across any of the eye tracking measures, and all participants looked to both the windows and doors across the unprompted condition. This again suggests the bias seen is specific to faces in both the ASD and TD participants. This control condition enabled confidence in the finding that any group differences were not reflecting cognitive or perceptual processes that were not of interest. For example, differences in attention and memory. It also effectively established that the eye bias was not reflecting a general bias to look at the upper half of an image.

Although the pattern of data within the house control task was not of specific interest, there were some differences in door and window looking that require comment. Across the two groups, there appeared to be a tendency to respond to the door changed stimuli faster than the window changed stimuli, a pattern that was also seen in the TD children in Chapter 4. The possibilities that this reflects the smaller size of the door ROI compared to the window ROI or that the door changes were more salient than the window changes were discussed in Chapter 4 (see page 91). However, in this study there was also increased accuracy for the door changed trials than the window changed trials by the ASD participants over the prompted trials. This may again reflect of the smaller size of the door region making it easier to remember the doors compared to the windows, an effect that was exaggerated when participants were explicitly directed to the regions and could optimise their looking. It appeared to be easier to initially follow an instruction to fixate on the doors than the windows, with no difference in the number of first fixations on the windows and the door when participants were prompted to look to the windows. This could possibly be the result of first fixations falling between the two windows, which was not included in the windows ROI. Due to the composition of a house, there is often a large space between the two windows, which could make this pattern possible. However, the inclusion of the space between the two windows as part of the windows ROI (as is done with the small gap between the eyes in the eye ROI) was not feasible due to the large amount of space between the windows. This could also be as a result of the exact locations of the windows being less predictable than the location of the doors, as they varied in size and location, whereas the size and location of the doors was more predictable.

The use of a larger sample size would be important in future research to enable investigation of any individual differences within the ASD group. The importance of identifying different eye tracking patterns across an ASD group has been explored by Falkmer, Bjallmark, Larsson, and Falkmer (2011) who divided their group of participants into two groups, those most successful in a recognition task and those who were least successful. They found that those in the most successful group had made significantly more fixations to the eyes than the least successful group. Corden et al. (2008) found a correlation between the differences in eye fixation patterns and the levels of social anxiety in their ASD participants, but they did not find a correlation between eye fixations and the severity of ASD symptoms. In addition, Pierce and colleagues found that within a large sample of young children with ASD there were a subgroup who preferred geometric patterns over social images, and these children had lower cognitive, language and social skills than the other children in the sample (Pierce, Conant, Hazin, Stoner, & Desmond, 2011; Pierce et al., 2016). All of these examples highlight the variation in performance that can be seen within different populations with ASD, particularly in terms of the extent to which autistic individuals show the same patterns of behaviour and cognition as TD individuals. Testing a larger sample with the current paradigm may reveal a subgroup with atypical performance. However, in the small and carefully matched sample included in Chapter 5, there was convincing and converging evidence that children with ASD could not be distinguished from TD children in terms of their automatic bias towards the eyes.

This study has demonstrated that participants with ASD are able to look to the eyes and extract the identity information needed to successfully complete a face recognition task. However, this paradigm does not show us how both groups of participants are able to extract more subtle information from the eyes. For example, Riby et al. (2013) found that the ASD group in their study were able to follow an instruction to look to the eye region, but then did not increase the amount of looking to the object that the gaze was orientating to, which suggests a difficulty in utilising gaze orientation information. In addition, the Reading Mind in the Eyes task has also demonstrated the difficulty that autistic individuals have in successfully extracting emotional information from images of the eyes, even when these eyes are provided in isolation of the face image (Baron-Cohen et al., 2001). Further investigation of the amount of information that could be extracted from the eyes during this paradigm, for example gaze direction and emotion recognition, could enable increased information of how much understanding of the subtleties of eye reading associate with this initial bias to look to the eyes.

Using the paradigm developed in this thesis, the current chapter has established an initial and difficult to inhibit bias to look to the eyes for children with ASD. This is the same as the bias found in NT adults and TD children, discussed in the Chapters 3 and 4. This bias to look to the eyes was not significantly different between the ASD group and the matched TD group. Both showed an ability to follow the prompt instruction over the full 2000ms stimulus presentation time, but difficulty inhibiting initial looking to the eyes. This may be considered a surprising finding, considering the behavioural presentation of ASD and the role of poorly modulated eye contact in the diagnostic criteria. However, it is important to remember that the previous literature in this area was mixed (see Chapter 1, page 9). In addition, although this is an interesting finding the sample size is small and an experimental task may not represent the complex visual, cognitive and social demands of everyday life.

Chapter 6: General Discussion and Conclusions

6.1 Aims of thesis

This thesis aimed to develop a new paradigm of social attention to investigate face processing patterns in both NT and ASD groups. The paradigm developed is novel as it investigates the ability of participants to follow gaze instructions whilst completing a face recognition task. It was developed to allow investigation of where people looked, whether people could change their looking patterns successfully in line with an instruction to look elsewhere, as well as how the addition of an instruction affected their performance on the task. This goes beyond previous research in the area as it aimed to investigate whether the different groups (NT adults, TD children, ASD children) had an automatic bias to look to the eyes and whether this bias could be moderated by specific instructions. An understanding of any bias in looking patterns is particularly important to understand in ASD, due to the large variation of results in previous experimental paradigms.

