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Domain general attention processes and stimuli properties underlying atypical social attention in high-functioning adults with ASD

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Domain General Attention Processes and Stimuli Properties Underlying Atypical Social Attention in High-Functioning Adults with ASD

by

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DEDICATION

To my mum, Lina Skripkauskienė, who has been and always will be my hero.

I miss you, Mamyte!

ABSTRACT

Atypical sensory processing is considered to have an important role in the development of Autism Spectrum Disorders (ASD). With respect to visual processing, research to date shows that individuals with ASD orientate less to social stimuli. Yet, others have suggested that these difficulties are not entirely social in nature and occur due to atypical sensory processing. For example, people with ASD may have difficulty extracting the general gist of the information and thus adopt a more piecemeal approach or have atypical attention mechanisms, resulting in trouble shifting attention between stimuli. Findings regarding these atypicalities are, however, relatively inconsistent. Thus, it remains unclear whether they are specific to the social domain or representative of a more general sensory issues existing across domains. The main aim of this thesis was to obtain a more comprehensive understanding of visual processing of both social and non-social information and the potential effects of audio distractors in high-functioning adults with ASD. The current research utilized measures of manual reaction times and eye-tracking to evaluate performance on tasks ranging from more typical hierarchical figures and gap-overlap paradigms to more complex or dynamic social scenes. The findings mostly suggest that adults with ASD exhibit similar attentional processing to typically developed (TD) adults. However, a combination of subtle domain general and social domain specific atypicalities also occurred throughout the studies. Taken together these findings suggest that whilst high-functioning adults with ASD have a social bias, just like TD adults, it occurs to a lesser extent. Furthermore, this lack of social bias cannot be explained by increased attention to the non-social aspects of the stimuli. Finally, the findings support a notion of enhanced perceptual capacity in high-functioning adults with ASD and suggest that it occurs across modalities.

The research for this project was submitted for ethics consideration under the reference PSYC 14/143 in the Department of Psychology and was approved under the procedures of the University of Roehampton's Ethics Committee on 9th of October 2014.

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Area of interest (AOI) – area of a display or visual environment that is of interest to the research or design team and thus defined by them.

Attentional capture – attentional shift of attention from its current to the new focus.

Attentional disengagement – shift of attention from its current focus.

Attentional engagement – looking or otherwise engaging with a target stimulus.

Fixation – a relatively stable state of eye movement.

Fixation duration – a metric representing a time spent gazing on a certain AOI, excluding saccades.

Gaze or visit duration (dwell time) – a time, including fixations and saccades, gazing within a certain AOI.

Proportional visit duration – the proportion of time looking at a particular display element.

Saccade – a rapid eye movement between two consecutive fixations.

Social attention – attentional engagement with social information.

Social content – number of people depicted in the stimulus.

Social context – absence or presence of social interactions depicted in the stimulus.

Social information (socially relevant information) – hereafter, representations of human figure or its parts.

Time to first fixation – a metric representing how long it takes before the gaze is fixated on a particular AOI.

Velocity – measure of speed of eye movement. The velocity is most commonly given in visual degrees per second (°/s).

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CHAPTER 1

GENERAL INTRODUCTION

Overview

Reduced social attention in ASD is often described as a core deficit that perseveres across cognitive ability (e.g. Klin, Jones, Schultz, Volkmar, & Cohen, 2002a). Yet, it remains unclear why such behaviour occurs and whether it persists into adulthood. Therefore, the current thesis aims to comprehensively examine a number of potential explanatory factors that could induce or account for atypical social attention in ASD. Thus, the primary aim of this chapter is to introduce the main themes that are explored across the thesis and provide a rationale for them. Firstly, the current chapter provides a general review of research into social attention in ASD. Secondly, several potential underlying mechanisms and related evidence are introduced. These include atypical hierarchical processing and attention shifting deficits. A more novel suggestion that intersensory processing deficits, instead, may be underlying ASD symptomology and related evidence for enhanced perceptual load is also discussed in more detail. The following section is devoted to reviewing potential characteristics of stimuli used in previous research that could account for the inconsistencies of findings to date. Furthermore, a rationale for the choice of participants regarding their age and functioning is provided. Finally, the chapter is concluded by outlining of the aims addressed across the thesis.

Autism spectrum disorders (ASD) are neuro-developmental disorders characterized by persistent deficits in communication and social interaction across contexts and restricted, repetitive patterns of behaviour, interests, or activities (DSM-5; American Psychiatric Association, 2013). It is seen as a pervasive developmental disorder with core deficits persisting throughout one's life-time. It should be noted that within the context of the DSM, ASD is a relatively new diagnosis. Examples of it were first described in case reports by Kanner (1943) and Asperger (1944). It was recognised as a standalone diagnosis even later, when it was included in DSM-III (American Psychiatric Association, 1980). Since then there has been a rise in research studying ASD, yet a full understanding of ASD still lags behind that of other psychiatric disorders and medical conditions (Thurm & Swedo, 2012). For instance, the primary focus of ASD research has been on children and adolescence populations (Mukaetova-Ladinska, Perry, Baron, & Povey, 2012), consequently little is known about how ASD presents throughout one's life. Although the past decade has seen an increase in the number of studies on employability and romantic outcomes of adults with ASD (e.g. Brown-Lavoie, Viecili, & Weiss, 2014), research on the processes underlying the manifestation of the core atypicalities in adulthood is scarce. This is especially true for high-functioning adults with ASD, given that the diagnostic criteria have broadened considerably over the years and started including more subtle forms of ASD relatively recently.

The most recent DSM-5 criteria now include unusual sensory behaviours under the category of repetitive patterns of behaviour, interests, or activities (American Psychiatric Association, 2013). Indeed, sensory processing abnormalities across modalities are common in individuals with ASD, with estimated frequency of 60% to 90% (Kern et al., 2007; Leekam, Nieto, Libby, Wing, & Gould, 2007). Higher rates of the sensory atypicalities across and within visual, tactile, and gustation/olfaction modalities are reported across the whole spectrum and continue into adulthood (Leekam et al., 2007). The presentation is heterogeneous, however, and can include hyper- and/or hyposensitivity to stimulation, delayed or otherwise distorted perception, and sensory overload (Bogdashina, 2003; O'Neill & Jones, 1997). Recent research suggest that ASD individuals' insistence on sameness and engagement with repetitive behaviours may, for example, be methods of moderating their sensory experiences (Tseng, Fu, Cermak, Lu, & Shieh, 2011). Furthermore, it is possible that, due to its heterogeneity, atypical sensory processing may underlie some inconsistent empirical findings in the presentation of ASD. For instance, as any perception requires sensory input, it is likely that distortions in sensory processing could also affect other perceptual processes, such as social attention.

Atypical Social Attention in ASD

In general, ASD is described as a social disorder with pronounced and pervasive deficits in reciprocal social communication (Mundy, Sigman, Ungerer, & Sherman, 1986). Atypical social behaviour in ASD, for example, may include a lack of gestures or facial expressions, unusual eye contact, poor and rare social overtures or responses (Lord et al., 2000). Such behaviours have led some researchers to suggest that individuals with ASD are particularly impaired in social attention (Klin et al., 2002a; Mundy & Newell, 2007). Social attention can be broadly defined as preferential selection of social information for attention (Ames & Fletcher-Watson, 2010). This social bias is typically visible in instances of joint attention, where pointing or gaze cuing is essential for successful communication. It can also be expressed via, for example, faster orienting, longer engagement with, or slower disengagement from social information (see Ames & Fletcher-Watson, 2010). Indeed, preferential attention to social rather than non-social information is seen in typically developed (TD) individuals from early infancy (e.g. Gliga & Csibra, 2007). A great deal is learned through interaction with other people and a failure to preferentially attend to social stimuli could lead to further deficits in joint attention (Mundy & Newell, 2007) or Theory of Mind (Baron-Cohen, 2000).

Klin and colleagues first introduced the idea of using eye-tracking to investigate visual social attention in ASD (Klin, Jones, Schultz, Volkmar, & Cohen, 2002b). They presented adults with ASD and TD with clips from a movie and found that adults with ASD spent less time than TD adults looking at actors' eyes, but longer looking at their mouths and bodies or off-person than TD individuals (Klin et al., 2002b). This influential study prompted 15 years of research into atypical gaze behaviour in ASD.

Several studies using static or dynamic stimuli failed to replicate findings of Klin et al. (2002b) that individuals with ASD look at eye regions of faces less than TD participants (e.g. Chawarska, Macari, & Shic, 2013; Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009; Freeth, Chapman, Ropar, & Mitchell, 2010; Hanley, McPhillips, Mulhern, & Riby, 2013; Nakano et al., 2010). Speer, Cook, McMahon, and Clark (2007) further found that decreased attention to eyes occurs in individuals with ASD only when looking at dynamic stimuli with multiple characters, but not static stimuli or dynamic scenes representing a single person. Norbury et al. (2009), however, showed that only language impaired adolescents with ASD, rather than those without language impairments, exhibited reduced attention to the eyes in dynamic scenes when compared to TD peers. In combination, these findings suggests that atypical facial processing in ASD with decreased attention to eyes and increased attention to mouths may be reflective of efforts to integrate synchronised visual and verbal information by those with language impairments (Nakano et al., 2010). This is further supported by evidence that mouth fixations are common in TD infancy (Hunnius & Geuze, 2004) and that TD adults also increase mouth fixations when the speech is masked with noise (Vatikiotis-Bateson, Eigsti, Yano, & Munhall, 1998). In other words, if one is having difficulty understanding what is being said, they will most likely focus on the speaker's mouth. Therefore, atypical attention to eyes as a universal characteristic of ASD has been heavily disputed (see Falck-Ytter & von Hofsten, 2011; Guillon, Hadjikhani, Baduel, & Rogé, 2014).