Four different groups were studied as part of this thesis. Firstly, the data from a group of autistic adolescents in a behavioural only version of the paradigm were analysed. Then an eye tracking component was introduced and a group of NT adults tested, a sample of TD children, and a group of children with and without ASD were tested. By using the same paradigm in a range of different groups this thesis aimed to allow comparisons of the patterns seen for different age groups, as well as those with a diagnosis of ASD and those without.

Another important aim of this thesis was to bring together both behavioural and eye tracking measures to allow an understanding of both where people were looking when they were completing the task, as well as how successfully they were extracting the relevant information to complete the task.

6.2 Summary of findings

The main findings from each chapter can be seen in Table 6.1. An important finding, replicated across chapters, was that first fixations to the eye region were difficult to inhibit even when participants were explicitly told to look to the mouth to help them to successfully complete the task. This bias is also supported by the time to first fixate data in Chapters 4 and 5, as across conditions participants first fixate on the eye ROI more quickly than the mouth ROI. Crucially, this eye bias was also found in participants with an ASD, as demonstrated by the lack of group differences in eye tracking data in Chapter 5. In summary, NT adults and autistic and TD children aged 8-11-years-old all demonstrate a bias to first look to the eyes during face viewing that is difficult to inhibit.

The development of the control task using house stimuli in Chapters 4 and 5 helped to demonstrate that the eye bias is face specific and not a generic bias to look towards the top of the image. Across the two chapters no substantial differences were found between the accuracy, RT and looking patterns of the windows and the door. The exception to this was that in in both Chapters 4 and 5 the RTs were shorter for the door change than the window change conditions and there was some evidence of looking to the door more quickly than the windows across both chapters. Critically, there was no difficulty inhibiting the bias to look to the windows, i.e. the feature in the upper part of the image, nor was there any difficulty in following the prompt to look to the doors. Further, although there were some minor differences between door and window looking there were no substantive differences that would suggest issues with understanding the task, which was particularly important to establish in the ASD group.

Finally, a ‘reversed order’ manipulation was introduced in Chapter 4 to eliminate the possibility that the improved performance in the prompted condition, which was performed second to prevent biased looking patterns in the unprompted condition was the result of a practice effect. In the reversed order manipulation, the prompted condition was completed first for 15 children and no significant differences in the pattern of results were observed with the children completing in the standard order. These data help to support the evidence that the effects of prompting are specific experimental effects.

Table 6.1: Summary of the key findings in each chapter

	Participants	Key methodological details	Key findings
Chapter 2	94 ASD adolescents and 54 non-ASD adolescents	• Behavioural measures of accuracy and RT. • 3500ms presentation time	*Accuracy:* • In the unprompted condition the ASD group were less accurate than the non-ASD group. In the prompted condition there was no overall difference. • In the unprompted condition both groups showed greater accuracy for the eyes than the mouth. There were no differences in the prompted condition. *Reaction time:* • Overall the ASD group had shorter RTs than the non-ASD group. • Both groups demonstrated shorter RTs for the eye change images than the mouth change images in the unprompted condition, but shorter RTs for the mouth change images than the eye change images in the prompted condition.
Chapter 3	41 NT adults	• Behavioural measures of accuracy and RT. • Eye tracking measures of dwell time and first fixation location. • 700ms presentation time.	*Accuracy:* • More accurate for eye change images than mouth change images in the unprompted condition. No significant differences in the prompted condition. *Reaction time:* • Shorter RTs when the eye was the changed region compared to the mouth in the unprompted condition. No significant difference in the prompted condition. *Unprompted eye tracking data:* • First looks more often to the eyes than the mouth

			• Dwell time was longer for the eyes than the mouth *Prompted eye tracking data:* • When prompted to look to eyes, first looks were more often to the eyes than the mouth. When prompted to look to the mouth, there were no difference in first look locations. • When prompted to look to the eyes overall dwell time was longer to the eyes. When prompted to look to the mouth overall dwell time was longer to the mouth. *Comparison of unprompted and eye prompt data:* • No differences found in any eye tracking data across the two conditions.
Chapter 4	64 TD 8-11-year-olds (50 in the main task and 14 as a reversed order group)	• Behavioural measures of accuracy and RT. • Eye tracking measures of dwell time, first fixation location and time to first fixate. • 2000ms presentation time • Reversed order group to control for order effects • Control task (houses)	*Accuracy:* • More accurate for eye change images than mouth change images *Reaction time:* • No difference in RTs for the eye and mouth change images *Unprompted eye tracking data:* • First looks more often to the eyes than the mouth • Looked to the eyes more quickly than to the mouth • Dwell time was longer for the eyes than for the mouth *Prompted eye tracking data:* • When prompted to look to eyes, first looks were more often to the eyes than the mouth. When prompted to look to the mouth, there were no difference in first look locations. • When prompted to look to both the eyes and the mouth, participants were faster to look to the eyes than the mouth. • When prompted to look to the eyes overall dwell time was longer to the eyes. When