Recently, it has been observed that social attention in ASD may in fact be atypical at two levels (see Chita-Tegmark, 2016). Firstly, there are the differences in specific strategies used to extract the relevant social information. These atypical strategies in ASD would be reflected in findings of decreased attention to eyes and increased attention to mouths or bodies in comparison to TD individuals (Klin et al., 2002b). Secondly, there is a more general bias towards social information in TD and a lack of such in individuals with ASD. In other words, a preference for social information in ASD may be reduced, especially in the presence of competing non-social information (Klin et al., 2002a). This in turn may reflect a reduced interest in the social world in general. The atypical strategies used to extract social information in ASD and their generally reduced social bias are clearly related. Yet, ultimately, they are two levels of the atypical social attention in ASD that reflect different processes and thus should be investigated separately. To be precise, the more general issue of reduced social bias in ASD represents a more basic social atypicality that may be underlying atypical strategies used to extract social information and thus should be investigated first (Chita-Tegmark, 2016). Therefore, the current thesis focuses on determining the existence of reduced social bias in ASD and the circumstances under which it occurs.

A recent meta-analysis by Chita-Tegmark (2016) confirmed that individuals with ASD indeed spend less time attending to social information than TD controls. Nevertheless, this lack of social bias does not always occur. Whilst most of the studies do find reduced attention to social information in ASD (e.g. Bird, Press, & Richardson, 2011; Chawarska et al., 2013; Riby & Hancock, 2008, 2009b; Sasson, Turner-Brown, Holtzclaw, Lam, & Bodfish, 2008), others do not (Fletcher-Watson et al., 2009; Freeth et al., 2010; Kuhn, Kourkoulou, & Leekam, 2010; van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2002). Thus, it remains unclear why and when this diminished social attention in ASD occurs. 77% of young adults diagnosed with ASD in childhood report poor social outcomes reflected in not having any friends (Eaves & Ho, 2008). In light of that, better understanding of the allocation of social attention in ASD and related underlying mechanisms is imperative for the design of efficient, targeted interventions for ASD.

Mechanisms Underlying Atypical Social Processing in ASD

Multiple underlying mechanisms have been proposed as potential explanations for social and communication difficulties in ASD. These, for example, have included deficiency in Theory of Mind (ToM; Baron-Cohen, 2000) or reduced empathising and increased systemizing (Baron-Cohen, 2009). Both of these theories roughly suggest that reduced attention to social information, and eyes in particular, in ASD reflects an inability to successfully infer other’s mental states. Yet, empirical studies challenge such beliefs by showing that, for example, children with ASD can identify others’ mental states as successfully as TD children even if the eyes are presented in isolation and irrespective of the presence of motion (Back, Ropar, & Mitchell, 2007).

Others, however, propose that the underlying mechanisms may not be specifically social in nature, but more domain general (e.g. Behrmann, Thomas, & Humphreys, 2006; van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2001). In other words, the suggestion here is that the atypical processing takes place not due to the socialness of the information, but atypical sensory processing instead. Indeed, this is supported by the presence of pervasive sensory processing atypicalities in ASD (Leekam et al., 2007), high rates of autism-like symptoms in congenitally blind children (Cass, 1998), and high rates of visual impairments in adults with ASD (Mouridsen, Rich, & Isager, 2017). Thus, increasing evidence suggests that atypical visual processing and atypical visual behaviours are present in individuals with ASD. Despite this, the assumption that these atypicalities are connected with atypical social behaviour often goes unchecked (Klin et al., 2002a).

Global and/or local processing. One of the potential domain general perceptual mechanisms has included atypical hierarchical processing (Frith & Happé, 1994; Happé, Ronald, & Plomin, 2006; Mottron, Dawson, Soulières, Hubert, & Burack, 2006; Plaisted, 2001). In general, visual perception requires perceptual organisation, which allows perception of scenes or patterns as structured wholes (i.e. gestalt) consisting of elements arranged in space (van der Helm, 2016). A number of studies indicate that both children and adults with ASD are superior in tasks that require attention to detail, including visual search, embedded figures and block design tasks (e.g. Cribb, Olaithe, Di Lorenzo, Dunlop, & Maybery, 2016; Plaisted, O'Riordan, & Baron-Cohen, 1998; Ropar & Mitchell, 2001).

Therefore, it has been suggested that atypical processing in ASD can be explained by weak central coherence or a bias towards local processing (Happé & Frith, 2006). That is, whilst typically developing individuals process information by extracting the general gist (global advantage), people with ASD tend to adapt a more piecemeal approach (local advantage), processing parts before the whole. Others propose, instead, that atypical behaviour exhibited by individuals with ASD comes about not due to weakness in global perception, but rather a superiority in low-level perception or enhanced perceptual functioning (Mottron & Belleville, 1993).

Atypical hierarchical processing in general concerns domain general perceptual processes, and thus also has implications for social perception. For instance, it has been suggested that hierarchical processing is critical for facial and emotion recognition as faces are defined by a specific spatial integration of different features changing in a characteristic way (Behrmann, Thomas, et al., 2006). Due to atypical visual perception, individuals with ASD may not be attuned to the meaning of subtle changes in facial features and thus become less biased towards the typical social behaviours (Hellendoorn et al., 2014).

Studies to date have found mixed results regarding the encoding of local and global visual information and how these two levels of processing impinge on each other in ASD. Some studies reported finding sensitivity to the local stimuli in participants with ASD (e.g. Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2001), whilst others found no group differences between ASD and TD groups (e.g. Edgin & Pennington, 2005). More surprisingly, a few other studies have found a global advantage in ASD, but not the control group (Mottron, Burack, Iarocci, Belleville, & Enns, 2003). Therefore, it remains unclear whether individuals with ASD process local and global visual information differently than TD individuals and whether it co-occurs with atypical social attention.

Attentional shifting. Atypical attention mechanisms have also been proposed to explain atypical visual behaviour and social stimuli processing difficulties in ASD.

Indeed, cognitive shifting abilities strongly predict the level of social understanding in ASD (Berger et al., 1993). Several studies have showed that children with ASD experience difficulties in orienting visual-spatial attention and in shifting attention between stimuli once visual attention has been engaged (e.g. Courchesne, Townsend, Akshoomoff, & Saitoh, 1994; van der Geest et al., 2001; Wainwright & Bryson, 1996). This inability to disengage attention may not only indicate a domain general attentional deficit but could also account for pervasive restricted and repetitive interests seen in ASD. Thus, at least in children with ASD, there is relatively clear evidence for difficulties with attentional disengagement (Rinehart et al., 2001), yet research of these processes in adulthood is lacking.

It is further suggested that given that the social environment is richer, multimodal, and more dynamic compared to non-social information, attentional shifting atypicalities may thus be more pronounced in social situations (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998). Yet, studies investigating attentional shifting in ASD usually utilize relatively simple stimuli (e.g. geometric shapes; van der Geest et al., 2001) and rarely directly research whether the same attentional processes apply for social information (e.g. J. Fischer et al., 2015; Kikuchi et al., 2010). It seems intuitive that there may be some domain general atypicalities in visual perception that may in turn be underlying atypical social processing in ASD. Yet, the inconsistency of the findings and the lack of research exhibiting existence of both perceptual and social attention deficits in the same sample has thus far precluded conclusive evidence of it.

Intersensory processing. Another domain general factor, which can potentially explain both social deficits and repetitive behaviours and interests characteristic to ASD, refers to intersensory integration difficulties (see Bahrick &

Todd, 2012). The explanation also attempts to account for the hierarchical processing difficulties and attentional shifting atypicalities. The suggestion is that individuals with ASD may be impaired in detection of intersensory redundancy (see Bahrick & Todd, 2012). To put it simply, intersensory redundancy occurs when the same amodal information is available concurrently over multiple senses. For example, the texture of an object may be perceived through both touch and vision. Similarly, a synchronised rhythm produced by the drums, for example, can be perceived audibly as well as visually. This successful unitization of synchronous information across senses is believed to simplify and reduce the overall amount of experienced stimulation (see Spear & McKinzie, 1994). Thus, impairments in the ability to perceive the stimulations across modalities as parts of the single stimulus, could result in reduced coherence and thus longer processing time, as well as increases in perceived stimulation and complexity (see Bahrick & Todd, 2012).

Research on intersensory integration of speech can also be used to support potential intersensory integration deficits in ASD (see Bahrick & Todd, 2012). Indeed, adolescents with ASD have been shown to be less susceptible to the McGurk's effect (e.g. de Gelder, Vroomen, & van der Heide, 1991). Additionally, the speech-in-noise paradigm used to detect a threshold for one's ability to recognise speech in background noise provides further evidence for atypical integration in ASD. To be precise, individuals with ASD require a louder speech signal compared to the background noise (e.g. Alcántara, Weisblatt, Moore, & Bolton, 2004) even with synchronised visual information present (Smith & Bennetto, 2007). In conjunction with research by Norbury et al. (2009), these findings might explain the processes underlying reduced attention to eye over mouth region seen in individuals with ASD (e.g. Klin et al., 2002b). Yet, it fails to directly account for the reduced attention to social information in general (e.g. Riby & Hancock, 2009b).

Nevertheless, impaired processing of intersensory redundancy is also proposed to result in difficulties processing unrelated, but concurrent, streams of multimodal information (see Bahrick & Todd, 2012). That is in line with autobiographical accounts of sensory overload in ASD notably influencing social aspects of life (see Bogdashina, 2003). This is further supported by research of Foss-Feig et al. (2010), who found that children and adolescents with ASD were as susceptible to the flash-beep illusions as TD participants, but also across a larger temporal processing window. In other words, when two beeps were presented along with a single flash, participants with ASD reported seeing two flashes even if the temporal disparity between the flash and the beeps was relatively large. Indeed, if individuals with ASD do require less synchrony between the modalities for the stimulations to be blended, noisy environments would be particularly detrimental. It may provoke accidental synchrony between multiple unrelated stimuli so impairing one’s ability to reach adaptable unitization and successfully guide attention to relevant information. Given that social interactions, compared to perception of objects, involve constant stream of dynamically changing multimodal information, it could be perceived as confusing and aversive by someone struggling to integrate all the concurrent sensory information. In turn, it could discourage one from social engagement, so promoting atypical social attention in ASD.

In terms of irrelevant noise, a possible explanation of atypical processing in ASD has also been proposed in connection to selective unimodal attention (Remington, Swettenham, Campbell, & Coleman, 2009). Load theory of selective attention suggests that attention paid to irrelevant information (e.g. distractors) depends on two mechanisms (Lavie, 2005; Lavie & Tsal, 1994). Regarding the first mechanism, it has been observed that high perceptual load tasks require more processing resources. If we assume that one has a limited amount of such resources, high perceptual load tasks may exhaust them. In other words, high perceptual load tasks may not leave any resources for processing of distractor stimuli, thus excluding distractors from perception. The second mechanism concerns tasks of low perceptual load. Due to the task not using up all the processing resources available, both a task relevant and task irrelevant stimuli could be perceived. Therefore, a mechanism of attentional control has to actively suppress processing of the distractors to minimize their interference effect. However, the effectiveness of attentional control mechanism depends on the resources available for the higher order cognitive control functions (e.g. working memory). High load on these cognitive control functions can obstruct their ability to effectively prioritise attentional targets, thus increasing distractor processing (Lavie, 2005; Lavie & Tsal, 1994). Other researchers elaborated on the load theory of selective attention by showing that similar processes are at work when intersensory stimuli are concerned. For example, it was shown that manipulation of a visual attentional load also moderated attention to irrelevant auditory stimulation (Zhang, Chen, Yuan, Zhang, & He, 2006).

Research by Remington et al. (2009) revealed that adults with ASD required higher levels of perceptual load than their TD counterparts for the effects of the first mechanism to be seen. This suggests an enhanced perceptual capacity. In other words, for individuals with ASD high perceptual load tasks would not exhaust their available processing resources as fast as it would for TD individuals (Lavie, 2010). Thus, although originally concerning stimulation in a single modality only, load theory suggests that individuals with ASD may be more susceptible to the distracting effects of irrelevant stimulation. Indeed, the finding of larger temporal window in ASD (Foss-Feig et al., 2010) further extends this possibility into intersensory perception.

Characteristics of the Stimuli Presented

As previously mentioned, whilst there is clear evidence that social attention is atypical in ASD, the previous findings have not been fully consistent (see Chita-Tegmark, 2016). It has been previously shown that the complexity of grading in the visuo-spatial tasks has an effect on the performance of individuals with ASD (Bertone, Mottron, Jelenic, & Faubert, 2005). To be precise, it was found that individuals with ASD exhibited an enhanced performance on a simple task, but diminished performance on a more complex task. Research using social stimuli, however, are hard to evaluate in the same terms of complexity. Nevertheless, there appear to be some common characteristics across the stimuli used in the previous studies finding (e.g. Bird et al., 2011; Chawarska et al., 2013; Riby & Hancock, 2008, 2009b; Sasson et al., 2008) or not finding (Fletcher-Watson et al., 2009; Freeth et al., 2010; Kuhn et al., 2010; van der Geest et al., 2002) signs of decreased attention to social information in ASD compared to TD. In general, there appears to be a trend towards more complex and ecologically valid stimuli inducing larger differences in social attention between individuals with and without ASD. If, indeed, reduced social attention in ASD is a reflection of atypical processing of any complex rather than just social information, that would further confirm the presence of underlying domain general deficits in ASD.

Chita-Tegmark (2016), for example, observed that the presence of the reduced social attention in ASD was partially moderated by social content (i.e. number of people in the scene or on the screen). To be precise, it was found that if more than one person was included in the stimulus, reduced social attention was more likely to occur. Nevertheless, some studies showed significant group differences in attention to social information even when the stimulus included only one person (Bird et al., 2011; Chawarska et al., 2013). Therefore, whilst the atypical social bias in ASD may increase with the social content, other factors seem to also be at play.

In their study Klin et al. (2002b) found that individuals with ASD differed from TD individuals not only on attention to social, but also non-social information. To be precise, they found that adults with ASD looked off-person more than TD participants. This has led researchers to suggest that atypical social attention in ASD may be occurring due to a bias towards non-social information (e.g. Tager-Flusberg, 2010). Yet, whilst some studies find reduced social bias in ASD being accompanied by increased attention to the background (e.g. Klin et al., 2002b; Riby & Hancock, 2009b), others do not (e.g. Riby & Hancock, 2008; Speer et al., 2007). Furthermore, not all studies even look at the differences in attention to the non-social parts of the scene (Hanley et al., 2013; Kuhn et al., 2010). Therefore, it is also still unclear whether atypical social attention is accompanied by atypical non-social attention in ASD and, if so, under what circumstances.

Few other stimuli characteristics have been proposed as potential explanations to why reduced social attention in ASD occurs in some studies, but not others (Chita-Tegmark, 2016; Guillon et al., 2014). In addition to the previously discussed social content, ecological validity in terms of how realistic the stimuli are has been suggested (Chita-Tegmark, 2016). To be precise, it has been proposed that atypical social attention in ASD may be more pronounced when more realistic stimuli (e.g. photographs; Riby & Hancock, 2008) rather than less realistic ones (e.g. drawings; van der Geest et al., 2002) are used. Furthermore, the dynamic presentation of the stimuli has also been raised as a potential moderator of atypical social attention due to increased ecological validity (Chita-Tegmark, 2016). Indeed, children with ASD seem to exhibit reduced preference for biological motion (Klin, Lin, Gorrindo, Ramsay, & Jonas, 2009). Furthermore, in the study by Speer et al. (2007) atypical attention to the scenes also occurred only in the one of the dynamic presentation conditions. Riby and Hancock (2009b), however, investigated moderating effects of both motion and ecological validity of stimulus presentation in a sample of children with ASD and found that the atypical social attention occurred despite the stimulus type. Thus, it appears that motion may not be a sufficient stimulus characteristic for inducing atypical social attention in ASD, at least on its own.

An alternative explanation is that reduced attention to social information in ASD may be related not to the socialness of it, but the general context of the scene, including the nature of the competing non-social information present (Chita-Tegmark, 2016; Guillon et al., 2014). In other words, it is possible that even a busy dynamic scene without any people may produce reduced attention to certain areas in ASD. For instance, pre-schoolers with ASD showed reduced attention to faces in isolation only when objects perceived as belonging to circumscribed interests (e.g. trains) were present as distractors (Sasson & Touchstone, 2014). Thus, it would not be surprising, if attention to social and non-social information in the scene would also depend on the context.

Recently, another factor in the form of the presence of social interactions has emerged as another potential moderator of reduced social attention in ASD. Stagg, Linnell, and Heaton (2014) compared children with and without ASD on their attention to interacting and non-interacting pairs of cartoon-like figures. They found that TD children and children with ASD, but with no language delay, looked at the interacting figures for longer than children with ASD and a language delay, whereas attention paid to the non-interacting figures was similar across the groups.

Comparisons between the gaze behaviour of the TD children and children with ASD but without a language delay were not explicitly reported. These findings indicate that a similar connection between language impairment and atypical social attention may be applicable not only to the eye to mouth processing ratio, but also to the presence of interactions. Such findings, however, do not fully account for why reduced social attention in ASD sometimes occurs even when only one person is presented as a part of the stimulus (Bird et al., 2011; Chawarska et al., 2013).

The Age and Functioning of Participants

Research examining general developmental outcomes of individuals with ASD find heterogeneity within the diagnosis: with some improving over time, others experiencing deterioration and many presenting stable profiles over time (see Levy & Perry, 2011; Magiati, Tay, & Howlin, 2014). There is some evidence that, for example, adaptive functioning skills pertaining to daily living, communication, and language somewhat improve over time (Magiati et al., 2014). Given that ASD involves both a lack of behaviours (e.g. poor eye-contact) associated with TD and a presence of ASD specific behaviours (e.g. compulsions), it is possible that these two types of symptoms adhere to different developmental trajectories and thus present differently in adults with ASD (Seltzer et al., 2003). A lot of behaviours observed in ASD may be representative of developmental delays. For example, children with ASD manifest some selective attachments to their parents and generally improved communicative skills by school age, whilst exhibiting profound communication skills previously. Yet, other communication deficits may manifest during adolescence when social requirements become more complex (see Burack et al., 2002). Therefore, due to different developmental trajectories, other ASD characteristics might also compare to the TD in adulthood differently than in childhood or adolescence.