			prompted to look to the mouth overall dwell time was longer to the mouth. *Comparison of unprompted and eye prompt data:* • No significant differences in mouth dwell times and mouth first looks across the two conditions. • Significantly more eye looking and first looks to the eye in the eye prompt condition than the unprompted condition.
Chapter 5	14 ASD children and 14 TD matched control group	• Behavioural measures of accuracy and RT. • Eye tracking measures of dwell time, first fixation location and time to first fixate. • 2000ms presentation time • Control task (houses)	*Accuracy:* • More accurate for eye change images than mouth change images (near significant) *Reaction time:* • ASD group: Shorter RT for the eye compared to the mouth change images in the unprompted condition. • ASD group: Shorter RT for the mouth compared to the eye change images in the prompted condition. • TD group: No *overall differences in RT between eye and mouth change images.* *Unprompted eye tracking data:* • Dwell time was longer for the eyes than for the mouth. No group differences • More first looks to the eyes than to the mouth in both groups. ASD group had less first fixations to either ROI compared to the TD group. • Non-significant pattern of looking to the eyes more quickly than mouth *Prompted eye tracking data:* • When prompted to look to the eyes, overall dwell time was longer to the eyes. When prompted to look to the mouth overall dwell time was longer to the mouth. No group

			differences • When prompted to look to eyes first looks were more often to the eyes than the mouth. When prompted to look to the mouth no difference in first look locations. No group differences.

6.3 Implications of the findings

The findings from this thesis provide further understanding of face processing patterns in both NT and ASD populations. The findings of each group will be considered separately.

6.3.1 Implications of the TD group findings

In the unprompted condition, i.e. in the absence of any instructions on where to look, participants looked more to the eyes than the mouth. This replicates a large body of previous research in this area (e.g. Itier et al., 2007; Janik et al., 1978; Laidlaw, Foulsham, Kuhn, & Kingstone, 2011; Walker-Smith et al., 1977) that has demonstrated that eyes are paid more attention than other face regions. Further, participants performed better when identification of the target face depended on detecting differences to the eyes (eye change condition) rather than changes to the mouth (mouth change condition). This supports previous studies showing that when the eye, as opposed to the mouth, needs to be processed to successfully complete the task increased accuracy is observed (Haig, 1985; Joseph & Tanaka, 2003; McKelvie, 1976)

Analysis of first fixation locations provided understanding of the initial, and perhaps more automatic, looking patterns. Previous research in this area suggested that an orienting fixation to the centre of the face occurs before moving on to look at the features and extract more meaningful information (Bindemann et al., 2009; Birmingham, Bischof, & Kingstone, 2007; Levy et al., 2013). However, I did not find evidence of a central orienting fixation. Instead, it appeared that participants most often look to the eyes with their first fixation, regardless of whether given no looking prompt or if told to look to the eyes or mouth. Notably, in the current studies, participants knew they would always be presented with faces of the same orientation, of a comparable size and in the same location. This predictability arguably meant an orienting fixation was not necessary and participants were able to directly attend to their preferred facial feature, the eyes. Indeed, other studies that have explored the centre of gravity effect when the location of the face was predictable have not found any evidence of a bias to the geometric centre, either with (Brielmann et al., 2014) or without (Peterson & Eckstein, 2012) the orientation of the face changing. Thus, our findings support evidence that a default orientation to the central location is not required when the face location is predictable. Future research aiming to target where first meaningful fixations occur within an image should use predictable stimuli to eliminate the need for an orienting fixation.

The inclusion of the time to first fixate measure had not previously been used in a face processing study using only the TD population and I included this measure with the TD children (Chapter 4). The reason for its inclusion was to enable a greater understanding of the intricacies of face processing patterns. This measure enabled a better understanding of how quickly participants looked to the ROIs of interest, and not just which of the two were fixated first. The data from this measure added further confirmation of the bias to look to the eyes, as the eyes were fixated more quickly in the unprompted condition as well as across both prompted conditions (eyes and mouth). The inclusion of this measure adds further support for the bias to look to the eyes. It is particularly notable that even when prompted to look at the mouth, participants were quicker to look to the eyes.

My thesis developed a novel prompt condition, which enabled insight into how easily individuals are able to overcome their natural looking patterns, particularly their dominant preference for looking to the eyes. My findings were clear in demonstrating that the bias to first look at the eyes could not be altered by instructions to look to the mouth. Indeed, the number of first looks to the eyes was not significantly different between the unprompted condition and the eye prompt condition, suggesting that eye looking is naturally at a maximum and cannot be enhanced. In addition, participants were quicker to fixate the eyes in both the eye and mouth prompt conditions, even though they had been explicitly told to look to the mouth in one of these conditions. Importantly, a novel dissociation was found between the first look and dwell time data. Although the bias to first look at the eyes could not be overcome, over the course of the entire stimulus presentation time the TD children and NT adults were able to adjust their looking and did demonstrate sensitivity to the mouth prompt. Previous findings in this area using different paradigms were mixed, with some finding that it is difficult to inhibit looking to the eyes when explicitly told not to (Kuhn et al., 2016; Laidlaw et al., 2012). However, Itier et al. (2007) found that first looks to the eyes were reduced in a head direction judgement task when participants were told that the eye information would not be informative. A strong form of the eye bias effect would predict first looks to the eyes regardless of task instruction. The participants completed two blocks of 108 trials per condition and were explicitly told in the head condition that they did not need to look at the eyes. Speculatively, the participants were in a specific cognitive set in the head condition, with strong motivation to ignore the eyes, which varied in direct and averted orientation and were therefore a distractor. In addition, it is possible that a central orienting fixation would be needed when the head was at different orientations as the location of the eyes was not predictable. However, this finding does suggest that further exploration of the limits of the eye bias effect would be fruitful.

The findings from the prompted condition can also be used to add to the discussion by Laidlaw et al. (2012) regarding whether looking to the eyes is automatic or under volitional control. Based on the findings of their paradigm the authors propose that looking to the eyes is not entirely under volitional control and there is an automatic component that helps to orient attention to the eyes. My findings would support this theory that some eye looking is under control (the dwell time data), however there is an automatic component driving initial eye looking (first look and time to first fixate data). Laidlaw et al. (2012) propose that that this automatic bias is related to holistic face processing, supported by their manipulation using inverted faces where this bias was not observed. Some future research ideas to further investigate this bias and the basis for it using the paradigm developed in this thesis will be discussed in Section 6.5 (see page 133).

The findings from the prompted condition can also contribute to the discussion of whether looking to the eyes is a top down or bottom up attentional process. The findings would suggest that the eyes capture attention initially, through a bottom up process, but over time there is an increased ability to exert top down attentional processes, to enable the participants to follow the instruction to look to an alternative face area. These findings would also support previous research that top down attention takes longer to deploy than bottom up attention (e.g. Hein, Rolke, & Ulrich, 2006; Ling & Carrasco, 2006; Liu, Stevens, & Carrasco, 2007; Müller & Rabbitt, 1989). In this context it could suggest that the eyes are more salient and initially capture attention, however once enough time has passed for top down attention to be deployed the participants are able to successfully alter their looking patterns in line with the prompt provided.

The findings from Chapters 3 and 4 help to provide further clarification to the previous studies, suggesting that it is just the very early viewing period (measured in the current studies by first fixation location and time to first fixate) which is difficult to inhibit to look away from the eyes. As discussed by Laidlaw et al. (2012), an obvious question is the extent to which eye looking is under top-down volitional control compared to the extent to which it is an automatic and reflexive process, triggered bottom-up by the stimulus. The data in this thesis suggest that there is an automatic bias to look to the eyes but that top-down volitional control is able to eventually overcome this bias. In the Itier et al. (2007) study, the block design may have facilitated sustained volitional control across trials, in a way that was not possible in the current studies where looking instructions varied trial-by-trial. It is also important to note that the inclusion of the mouth condition in the current paradigm, as well as the house control task (in Chapter 4), suggests that this difficulty of changing face processing patterns is eye specific.

Overall, these findings provide insight into why the eyes are more often fixated during social interactions as not only are the eyes fixated first but it is difficult for individuals to prevent this initial eye look. This bias to initially look to the eyes may help to explain social phenomena that often happen in everyday life, for example catching the eyes of a stranger across the room when scanning a room full of people, despite no intention to look anyone in the eyes.

6.3.2 Implications of the ASD group findings

Firstly, the findings of Chapter 2 add to the previous behavioural literature in this area, providing support to previous studies that show an overall deficit at remembering faces (For a review see Weigelt et al., 2012), but there is no specific eye deficit when compared with the mouth (Bar-Haim et al., 2006). However, the data are in contrast to some pervious findings that did find a deficit for processing the eye region in ASD when compared to a control group (Riby et al., 2009; Rutherford et al., 2007; Wolf et al., 2008). However, it is interesting to note that Chapter 2 included adolescents with ASD with lower IQs than are typically included in similar paradigms. It is important to understand the full spectrum of autism, of whom half have intellectual disabilities (Brugha et al., 2016) and ensure that findings are relevant to the widest range of autistic individuals as possible; this is an important area for further development (discussed further in section 6.5, page 133).

As discussed in Chapter 1 (see page 8) the previous research looking at how ASD participants look at faces is varied, with some finding differences in the amount of eye and mouth looking when compared to control groups, and others not finding any differences. The current study (Chapter 5) added to this diverse literature by finding no differences in the overall looking patterns of the participants with ASD and the matched TD control group. In addition, that the pattern of first fixations are not significantly different in the ASD and TD groups is in support of previous literature in this area (Rutherford & Towns, 2008; Sawyer et al., 2012; van der Geest et al., 2002). The time to first fixate findings are in line with the previous research showing no difference in the amount of time individuals with ASD first fixate to the eye or to the mouth region when compared to a control group (Gillespie-Smith et al., 2014; Grossman et al., 2015). The eye tracking data in Chapter 5 are also supported by the findings from Chapter 4 (with TD children) that there was no correlation between a measure of social communication and any of the eye tracking measures. This adds further support to the finding that there is a bias to look to the eyes across the spectrum of social communication, in both TD participants and those with a social communication disorder.

Importantly, the prompting paradigm used in the current study demonstrates that the autistic children in Chapter 5 have the same initial and difficult to inhibit bias to look to the eyes that was seen in both the NT adults in Chapter 3 and the TD children in Chapter 4. This suggests that this same automatic component of looking to the eyes that Laidlaw et al. (2012) proposed was not under volitional control, also seems to exist in this sample of ASD children. It also suggests that the ASD children in this study show the same bottom up attentional bias to look to the eyes as seen in the TD children and NT adults, and it is only after the top down control is deployed later in the process that they are able to successfully follow a prompt. This has some interesting implications for the study of face processing in ASD, as it is perhaps not the finding expected when you consider the anecdotal accounts of not looking to the eyes (e.g. Robison, 2007) and the diagnostic assessment methods used for diagnosing ASD, which include measurement of atypical eye contact (Leekam et al., 2002; Lord et al., 2012; Wing et al., 2002).