Improvements and positive outcomes in adulthood are also dependent on certain individual characteristics including higher cognitive functioning (IQ >70; Levy & Perry, 2011). Indeed, maturation and cognitive functioning both affect acquisition of skills in general, yet it may interact with each other and core symptoms of ASD differently (Burack, Charman, Yirmiya, & Zelazo, 2001). It is particularly relevant when matching younger and low-functioning participants with ASD to comparison groups. Typically, a solution includes matching one control group on cognitive ability and another to mental age. Indeed, such technique successfully ensures that the performance differences are not occurring due to the lower cognitive functioning or developmental stage only. Yet, the lack of interaction between these qualities in either of the comparison groups is problematic (see Jarrold & Brock, 2004). In particular, it can mask the fact that individuals with ASD may still experience deficits due to cognitive functioning in comparison to age matched controls, but compensate for that deficit due to their greater experience in comparison to an IQ matched group. Therefore, atypical performance exhibited by younger, low-functioning individuals with ASD may be representative of behaviours applicable to that group only rather than those unique to ASD overall.

Examining higher-functioning individuals with ASD, thus offers a unique opportunity for examining characteristics unique to ASD. To be precise, testing individuals within a higher IQ (> 70) range, allows a comparison to TD individuals who are matched on both age and IQ and thus controls for deficits occurring due to the interaction between these characteristics. Considering the array of existing studies on children and adolescents with ASD, researching adults with ASD also offers additional insight into the disorder as a whole and its developmental trajectory. Furthermore, research into general outcomes in adults with ASD indicate that one’s wellbeing is dependent on the presence of suitable interventions and social support (Levy & Perry, 2011). Nevertheless, the availability of suitable support services for adults with ASD and no intellectual impairments is very limited (see Lorenc et al., 2017). Therefore, a better understanding of the disorder and its presentation in high-functioning adults with ASD specifically could also help inform the development of suitable support services.

Aims

It is generally agreed that individuals with ASD exhibit atypical attention to social information (Chita-Tegmark, 2016). Arguments have been made claiming that general atypicalities, such as hierarchical processing (Frith & Happé, 1994; Happé et al., 2006; Mottron et al., 2006; Plaisted, 2001) or attentional shifting (e.g. Courchesne et al., 1994; van der Geest et al., 2001; Wainwright & Bryson, 1996), might also be characteristic of ASD. Given the rudimentary nature of these processes and complexity of social information, it is suggested that these domain general atypicalities may be preceding and thus giving rise to social deficits in ASD. Others attempt to unravel atypical social attention in ASD by focusing on the circumstances under which it occurs (e.g. Fletcher-Watson et al., 2009; Hanley et al., 2013; Riby & Hancock, 2009b). Surprisingly, however, there is little evidence directly connecting the rudimentary domain general atypicalities and atypical social attention in ASD. Furthermore, while more research is available regarding the effect of stimuli characteristics, the empirical findings so far have not been conclusive. Therefore, the overall aim of the current thesis was to comprehensively investigate domain general attentional processes and stimuli properties that may be underlying atypical social attention in a consistent group of high-functioning adults with ASD.

The main aim of this thesis can be further broken down into three sub-aims that were addressed across, rather than within, different chapters. Firstly, the current research aimed to examine whether any of the three domain general mechanisms previously suggested to be underlying atypical social attention were co-occurring with the reduced social attention in ASD. This was done across the seven experiments described in this thesis. To be precise, potential global and/or local processing difficulties were directly addressed in Experiment 1 described in Chapter 3 and Experiment 6 reported in Chapter 7. Attentional shifting atypicalities were focused on in Experiment 2 and 3 described in Chapter 4 and Experiment 4 discussed in Chapter 5. The possibility of intersensory integration difficulties, and/or enhanced perceptual load, in ASD was also examined across the thesis. To be precise, Experiment 2 of Chapter 4 and all the experiments described in Chapters 5 through 8 (Experiments 4 through 7) were presented either with or without background noise. This was done in order to investigate whether the presence of background noise can indeed disturb processing in individuals with ASD more than in TD, as suggested by Bahrick and Todd (2012). Furthermore, intelligibility of the background noise was manipulated in order to explore how perceptual load of the visual task (e.g. Lavie, 2010) and that of the auditory distractor may be affecting performance of high-functioning adults with ASD when compared to TD.

Secondly, the current thesis aimed to investigate potential stimulus characteristics that may be moderating reduced social attention in ASD as suggested in previous literature (e.g Chita-Tegmark, 2016). For instance, the social stimuli utilized varied in their ecological validity across the experiments. To be precise, Experiment 2 described in Chapter 4 and Experiment 6 reported in Chapter 7 both used simple drawings of faces. Experiment 3 outlined in Chapter 4, however, involved photographic stimuli, although they were presented in isolation (i.e. no background). Chapter 5 and 6 both described experiments (Experiments 4 and 5, respectively) involving photographs of complex naturalistic scenes. Experiment 7 in Chapter 8 made use of dynamic scenes. Other stimulus characteristics like social content (i.e. number of people presented) and subjective relevance of information depicted (e.g. Chapter 6), presence or absence of social interactions (e.g. Chapter 7), and general context (e.g. Chapter 8) were also addressed across the thesis.

Finally, one of the overarching aims of the current project was to further the understanding of ASD and its presentation in adulthood. For instance, it is unclear how evidence of hierarchical processing atypicalities in children with ASD relate to performance in high-functioning adults with ASD (Chapter 3). Moreover, the current research aimed to measure behaviour of the same sample of participants across the seven experiments described in the current thesis. A range of tasks and stimuli were used across the experiments in this thesis to address the overarching question regarding mechanisms underlying atypical social attention in ASD and thus the performance in different tasks will not be directly compared. However, the use of a consistent sample across the different experiments in this thesis mitigated the issue of sample heterogeneity. In turn, this enabled overarching, albeit tentative, conclusions to be drawn regarding whether different domain general atypicalities and reduced social attention are co-occurring in ASD (Chapter 9). To further avoid confounding effects of heterogeneity and ensure that the diagnostic differences observed are due to ASD presentation and not cognitive impairments or developmental delay, only high-functioning individuals were included in the sample across the current experiments (see Chapter 2). Indeed, it is not yet known how maturation and cognitive functioning may interact with ASD presentation (see Burack et al., 2001). In other words, using this particular sample of participants allowed to determine which, if any, of atypicalities often assigned to ASD (e.g. reduced social attention, hierarchical processing, delayed attentional shifting, or intersensory integration) are universal to it despite the high-functioning level and experience of the participants.

Outline of Experimental Chapters

Chapter 3

Chapter 3 is devoted to determining whether atypical hierarchical processing is present in the current sample. Experiment 1 described in this chapter aimed to confirm a presence of global advantage and global interference effects in TD adults. Yet, more importantly it aimed to evaluate how, if at all, it differs in adults with ASD.

Chapter 4

Chapters 4 focused on potential attentional shifting atypicalities in the current sample. To be precise, two experiments (i.e. Experiments 2 and 3) using customised gap-overlap paradigm were utilized to investigate endogenous and exogenous attentional disengagement to and from both social and non-social information. These experiments varied slightly in the ecological validity by using either drawn or photographic stimuli.

Chapter 5

The aim of Chapter 5 was to further extend on the previous chapter by investigating similar attentional processes (e.g. attentional disengagement and capture) pertaining to social information using naturalistic scenes rather than isolated stimuli. Experiment 4 reported in Chapter 5 was also used to confirm whether reduced attention to social information occurred in the current sample of high-functioning adults with ASD in comparison to TD.

Chapter 6

Chapter 6 of the current thesis evaluated whether the reduced social attention in ASD was accompanied by increased attention to non-social information of naturalistic scenes. Moreover, Experiment 5 described in this chapter was designed to disentangle some factors that may moderate atypical social attention in ASD when compared to TD. These included a level of social content of the overall scene and the subjective relevance of the areas investigated.

Chapter 7

Similarly to Experiment 1 of Chapter 3, Chapter 7 also aimed to compare the effects of global interference in high-functioning adults with ASD and TD adults. To be precise, Experiment 6 touches upon social hierarchical processing by investigating whether task irrelevant interactions or changes in the pattern affects participants' performance or visual attention. In other words, due to suggested piecemeal processing approach in ASD (Frith & Happé, 1994; Happé & Frith, 2006), the effects of global interferences from socially relevant and irrelevant feature changes was evaluated in high-functioning adults with ASD in comparison to TD. Moreover, Experiment 6 also aimed to distinguish between different types and levels of structure of the socially relevant information. It aspired to shed some further light on the distinction between the social content and non-social aspects of it. To be precise, it aimed to evaluate whether manipulation of a pattern structure based on the change in features and that based on the presence of social interactions yielded different performance and/or attention in adults with ASD and TD.

Chapter 8

Disentangling of the general and social content of social information was further addressed in Experiment 7 of Chapter 8. The presence of social bias between

TD adults and adults with ASD was compared when looking at social stimuli that were low in social content and social interactions, but still ecologically valid in terms of motion and general context (i.e. not presented in isolation).