The key finding that ASD participants have an initial automatic bias to look to the eyes, as evidenced by the time to first fixate and the first fixation data provides some support to the theory of gaze aversion (Hutt & Ounsted, 1966; Kliemann et al., 2010). This theory suggests that individuals with ASD consciously choose to avoid looking to the eyes. My data supports this theory by showing that individuals do have an initial and difficult to inhibit bias to look to the eyes (as evidenced by first fixation data) and therefore it can be assumed that any decreased looking in every day social situations is a conscious choice to avoid eye gaze. In contrast, my data does not provide support for the theory of gaze indifference (Cohen et al., 1989; Senju & Johnson, 2009). This theory proposes that individuals with ASD have an insensitivity to the social signals of others' eyes. In contrast, my data suggests that those with ASD do look to the eyes in controlled laboratory conditions and are able to successfully extract relevant information from the eyes. Although, it would also be useful to expand the current paradigm to investigate how successfully alternative forms of information are extracted from the eyes, e.g. emotional information.

One explanation for the findings might be that they are specific to the type of stimuli used. Specifically, it is highly likely that looking to the eyes of a static black and white image is much easier than looking to the eyes of a person in a real life interaction (e.g. as was seen in Foulsham, Walker, & Kingstone, 2011). Subsequently, it is possible that the effect seen is specific to the laboratory environment and there would be no bias to look to the eyes in everyday life. The reason for this dissociation might be because the experience of the automatic bias is unpleasant in real life, causing discomfort or anxiety, and is actively inhibited using the same volitional control that is seen in the later stages of the laboratory study. This explanation is compatible with the intense world hypothesis of autism, which proposes that hyper-perception, hyper-attention and hyper-memory lie at the heart of most autistic behaviours (H. Markram, Rinaldi, & Markram, 2007; K. Markram & Markram, 2010). The theory proposes that excessive neuronal processing results in the world being painfully intense. The social intensity that occurs with eye contact would be too much for individuals with ASD and the eye bias instinct would be inhibited. This proposal requires further investigation and will be discussed below (Section 6.5, page 133). This potential explanation of the findings has implications for social interactive training methods that are sometimes used in children with ASD. These have been shown to improve social skills, including increasing the amount of eye contact (for a review see Hwang & Hughes, 2000). However, if autistic people do have this bias to look to the eyes but they actively inhibit it due to anxiety or an unpleasant sensation from looking into another's eyes then this would call into question the ethics of using such interventions. Instead, it would suggest that perhaps interventions should focus on reducing anxiety or understanding sensory overload. These approaches may actually indirectly facilitate activation of their natural eye bias. Going forward, it is also important to establish whether autistic individuals are able to overcome their bias to look to the eyes with more socially realistic and demanding stimuli. Finding the 'tipping point' at which autistic people start to inhibit their bias has potential to inform both theory and practice.

It is important to remember that the diagnostic criteria for ASD refer to poorly modulated eye contact, rather than reduced eye contact. For example, the ADOS codes for poorly modulated eye contact that is used to initiate, terminate or regulate social interaction (Lord et al., 2012). In addition, the DISCO enquires whether the person with ASD stares too long and hard (Leekam et al., 2002; Wing et al., 2002). It is also true that eye contact does not have to be atypical for a person to receive a diagnosis. Given that some people with ASD show typical eye contact or too much eye contact, it is perhaps less surprising that I found no group differences between the ASD and TD children. The diagnostic criteria therefore suggest that heterogeneity needs to be considered. It is possible that there are different patterns of eye bias in ASD that reflect the different behavioural presentations in real life. For example, individuals with ASD who show typical eye contact in real life may show the same patterns of eye looking in the experimental paradigm as the NT participants, but in contrast those with reduced eye looking in real life may show a reduced eye bias effect. I was not able to include enough participants to allow an analysis of individual differences but future research should carefully consider behavioural subtypes and use these to predict patterns of performance.

In summary, the key finding is that children with ASD demonstrate the same difficult to inhibit initial bias to look to the eyes as their non-autistic counterparts. These findings warrant further investigation and their potential for impact on the autism community will be discussed further in section 6.5 (see page 133).

6.4 Strengths and limitations

6.4.1 Strengths

One of the key strengths of this thesis is the replication of results that has occurred in each chapter. Each chapter has built on the previous one to further develop the paradigm and comparable patterns of results are seen across chapters. Most notably, the eye tracking patterns for the NT adults collected on a 1000hz Eyelink static eye tracker in a laboratory environment were broadly the same as those collected in 8-11 year-old-children on 60hz portable Tobii Eyetracker in various school environments. Replication of results is a particularly topical issue across the academic community at the current time, with 90% of respondents to a survey in Nature agreeing there is a 'reproducibility crisis' in academic work (Baker, 2016). Koole and Lakens (2012) summarise the current controversies in psychological science standards and practice as being characterised by defective statistical methods, publication bias, selective reporting, and data fabrication. The authors go on to say that each of these controversies would result in problems in replication and therefore replication of findings would allow researchers to identify key research findings that are both reliable and trustworthy. Schmidt (2009) advocates the use of direct replication (using the same methods as the original study) as a way of overcoming the current controversies in science. However, it is recognised that direct replications are rarely published. Nosek, Spies, and Motyl (2012) support this idea by highlighting that positive and novel results are more likely to be published than negative results or results that are replications of previous work, and as a result there is a bias for positive and new findings to be published. Munafò et al. (2017) have responded to this discussion by producing a manifesto for reproducible science, which includes the importance of replicating previous findings using similar methodology to ensure the same pattern of results is seen a second time.