CHAPTER 2

GENERAL METHODS

Summary

The current chapter provides background for and outlines the relevant methodological considerations. Firstly, the recruitment procedure and participant matching on age, gender, and IQ are described. The differentiation of participant groups based on the ASD characteristics is also detailed. In general, the data of 53 high-functioning adults (27 with ASD and 26 TD) was collected and analysed in Phase 1 of testing, with the data from 35 of those participants (18 with ASD and 17 TD) also included in analyses of Phase 2 tasks. Secondly, the chapter provides an overview of the research design. After that, a comprehensive overview of the testing procedure utilized is offered. Then, a general introduction to the eye-tracking methodology followed by details of current experimental set-up, stimulus presentation, and data collection are provided. The chapter is finished with a reflection on the aspects of data analysis, including the multilevel modelling and data extraction techniques used. The final section also provides additional information concerning the multilevel modelling with a specific focus on the statistical decisions pertaining to the studies of the current thesis.

Participants

Recruitment

Originally, 27 high-functioning adults with ASD and 27 gender, age, and IQ matched TD participants were recruited for the studies described in the current thesis. One participant recruited for the TD group was excluded from the analyses due to scoring above the cut-off point of 32 on the Autism Spectrum Quotient (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). Participants with ASD were recruited through the National Autistic Society in the UK or contacted due to their previous participation in research at the University of Roehampton or Goldsmiths College, University of London. TD participants were recruited through an opportunity sample and advertising online (i.e. website for free classifieds ads in the UK). All the participants were living without direct support and were able to travel independently. Also, all participants had normal or corrected to normal vision. Participants in the current study were tested on two occasions (Phase 1 and Phase 2; see Data Collection section for more information). It should be noted that all participants, who took part in Phase 2, previously completed Phase 1 testing.

Background measures. Several assessment and self-report measures were utilized to obtain a comprehensive overview of both groups of participants. This included measure of cognitive, emotional, and sensory profiles, as well as, a screening for ASD characteristics. Background information including age, gender, and cognitive abilities was also utilized to match the participant groups at the group level. The severity of some symptoms generally decrease in high-functioning individuals with ASD (Levy & Perry, 2011). Thus, in addition to describing the sample, the measures of autism characteristics, including sensory atypicalities and level of alexithymia, were also used to discriminate between the participant groups. This was done to ensure that the two experimental groups, on average, presented with distinct profiles that were characteristic of those with and without ASD, rather than the asymptomatic typology.

The Wechsler Abbreviated Scales of Intelligence (WASI). The WASI (Wechsler, 1999) is an assessment designed to screen verbal, non-verbal, and general cognitive ability. This test contains four subtests. In the Vocabulary subtest, the individual is asked to provide a verbal definition for a given word. The Similarities subtest requires for the individual to identify the underlying concept shared by two words. The Block Design subscale includes replication of two-dimensional patterns using two-tone cubes under timed conditions. In the Matrix Reasoning subtest, the individual is instructed to indicate which of five picture fragments best completes the partial picture/pattern presented. The Vocabulary and Similarities subtest scores are combined to represent a verbal IQ score (VIQ), the Block Design and Matrix Reasoning produce a performance IQ score (PIQ) and their combined scores generate the individual's full-scale IQ score (FSIQ).

The purpose of this assessment was two-fold. Firstly, it was administered to confirm that only high-functioning adults were participating in the study. Within ASD a distinction is accepted between high-functioning (IQ 70 or above) and low-functioning (IQ below 70) individuals (Tsai, 1992). All participants recruited scored at least 77 on their WASI assessment. Secondly, this ensured that any differences occurring between participants with ASD and TD across the experiments were not due to group differenced in cognitive functioning (Table 2.1; Table 2.2).

Autism Diagnostic Observation Schedule (ADOS-2). Participants' pre-existing diagnoses were confirmed by the researcher using the ADOS module 4 (Lord et al., 2012). This semi-structured interview has been designed for use in the diagnosis and/or classification of ASD (Lord, Rutter, DiLavore, & Risi, 2008). It involves social interaction between the trained examiner and the participant. The examiner observes and identifies segments of the participant's behaviour in order to confirm a pre-existent diagnosis. Symptom severity is evaluated in the areas of: Communication ("stereotyped/idiosyncratic use of words or phrases") Reciprocal Social Interaction ("empathy/comments on others' emotions"), Imagination and Creativity ("spontaneous, inventive, creative activities or comments in conversation") and Repetitive Behaviours ("excessive interest in or references to unusual or highly specific topics or objects"). Five modules of the assessment are available based on individual's expressive language ability and age. Module 4 of the ADOS-2 is recommended for the use with older adolescents and adults exhibiting fluent speech. The ADOS scoring utilizes an algorithm-based approach where a subset of coded items is used to generate a score for each area of symptoms: Communication (C: 0-8), Reciprocal Social Interaction (S: 0-14), Combined Communication and Social Interaction (T: 0-22), Imagination and Creativity (I: 0-2), and Repetitive Behaviours (SR: 0-8). For Module 4 of the ADOS-2, Cronbach's alpha exceeds .75 for the communication symptoms and .85 for the social interaction characteristics, but it reaches only .47 in the repetitive behaviours domain (McCrimmon & Rostad, 2014). Cut-off scores are provided as diagnostic suggestions (ASD: C > 2, S > 4, and T > 7; autism: C > 3, S > 6, and T > 10; Lord et al., 2012). Since its publication, the ADOS has increasingly been considered the gold standard observational instrument (Kanne, Randolph, & Farmer, 2008). The author obtained her ADOS-2 training to the level of research reliability (inter-rater reliability of over .80) with *BeginningwithA* consultancy at Cambridge, UK.

Only participants with a pre-existing ASD diagnosis were invited to partake in the studies described in the current thesis. Yet, 5 out of 27 adults with ASD recruited did not meet the overall diagnostic criteria of ADOS-2 when administered by the researcher. Module 4 of the ADOS-2 has been shown to have a substantial, but not perfect agreement, with full clinical assessment (61- 66%; Fusar-Poli et al., 2017). Thus, it is not surprising that 19% of participants in the current sample would have received a diagnosis based on full clinical evaluation, but not the ADOS-2 assessment. For instance, this could reflect a tendency of ASD symptomology to decrease with age in high-functioning individuals (see Levy & Perry, 2011). Furthermore, these individuals did not differ from the rest of the participants with ASD on any other background measures included in the current study (*p*s > .099). In light of sample similarity and given that all of them had previously been diagnosed by clinicians, they were retained in the final sample.

Adult Autism Spectrum Quotient (AQ). The AQ is a 50-item self-report questionnaire designed to assess the presence of autism traits (Baron-Cohen et al., 2001). Respondents rate items pertaining to Social Skills (e.g. "I would rather go to a library than a party"), Attention Switching (e.g. "I frequently get so absorbed in one thing that I lose sight of other things"), Attention to Detail (e.g. "I often notice small sounds when others do not"), Communication (e.g. "Other people frequently tell me that what I've said is impolite, even though I think it is polite") and Imagination (e.g. "When I'm reading a story, I find it difficult to work out the characters' intentions"). Each item is rated on a 4-point Likert scale, ranging from 1 (definitely agree) to 4 (definitely disagree). Then each item is scored by examiner either 0 (non-ASD-like) or 1 (ASD-like). The AQ is not a diagnostic measure, yet authors suggest that the total score of 32 or more indicates a high level of autism traits and thus a high likelihood of diagnosis (Baron-Cohen et al., 2001). The AQ has been shown to have a good testretest reliability and moderate internal consistency with Cronbach's alpha varying from .63 to .78 (Baron-Cohen et al., 2001).

In the current project, the AQ was used as a screening measure for ASD traits in the TD adults recruited. One person was removed from the analyses due to the score above the threshold level. In line with the descriptive rather than diagnostic nature of the quotient and previous studies (see Ruzich et al., 2015), none of the low scoring individuals with clinical diagnosis of ASD were removed from the study based on their AQ score. Instead, the AQ self-report was also used with adults with ASD in order to ensure that the two groups recruited differed on their overall level of ASD traits (Phase 1: see Table 2.1; Phase 2: see Table 2.2).

Toronto Alexithymia Scale (TAS-20). The TAS-20 is a 20-item self-report instrument measuring alexithymia (Bagby, Parker, & Taylor, 1994). Alexithymia is a subclinical condition characterized by difficulties in identifying and describing one's own emotional state (Nemiah, Freyberger, & Sifneos, 1976). For example, individuals with alexithymia might know that they are experiencing an emotion, but be unaware whether that emotion is sadness, anger or fear. The TAS-20 measures alexithymia across three subscales: Difficulty Describing Feelings (e.g. "It is difficult for me to find the right words for my feelings"), Difficulty Identifying Feeling (e.g. "I am often puzzled by sensations in my body"), and Externally-Oriented Thinking (e.g. "I prefer talking to people about their daily activities rather than their feelings"). Each item rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The total TAS-20 score was again calculated by summing the scores across the subscales. Although it is not a diagnostic measure, authors suggests that scores under 51 indicate a lack of alexithymia, while scores over 61 indicate a presence of alexithymia (Bagby et al., 1994). The TAS-20 has previously been used to investigate alexithymia in various psychiatric populations due to its high validity with Cronbach's alpha of .76 (Bagby et al., 1994) and ease of application (Berthoz & Hill, 2005).