In addition to replicating the key findings across chapters another key strength is the use of a range of different eye tracking measures to provide a greater understanding of looking patterns and how they are characterised. The use of the dwell time measure provides an index of how much participants are looking to the key ROIs across the whole viewing period, whereas the measures of first fixation location and time to first fixate provide a more sensitive measure of how quickly people fixate to the ROI. Chapter 3 used the measures of dwell time and first fixation location, which resulted in an understanding that this bias to look to the eyes appears to be most difficult to inhibit with the first fixation, but looking patterns can change in line with a prompt over the whole viewing period (dwell time). To further build on this Chapters 4 and 5 introduced the measure of time to first fixate to examine how quickly participants look to different ROIs. This additional measure provided an alternative way to measure initial looking to each ROI. The inclusion of this measure is important as previous findings in this area are mixed with some showing delayed first fixations to the face, but not to objects (Freeth, Chapman, et al., 2010) or to the eyes (Norbury et al., 2009), whereas others showed no differences when the ASD group were compared to TD controls (Gillespie-Smith et al., 2014; Grossman et al., 2015). Therefore further understanding of the amount of time it takes participants to look to the different ROIs provided further intricate details of the time course of looking and any variations between groups. The complementary findings between time to first fixate and the first fixation measures provided more robust evidence of the eye bias and provide an example of conceptual replication, by replicating the findings through a slightly different method (Schmidt, 2009).

Another key strength of this thesis is the use of eye tracking measures alongside the collection of behavioural data (accuracy and RT data). As was highlighted by Table 1.1 (page 12) many studies have been conducted in the ASD population comparing eye and mouth looking. However, the number of studies to consider behavioural data alongside this eye tracking data is much smaller and limited to emotional recognition paradigms (Pelphrey et al., 2002; Rutherford & Towns, 2008; Sawyer et al., 2012) and memory tasks (Snow et al., 2011; Wilson et al., 2010). The main limitation of pure eye tracking studies is that eyetrackers only indicate the centre of a fixation but not the amount of information successfully obtained, either from the fixation point or the surrounding peripheral vision. The paradigm developed in this thesis goes further than the studies outlined above as the behavioural measures collected are specific to the key ROIs on the face i.e. accuracy and RT for detecting differences to the eyes and mouth, rather than being more general behavioural outcomes (e.g. identity recognition or emotion identification in response to changes to the whole face). The current paradigm means we can understand both where people are looking when they are prompted to look at the eyes or mouth, and also how successfully they are able to extract information in line with that specific prompt. This paradigm subsequently provides information on both a bias to look to the eyes (through the eye tracking data), but success in extracting the required information throughout the task (as shown by improved performance in the prompted condition).

6.4.2 Limitations

There are some limitations with the testing procedures used throughout the different studies. The studies in Chapters 2 and 3 were conducted in university laboratory facilities and were therefore in a relatively controlled environment. However, the studies in Chapters 4 and 5 were primarily conducted in the participants' school environment. This had advantages as it enabled anxious participants to be in a more familiar environment and not have to travel, however, there are also some limitations that should be considered. Firstly, there was some variety in the amount of disruption experienced throughout the testing phase, both in different schools and at different times of the day. Further, the quality of data collected on the eye tracker varied in different locations and on different days due to different light levels and set up options available. This can result in more variable data quality when compared to more controlled laboratory based environments.

A further difference between the data collected in Chapter 3, when compared with Chapters 4 and 5, is the eye tracker used. In Chapter 3 a static 1000hz eye tracker was used, whereas the studies in Chapters 4 and 5 used a portable, non head-mounted, 60hz eye tracker. The 60hz eye tracker has some clear advantage, most notably that it is portable and could therefore be set up in the participants' schools. In addition, as it is portable less set up and calibration was required, which is important especially for children who find it difficult to concentrate for long periods of time. Finally, this eye tracker did not require any equipment to make contact with the participant (the static eye tracker required a chin and head rest), which is particularly important for those participants with ASD who may have heightened sensory experiences. Although there is a substantial list of reasons for using this portable eye tracker, it is also important to acknowledge that the data quality of a 60hz eye tracker is a lot lower than that of a 1000hz eye tracker. In addition, although the children were encouraged to sit still the children were still able to move, which results in the eye tracker being less accurate or not collecting data. The combined consequence of the lower resolution and the higher levels of participant movement is an increase in missing data and subsequently fewer fixations recorded. In addition, it resulted in a high dropout rate across both the TD and ASD groups. With constantly evolving technology, higher quality data could be achieved in future research by using a portable eye tracker with a faster refresh rate.

The use of the time to first fixate measure has been previously discussed and although it has advantages of providing a richer picture of the overall eye tracking data, there are also limitations to this measure that need to be acknowledged. For example, in Chapter 5, in the unprompted condition 10 of the 28 participants did not fixate the mouth at all and therefore were excluded from the analysis. In the prompted condition a higher number of participants did not fixate the mouth at all (15 out of 28) and therefore there were not enough data to analyse this condition. As well as decreasing the sample size, the effect of excluding these particular participants should be considered. It is possible that the excluded participants were the ones who showed the largest bias to look to the eyes, as they are the ones that did not fixate the mouths at all during the whole 2000ms viewing period. With a longer viewing period they may have first fixated the mouth later (for example after 3000ms) and this would have produced strong support for the eye bias effect. Therefore, although the time to first fixate measure is very useful for creating a fuller picture of looking patterns and providing support for the patterns found in the first fixation location data, the interpretation of the results with a relatively short viewing period must be done with the above caveat in mind.