Alexithymia has been estimated to occur in 40 to 65 % of cases with ASD and only 10 % of TD population (Berthoz & Hill, 2005; E. L. Hill, Berthoz, & Frith, 2004). Therefore, the current sample has been evaluated and compared on their degree of alexithymia (Phase 1: see Table 2.1; Phase 2: see Table 2.2).

The Adolescent/Adult Sensory Profile (AASP). The AASP is a 60-item self-report questionnaire on behavioural responses to everyday sensory experiences (Brown & Dunn, 2002). Individuals are requested report frequency of their response (almost never, seldom, occasionally, frequently, almost always) across modalities. The sensory modalities included pertain to taste/smell, movement, visual, touch, activity level, and auditory processing. Participant answers are rated from 1 (almost never) to 5 (almost always) and used to derive quadrant scores: Low Registration (e.g. "I don't get jokes as quickly as others"), Sensation Seeking (e.g. "I like to wear colourful clothing"), Sensory Sensitivity (e.g. "I am distracted if there is a lot of noise around") and Sensation Avoiding (e.g. "I stay away from crowds"). Higher score within each quadrant represent higher rates of that sensory atypicality. Cronbach's alpha for AASP range from .47 to .91 across different subscales (Dunn, 1999).

Sensory abnormalities are self-reported to be highly prevalent is ASD (e.g. Leekam et al., 2007). Recently, atypical sensory processing has been included in characteristics of ASD in DSM-V (American Psychiatric Association, 2013). Therefore, the participant groups in this study were also compared across their scores in each of the sensory atypicality quadrants (Phase 1: see Table 2.1; Phase 2: see Table 2.2).

The State-Trait Anxiety Inventory (STAI). Participants' level of anxiety has also been evaluated and compared across the groups (Phase 1: see Table 2.1; Phase 2: see Table 2.2). The STAI is a self-report psychological inventory consisting of two forms that each measure a different type of anxiety (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983)

Trait anxiety. Form Y-2 of the STAI (Spielberger et al., 1983) consists of 20 items assessing anxiety as a general personality characteristic (e.g. "I have disturbing thoughts"). Participants are requested to rate the frequency of feelings described in each statement as a reflection of their general state. Each statement in the Trait Anxiety subscale is scored on a 4-point Likert scale ranging from 1 (almost never) to 4 (almost always). The total sum score can range from 20 to 80 with higher scores representing higher self-reported anxiety. The Trait Anxiety subscale has been reported to have high validity with Cronbach's alpha of .91 (Egloff & Hock, 2001).

State anxiety. Form Y-1 of the STAI (Spielberger et al., 1983) consists of 20 items measuring the level of anxiety in response to a specific event (e.g. "I feel confused"). Thus, this subscale is particularly convenient for evaluation of potential testing induced anxiety. Participants are requested to rate how much each statement applies to their current state. Each statement in the State Anxiety subscale is scored on a 4-point Likert scale ranging from 1 (not at all) to 4 (very much so). The State Anxiety subscale has Cronbach's alpha of .74 (Egloff & Hock, 2001). As participants were requested to complete this subscale at the beginning and the end of each testing session, changes in State Anxiety score were calculated by subtracting the total post-testing score from the total pre-testing score.

Phase 1 Participants

The final participant sample for experiments completed in Phase 1 consisted of 27 high-functioning adults with ASD (14 females) and 26 TD adults (13 females). The average age for participants with ASD was 38 years and 2 months old, ranging between 18 years 5 months and 63 years 3 months. For TD participants, the average age was 37 years and 2 months with a range from 19 years 11 months to 64 years.

No significant differences in gender ($\chi^2(1) = 0.02$, $p = .893$) or age ($t(51) = 0.26$, $p = .797$) were observed between the groups. The participants recruited were also matched on full, verbal, and performance IQ as estimated by the full Wechsler Abbreviated Scale of Intelligence (Table 2.1). Adults with ASD presented with significantly higher scores on background measures assessing ASD, such as characteristics measured by the Autism Spectrum Quotient, Toronto Alexithymia Scale, and Adolescent/Adult Sensory Profile (Table 2.1). TD adults, however, self-reported more sensation seeking behaviours (e.g. adding spice to food) than adults with ASD. The recruited sample of adults with ASD also appeared to be generally more anxious than the TD adults in the study, yet importantly no differences were observed in changes of their anxiety in response to the testing experience (Table 2.1).

Phase 2 Participants

A smaller sample of participants completed Phase 2 of testing. This sample included, 18 high-functioning adults with ASD (8 females) and 17 TD adults (10 females), who had previously completed Phase 1 testing. The average age for participants with ASD was 38 years and 3 months old, ranging between 19 years 6 months and 63 years 3 months. For TD participants, the average age was 36 years and 10 months with a range from 19 years 11 months to 64 years.

Again, participants were matched on gender ($\chi^2(1) = 0.72$, $p = .395$), age ($t(33) = 0.31$, $p = .762$), and all subscales of the WASI (Table 2.2). Similarly to Phase 1, group differences were observed on most of the background measures assessing ASD like characteristics. Yet, participants with ASD and TD in Phase 2 did not differ on the level of externally oriented thinking or sensation seeking scores anymore. Adults with ASD also remained a more anxious group, but in comparison to TD adults that again did not result in higher rates of anxiety as a result of testing (Table 2.2). Therefore, even after attrition, the two experimental groups remained clearly distinct on ASD characteristics, including socio-emotional and sensory atypicalities

Table 2.1

Participant Comparison on Background Measures for Testing Phase 1

	ASD (n = 27)		TD (n = 26)		t(51)	p
	M (SD)	Range	*M (SD)*	Range		
WASI: Full Scale IQ	110.33 (14.44)	77-134	110.39 (11.07)	83-125	-0.01	.989
Verbal IQ	107.59 (14.64)	71-129	108.92 (10.52)	81-127	-0.38	.706
Performance IQ	111.00 (14.05)	80-136	109.89 (12.59)	84-138	0.30	.762
AQ: Total	34.93 (6.72)	21-48	18.62 (5.83)	5-29	9.42	<.001
Social Skills	6.85 (2.57)	0-10	2.65 (2.06)	0-7	6.55	<.001
Attention Switching	8.26 (1.38)	6-10	4.69 (1.64)	2-7	8.58	<.001
Attention to Detail	7.37 (2.06)	1-10	5.23 (2.63)	1-10	3.31	.002
Communication	6.56 (2.03)	2-10	2.54 (1.90)	0-7	7.44	<.001
Imagination	5.89 (1.89)	3-10	3.50 (2.02)	0-8	4.44	<.001
TAS-20: Total	64.78 (12.13)	42-84	49.27 (9.80)	35-73	5.11	<.001
Describing Feelings	18.33 (4.25)	10-25	13.69 (4.49)	8-24	3.86	<.001
Identifying Feeling	23.78 (7.77)	7-35	16.54 (4.87)	7-28	4.08	<.001
External Thinking	22.67 (4.47)	11-32	19.04 (4.36)	10-31	2.99	.004

	ASD (n = 27)		TD (n = 26)		t(51)	p
	M (SD)	Range	*M (SD)*	Range		
AASP: Total	175.11 (25.89)	132-230	157.04 (22.22)	115-193	2.72	.009
Low Registration	40.22 (7.80)	27-58	33.69 (5.95)	24-46	3.42	.001
Sensation Seeking	39.19 (11.27)	16-63	47.50 (7.27)	29-59	-3.18	.003
Sensory Sensitivity	47.67 (8.81)	34-66	37.92 (8.38)	22-50	4.12	<.001
Sensation Avoidance	48.04 (10.35)	29-70	37.92 (6.85)	25-55	4.18	<.001
STAI: Trait Anxiety	54.33 (10.78)	33-75	47.00 (11.07)	28-72	2.44	.018
State Anxiety	1.48 (8.36)	-18-24	-1.38 (8.08)	-20-19	1.27	.211
ADOS-2: Total	9.78 (3.42)	3-17	-	-	-	-
Communication	3.48 (1.45)	1-6	-	-	-	-
Social Interaction	6.44 (2.72)	2-12	-	-	-	-

Note. WASI = the Wechsler Abbreviated Scales of Intelligence, AQ = Autism Spectrum Quotient, TAS-20 = Toronto Alexithymia Scale, AASP = the Adolescent/Adult Sensory Profile, STAI = the State-Trait Anxiety Inventory, and ADOS-2 = Autism Diagnostic Observation Schedule.