A further limitation with the studies presented in this thesis is the limited ecological validity of using a paradigm with static black and white images on a computer screen. Given the novelty of the current paradigm it was important to provide proof of concept in a controlled setting, while further research can develop the paradigm into more naturalistic conditions. However, the limitations of how far the results can be generalised to 'real life' need to be considered, Speer et al. (2007) only found reduced eye looking in the most ecologically valid condition of their study (social-interactive stimuli) and not in any of the less ecologically valid conditions. However, as discussed in Chapter 1 (see page 9) there is no clear pattern among previous studies of which ones found differences in eye and mouth gaze, even when considering stimuli type. However, there are studies that have been conducted that contain more ecologically valid methods, which would help to provide research more relevant for the real world. This includes studies with a live interaction with an experimenter (Hanley et al., 2015; Hanley et al., 2014), recording of eye tracking patterns on a head mounted eye tracker whilst participants walked around a university campus (Foulsham et al., 2011) and gaze behaviour when viewing what the participants believed to be a live video feed (von dem Hagen & Bright, 2017). The drive to move to more ecologically valid stimuli and methods in the field of eye tracking research is a positive one, but it can be difficult to create a well-controlled paradigm addressing specific research questions, for example looking at automatic looking patterns and whether these can be changed. This move towards more ecologically valid research will be considered in the following section.

6.5 Areas for further research

The paradigm developed throughout this thesis provides a good understanding of the initial bias to look to the eyes that exists in NT adults, TD children and autistic children. With development this paradigm could provide further impact to the field of face processing and autism research.

Further research could be conducted to understand this automatic bias to look to the eyes in the NT population to enable further investigation of the extent to which this bias exists. Laidlaw et al. (2012) propose that the eye bias found in their paradigm is as a result of holistic face processing, evidenced by the same effect not found in inverted faces. It would be interesting to also use the paradigm developed throughout this thesis with inverted faces to see if the findings from the alternative paradigm could be replicated. If, once again, it was found that this automatic bias to look to the eyes no longer existed in inverted faces it would provide converging evidence that the effect seen is associated with holistic face processing mechanisms.

It is important to understand if this bias exists across a range of different people with ASD, including adults, those with lower IQs and non-verbal participants. The behavioural paradigm presented in Chapter 2 was conducted with a range of ASD participants with varying IQ and abilities who were matched with a mixed control group of both TD adolescents and those with a range of learning disabilities and other developmental diagnoses. This is a strong advantage of this chapter as it enabled investigation of a wider range of participants with ASD than is normally used. However, the majority of eye tracking studies in ASD include participants with average IQs due to methodological difficulties of testing participants with below average IQ.

Although Chapter 2 indicates that the paradigm is accessible for participants with low IQ, these participants were all testable on the WASI, which is above the ability levels of some of the more intellectually impaired individuals with ASD. It is also more difficult to test intellectually lower functioning participants on eye trackers due to reduced understanding of the importance of sitting still, and it is unclear how successfully some of the adolescents in Chapter 2 could have been tested using an eye tracker. A recent study used eye tracking in an attention training paradigm and as part of this study they included ASD children who were severely intellectually impaired (Powell, Wass, Erichsen, & Leekam, 2016). Of the 27 participants recruited, 17 completed the full range of testing sessions, suggesting it is possible to successfully eye track a range of children with ASD. However, the authors do note that the quality of data in the study was lower than in a previous study using the same methodology but instead testing babies (Wass, Porayska-Pomsta, & Johnson, 2011). However, as technology develops the quality of data in such experiments may improve. The paradigm used by Powell et al. (2016) was a gaze contingent attention training programme. The advantage of a gaze contingent paradigm is a reduced level of verbal or written instruction, meaning those with lower than average IQs, as well as young children, are able to fully participate. In future research the area of eye bias could be investigated through gaze contingent paradigms, e.g. getting a visual reward when looking to the eyes/ mouth/ other features to see how quickly participants are able to suppress any automatic looking patterns they may have. The development of an alternative method to test for the existence of the same bias found in the current study would be advantageous as it would enable a larger group of participants to be tested (e.g. young children and participants with a lower than average IQ), but it would also be a conceptual replication of the current task (replication of the same hypothesis and the theory behind it, but using a different method), which Schmidt (2009) highlight as another important method for overcoming the current replication crisis in research.

The proposal earlier in this chapter (page 127) that reduced eye looking in everyday life may be a choice by autistic individuals as a result of discomfort, either through sensory overstimulation or anxiety of looking to the eyes, despite the ability to demonstrate an eye bias in a controlled lab environment merits further investigation in the future. There are two main ways to investigate this. Firstly, a qualitative study asking opinions of those with ASD about eye looking, how do they feel when looking at another's eyes and how naturally does this come to them would be informative. The importance of asking opinions of those in the autistic community has been highlighted in research undertaken by Pellicano, Dinsmore, and Charman (2014). A good example of this approach in practice is work by Joyce, Honey, Leekam, Barrett, and Rodgers (2017). These researchers found that young people with ASD can self-report their own behaviours, specifically restricted and repetitive behaviours and their relationship to anxiety, and show insight into these through questionnaires and in semi-structured interviews. The addition of similar practices when considering the eye bias and eye looking in ASD would be informative as it would enable further understanding of why looking patterns are as they are, as well as understanding the experiences of those in autistic community. The qualitative approach is an ideal opportunity to probe for subgroups with different looking preferences, or reactions to eye contact. Identification of these groups could then be followed up in larger experimental studies, where the overall group effects that show no difference to TD participants may be parcelled into subgroups with their own distinct profiles of eye bias.

A second important method for investigating why some autistic people do not manage to modulate eye contact in real life, despite showing typical biases in the lab, would be to measure stress responses whilst completing a paradigm similar to the one developed throughout this thesis. One way of doing this could be to measure levels of cortisol, the primary stress hormone, during a task prompting participants to look to the eyes, and then again when prompting to look at the mouth to allow comparison of cortisol levels between these two manipulations. A previous study managed to successfully measure cortisol levels in children with ASD in a paradigm investigating play with peers (Schupp, Simon, & Corbett, 2013), highlighting that successful collection of cortisol is possible in an ASD sample aged 8-12-years-old. By measuring cortisol levels when being prompted to look to the eyes and comparing this to being prompted at the mouth would enable investigation of whether, although the autistic participants have this bias to look to the eyes, they find it stressful and as a result look away in real life interactions. This may offer an explanation for the existence of this bias to look to the eyes, but reduced eye gaze in real life interactions. By using the two proposed methods here to both understand the opinions of the autistic community about their experiences of eye gaze, as well as measuring levels of stress during the already established paradigm, further understanding of the current pattern of findings could be demonstrated.

It would also be important for further research to consider the finer intricacies of eye gaze when looking at a face. As discussed previously in this chapter (see page 128), the diagnostic criteria for ASD discuss poorly modulated eye contact, and the DISCO has a measure about too much eye contact (staring: Leekam et al., 2002; Wing et al., 2002). As a result, focussing just on the overall amount of eye contact may not be the most reliable measure to fully understand more intricate differences that occur between ASD and NT groups. The current study has started to address this by incorporating the measures of first fixation location and time to first fixate, alongside the more common measure of dwell time. In future, further time course analysis could be useful when testing this clinical group, including examining the second fixation, or any return fixations to a feature. For example, it is possible that the TD groups look away from the eyes but are continually drawn back, whereas in the ASD group it may take longer to disengage their initial looking to the eyes but then do not return to this ROI. With a scene viewing paradigm Freeth, Chapman, et al. (2010) found, using a time course analysis, that the TD participants looked more to the face initially and then less to the face as time went on, compared to the ASD participants who showed higher looking to the face in the early and late viewing period, but less during the middle. However, by considering overall viewing time the authors found no differences between the two groups, highlighting how overall summaries of dwell time can be the same, but patterns over the time course can vary. With the evolution of more sophisticated eye tracking technologies such time course analysis with clinical groups should become easier.

A final area that would benefit from future research would be an investigation of this eye bias in both clinical and non-clinical samples using different stimuli types and in different tasks. Firstly, it would be interesting to investigate whether the same effect is seen in emotional stimuli, as well as with the neutral stimuli used throughout this thesis. In addition, as discussed in Chapter 3 (see page 64) it would be useful to examine the bias in different task types, as well as different stages of the same task, for example in emotional recognition tasks and in the memory phase of a task, as well as the initial encoding phase. If it is an automatic bias to look to the eyes, the eyes should still be fixated first even if the mouth is more interesting, for example for an image of a person smiling, and therefore may be more likely to catch attention throughout the rest of the dwell time period. It would also be interesting to investigate whether this bias to look to the eye remains when the image has averted, rather than direct gaze. In addition, using more ecologically valid stimuli would make any findings more relatable to real world encounters and enable a greater understanding of what happens in real life. As discussed earlier (page 133), there have been some developments in using eye tracking during live interactions (Hanley et al., 2014), whilst participants are walking around (Foulsham et al., 2011) and when viewing a “live” video feed (von dem Hagen & Bright, 2017). If more ecologically valid testing methods could be adapted for use with a paradigm investigating an initial eye bias a greater understanding of this bias in everyday life could be established. One potential way to do this could be through the use of video chat software whereby a two way interaction with an experimenter occurs, but eye tracking measures can still be collected. Participants could be primed in advance to look to the eyes during one of the interactions and to the mouth during the other interaction.

6.6 Conclusion

Throughout this thesis I have used a novel prompting paradigm to understand both where people look, as well as how easily participants are able to adjust their looking pattern in line with a prompt. Adolescents with a diagnosis of ASD first completed a version of this paradigm without eye tracking, and then the full paradigm was completed by NT adults, TD children and finally children with a diagnosis of ASD. Throughout this thesis I have demonstrated comparable behavioural and eye tracking patterns between both NT groups and the ASD children. The most striking finding has been the existence of an initial and difficult to control bias to look to the eyes, which existed across groups and was primarily displayed through the first fixation and time to first fixate data. This bias was replicated in different groups and using different equipment and testing environments, suggesting its reliability. This key finding warrants further investigation to fully understand more about this complex relationship between a bias to look to the eyes in the lab and the behavioural presentation of ASD, which is often associated with poorly modulated eye contact, often as a result of reduced eye looking in everyday life.

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