Table 2.2

Participant Comparison on Background Measures for Testing Phase 2

	ASD (n = 18)		TD (n = 17)		t(33)	p
	M (SD)	Range	*M (SD)*	Range		
WASI: Full Scale IQ	110.56 (14.64)	77-133	111.77 (10.16)	83-125	-0.28	.780
Verbal IQ	107.94 (15.55)	71-129	109.24 (11.44)	81-127	-0.28	.782
Performance IQ	111.11 (13.93)	80-136	112.00 (11.36)	88-138	-0.21	.838
AQ: Total	33.83 (7.07)	21-44	16.65 (5.74)	5-24	7.86	<.001
Social Skills	6.44 (2.77)	0-10	2.29 (2.08)	0-7	4.99	<.001
Attention Switching	8.00 (1.37)	6-10	4.18 (1.51)	2-7	7.85	<.001
Attention to Detail	7.22 (2.34)	1-10	5.00 (2.85)	1-10	2.53	.016
Communication	6.56 (2.25)	2-10	2.06 (1.82)	0-7	6.47	<.001
Imagination	5.61 (1.88)	3-9	3.12 (1.80)	0-6	4.00	<.001
TAS-20: Total	62.56 (12.08)	42-84	48.35 (10.00)	37-73	3.78	.001
Describing Feelings	17.61 (4.19)	10-25	12.94 (4.22)	8-24	3.29	.002
Identifying Feeling	22.72 (8.11)	7-35	16.00 (5.07)	7-28	2.96	.006
External Thinking	22.22 (4.97)	11-32	19.41 (4.32)	10-31	1.78	.084

	ASD (n = 18)		TD (n = 17)		t(33)	p
	M (SD)	Range	*M (SD)*	Range		
AASP: Total	174.39 (26.03)	132-212	151.59 (19.03)	115-188	2.97	.006
Low Registration	40.56 (7.69)	27-58	33.65 (6.16)	24-46	2.92	.006
Sensation Seeking	40.33 (12.43)	16-63	46.59 (6.11)	37-58	-1.90	.070
Sensory Sensitivity	47.44 (8.72)	34-66	36.06 (7.23)	22-50	4.19	<.001
Sensation Avoidance	46.06 (10.28)	29-70	35.29 (5.65)	25-45	3.80	.001
STAI: Trait Anxiety	54.06 (10.82)	33-71	45.18 (11.72)	28-72	2.33	.026
State Anxiety	-2.17 (8.24)	-20-11	-0.06 (6.60)	-16-15	-0.83	.411
ADOS-2: Total	9.22 (3.72)	3-17	-	-	-	-
Communication	3.28 (1.53)	1-6	-	-	-	-
Social Interaction	5.94 (2.82)	2-12	-	-	-	-

Note. WASI = the Wechsler Abbreviated Scales of Intelligence, AQ = Autism Spectrum Quotient, TAS-20 = Toronto Alexithymia Scale, AASP = the Adolescent/Adult Sensory Profile, STAI = the State-Trait Anxiety Inventory, and ADOS-2 = Autism Diagnostic Observation Schedule.

Research Design

A multi-method approach was applied to obtain a comprehensive understanding of the mechanisms underlying attention to social and non-social information in high-functioning adults with ASD. Experimental designs with varying degrees of visual stimulus complexity and auditory distractors were utilized to achieve that. For the purposes of the current thesis, manual reaction time data and/or a number of eye-tracking measures were further analysed as indices of attention under different conditions. The data for the studies described in the current thesis were collected in two phases (see Table 2.3).

Table 2.3

An Overview of Tasks in Each Testing Phase with Corresponding Chapter Information and Outcome Measures

Task	Chapter	Outcome Measures
Phase 1:		
Experiment 1: Navon’s hierarchical figures task	Chapter 3	Reaction time
Experiment 2: Gap/overlap task with competing social and non-social information (schematic stimuli)	Chapter 4	Saccadic latencies
Experiment 5: Attention engagement with competing social and non-social information in naturalistic scenes	Chapter 6	Visit duration
Experiment 6: Manipulation of social and feature structure in patterns	Chapter 7	Reaction time Fixation duration
Phase 2:		
Experiment 3: Gap/overlap task with competing social and non-social information (photographic stimuli)	Chapter 4	Saccadic latencies
Experiment 4: Attentional capture by and disengagements from social information in naturalistic scenes	Chapter 5	Proportional dwell time Time to first fixation
Experiment 7: Attention to dynamic social information	Chapter 8	Fixation duration

Note. See Stimuli and Apparatus section for more details on outcome measures.

Procedure

Ethical Approval

The research described the current thesis was approved under the procedures of the University of Roehampton's Ethics Committee (PSYC 14/143). Informed, written consent was obtained from all participants before each testing occasion (Appendix A). After each testing session, a full written and verbal debrief was provided. All participants were also reimbursed for their participation (a sum calculated on an £8 per hour rate) and their travel expenses.

Data Collection

In general, the data collection procedure for the current thesis can be roughly divided into four main parts: online data, assessment, experimental data in Phase 1, and experimental data in Phase 2 (see Table 2.4). Whilst the online data collection could be completed at any location of each participant's choice, the assessment and experimental data collection all took place in the dedicated lab within the Department of Psychology, University of Roehampton. The tasks were presented in two phases (see Table 2.3 and Table 2.4) with all the data within each phase collected on the same day. Although most participants partook in the research on two occasions around a year apart, a few did so in a space of one week or couple of days. Other than the State Anxiety subscale, the order of all the tasks and blocks of tasks in each testing phase were randomised for each participant.

Table 2.4

An Overview of Tasks, Completion time and Number of Trials per each Testing Type

	Time	No. of Trials
Online Data:	35 min	
Autism Spectrum Quotient (AQ)	10 min	
Toronto Alexithymia Scale (TAS-20)	10 min	
Adolescent/Adult Sensory Profile (AASP)	10 min	
State-Trait Anxiety Inventory (STAI): Trait Anxiety	5 min	
Phase 1:	3 h 20 min (ASD) or 2 h 35 min (TD)	
State-Trait Anxiety Inventory (STAI): State Anxiety	2 x 5 min	
Assessment:	1 h 15 min (ASD) or 30 min (TD)	
Wechsler Abbreviated Scales of Intelligence (WASI)	30 min	
ADOS-2	45 min (ASD only)	
Experimental data:	1 h 55 min	
Navon's hierarchical figures task	10 min	144
Gap/overlap task with competing social and non-social information (schematic stimuli)	15 min	72
Attention engagement with competing social and non-social information in naturalistic scenes	3 x 20 min	3 x 64
Manipulation of social and feature structure in patterns	3 x 10 min	3 x 64
Phase 2:	1 h 10 min	
State-Trait Anxiety Inventory (STAI): State Anxiety	2 x 5 min	
Experimental data:	1 h	
Gap/overlap task with competing social and non-social information (photographic stimuli)	3 x 15 min	3 x 144
Attentional capture by and disengagements from social information in naturalistic scenes	10 min	39
Attention to dynamic social information	< 5 min	9

Online data collection. Before participation in the experimental part of the data collection, participants had to provide some demographic information and complete the self-report questionnaires online. The questionnaires were provided via the automated online survey system (Qualtrics, Provo, UT). Therefore, all questionnaires could be carried out in any location convenient for the participant (e.g. at home). Participants were also able to take breaks whenever necessary, as personalised links were provided. The order of the questionnaires, and of the questions within, was fully randomised. Online data collection took less than 35 minutes for each participant.

Assessment. After the online data was collected and a suitable Phase 1 testing occasion had been arranged, participants came to the University of Roehampton, where the assessments and the experimental data collection took place. In this part of the data collection TD individuals participated in the assessment of cognitive abilities only (WASI; 30 min). In addition to the cognitive assessment, individuals with ASD also had to be assessed for ASD presentation (ADOS-2; 45 min). Completion of these semi-structured assessments took place during the first testing session (i.e. Phase 1).

Experimental data collection. After the online data had been collected and the assessments completed, participants took part in the experimental data collection. The same general testing procedure was utilized during both phases of testing. Firstly, before and after each testing session the participants completed the State Anxiety subscale of the State-Trait Anxiety Inventory (Spielberger et al., 1983). After that, each participant was seated on a chair by a height-adjustable desk. A computer monitor display was positioned 80 cm away from the participant at the height where their eyes focused on the centre of the monitor. A Tobii x120 eye-tracker (Tobii Technology AB, 2010) was positioned below the monitor and 60 cm away from the participant. Each participant was then introduced to the eye-tracker, informed of the procedure and their movement window (i.e. boundaries in space where the eye-tracker signal disappears). All participants were requested to stay as still as possible during the testing session. The eye-tracker was calibrated for each participant using a 9-point calibration procedure (Holmqvist, Nyström, & Andersson, 2011). The set-up and calibration procedure was repeated every time the participant left and came back to the desk or if readjustments were required for other reasons (e.g. seating position changed). Before each task, participants received on-screen and verbal instructions pertaining to the task at hand and, if applicable, were reminded to wear the headphones. Most of the tasks included a break screen appearing every 2 to 5 minutes, depending on the task. Participants were informed before each task that they could use this screen prompt to take a break from the task by closing their eyes and/or removing the headphones for as long as needed. They were requested not to leave the desk during the break. During the tasks where the break screen was not explicitly provided (e.g. Navon's hierarchical figures task), participants were informed to use the block instruction screen as a break. The experimental data collection for Phase 1 took approximately 2 hours, whilst for Phase 2 it took approximately 1 hour (see Table 2.4).

Stimuli and Apparatus

Introduction into Eye-Tracking

Visual perception. Eye-tracking methodology is based on the assumption that we know how visual perception works. In general, the visual perception of an image can be described in the following steps: (1) the light goes into the eye through the pupil, (2) the image is then turned upside down in a lens, (3) the upside-down image is subsequently projected on the retina, where (4) cones and rods transduce the light into electrical signals, which (5) then travel through the optic nerve to the visual cortex, (6) where they are processed (Holmqvist et al., 2011). A foveal (around 2°) part of the retina differs from the rest in its cone density. This foveal information is prioritised with potentially as much as 25% of the visual cortex processing the centre, about the size of a thumbnail at arm's length, of the visual scene (De Valois & De Valois, 1980). Thus, rather than devote resources to processing it all in detail, only a small portion of the visual world is inspected at once (Treue, 2001).

Eye movements allow one to process different parts of the visual field in rapid sequence (Treue, 2001). Indeed, most of the eye movements serve to keep the fovea on a visual target. Such movements include large ballistic scanning motions called *saccades* that typically occur three or four times per second. Saccades usually last 30 to 80 milliseconds during which they reach a velocity of 30° to 500° per second and amplitude of 4° to 20° (Holmqvist et al., 2011). Due to the speed of the movement, however, one's visual sensitivity drops to near blindness level during the saccade (Thiele, Henning, Kubischik, & Hoffmann, 2002). Therefore, perception happens during the 200 - 300 millisecond period when the eye is relatively still, called *fixation.* Fixations take up around 90% of the viewing time and provide high acuity colour vision (Privitera & Stark, 2000). The relationship between saccades and fixations is typically the primary interest for research involving eye movements and attention (Holmqvist et al., 2011).

An important assumption underlying eye-tracking methodology is the *eye-mind hypothesis* as proposed by Just and Carpenter (1980). It suggests that eye movements provide a dynamic trace of where attention is being directed. Put simply, where one looks directly represents what they think about (i.e. overt attention). This view is evidenced by the fact that gaze pattern can, indeed, be manipulated by attentional control processes. On the one hand, one's attention is guided by top-down processing such as behavioural goals, motivational state, and memory (i.e. endogenous attention; Le Meur, Le Callet, & Barba, 2007). Indeed, Yarbus (1967) has showed that viewers' scanpaths were moderated by the task given. For example, when asked to determine a person's age viewers looked at the face of the person in the image, whereas if asked to determine the material circumstances of the family participants looked at the background more. On the other hand, bottom-up processing can also guide attention allocation (i.e. exogenous attention; Le Meur et al., 2007). That has been clear since the first scene perception research by Buswell (1935) showing that one's fixations tend to centre on interesting or informative areas of the image, leaving blank or uniform regions uninspected. One's gaze is also drawn to objects that are salient based on low-level visual properties, such as high contrast parts of the scene, different colours, or moving objects (Parkhurst & Niebur, 2003).

The existence of covert attention that cannot be directly deduced from looking at one's gaze pattern also must be acknowledged. Posner (1980) clearly demonstrated that it is possible to focally fixate on one location while simultaneously diverting attention to another using the go/no-go paradigm. In general, the human functional field can span from 2.6º to 10º, which extends beyond the 2º of foveal vision and thus results in less accurate perception (Henderson & Hollingworth, 1999; Henderson, Williams, Castelhano, & Falk, 2003). Indeed, a gist of the scene can be acquired in a single glance (40 ms; Castelhano & Henderson, 2008), which means that some visual information is perceived without the foveal exploration of the scene. Thus, one can monitor a visual field of about 200º (Levi, Klein, & Aitsebaomo, 1985) with acuity of perception increasing closer to the foveal field of vision. Nevertheless, although an insight into covert attention can be achieved via the use of sophisticated experimental manipulations, the usual focus of eye-tracking methodology is overt attention. Where our eyes are looking is normally where we are paying attention to, and as we prepare to shift our attention we prepare to shift our eyes. Hence, tracking eye movements still offers a unique and objective insight into both exogenous and endogenous locus of control.

Eye-tracking methods. The first eye-tracking discoveries were made in the 19th century and heavily relied on introspection or observation of the reader's eye via the mirror, telescope, or a peep hole (Richardson & Spivey, 2004). Since then, however, several more precise eye-tracking techniques have been developed.

Scleral contact lens/Search coil. This approach is the earliest and arguably most precise modern eye-tracking method that was widely used in 1960s (e.g. Yarbus, 1967). This technique encompasses a wide range of methods that involve attaching a mechanical or optical reference object mounted on a contact lens which is then worn directly on the eyes. Despite its precision, the intrusiveness of such contact lens methods has resulted in their disappearance from human eye movement research (see Richardson & Spivey, 2004).

Electro-OculoGraphy (EOG). Albeit peeking in popularity during 1970s (Duchowski, 2007), this electric potential-based technique is still used to measure of saccadic responses with ASD participants (e.g. Kikuchi et al., 2010; van der Geest et al., 2001). EOG relies on measurement of electric potential differences of the skin surrounding the ocular cavity measured via electrodes. The main strength of EOG technique is its robustness in detecting blinks and gaze shifts even with eyes closed. However, it measures eye movements relative to head position, thus without a point of regard (i.e. fixation location), which does not allow determining where exactly the participants are looking at. Thus, notwithstanding EOG's use in saccadic shift measurements or sleep research, it limits the knowledge pertaining to the direction and spatial position of the gaze (Duchowski, 2007).

Photo-OculoGraphy (POG) or Video-OculoGraphy (VOG). This category includes a wide variety of eye movement recording techniques involving the measurement of distinguishable features of the eyes under rotation/translation. Recording of eye movements then allows one to determine their direction and frequency. Nevertheless, it usually requires manual processing and coding and thus is susceptible to human error. More importantly, a common factor between these techniques and that of EOG, is the lack of a point of regard (i.e. location of the eye gaze). Consequently, head restraints are often required when using these techniques, making them more intrusive and thus less convenient for certain populations (Duchowski, 2007).

Double Purkinje reflection. The basic concept of this technique is to use an infra-red, light source to illuminate the eye and calculate a point of regard based on the position of multiple ocular features. The incoming light creates Purkinje reflections (see Figure 2.1) that are then captured in the image of the eye using a camera. The first (i.e. corneal) and the fourth (i.e. rear surface of the lens) Purkinje reflections are then identified and used to separate eye and head movements. This is achieved by calculating a vector formed by the angle between the cornea and pupil reflections. The distance between the two reflections changes with pure eye rotation (see Figure 2.2), but remains relatively constant with minor head movements (see Duchowski, 2007).

A measure of multiple ocular features at the same time allows one to measure eye movements with not only high temporal, but also spatial accuracy. Whilst double Purkinje reflection-based eye-trackers come in variety of setups including head and tower mounted arrangements, the ability to separate the eye and head movement using two ocular references enables a completely remote and non-intrusive monitoring of eye movements. As a result double Purkinje eye-trackers are suitable for the use across variety of populations irrespective of their age and level of functioning (Guillon et al., 2014).

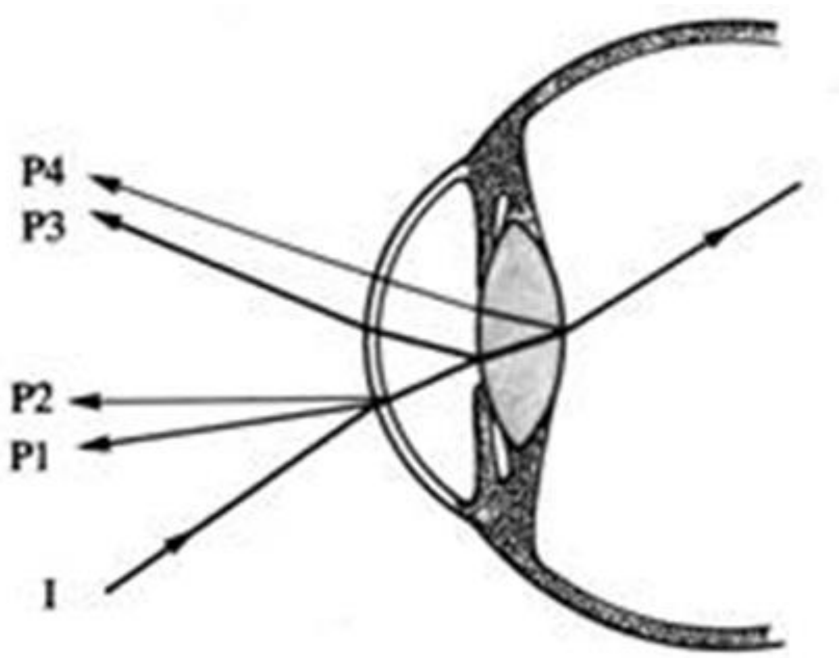

Figure 2.1. Purkinje reflections. After the light (l) hits the eye, the first reflection (P1) takes place at the anterior surface of the cornea, while the fourth (P4) occurs at the posterior surface of the lens. Adapted from “Dual Purkinje Eyetrackers” by KU Leuven, 2017. In the public domain.

Eye-tracking measures. The ability to calculate a spatial angle of gaze using the double Purkinje reflection tracking allows one to map the rotations of the eyeballs (Figure 2.2) onto the 2D coordinates on the screen, reflecting where light was captured from by the eyes. In combination with the stimulus properties on the screen and temporal information about the gaze, these coordinates can be used to devise variety of measures. Having the temporal gaze coordinates enables one to extract information about fixations: when they happened, how long each one lasted for, how many fixations there were in a certain area of the scene, and the total duration of fixations in a scene. Regarding the saccades, it presents one with the possibility to measure the tracking of objects, record the order of scanning, or to determine when a saccade was initiated, how fast it was and what shape it took over space and time (Holmqvist et al., 2011). Thus, different metrics can be defined to determine eye movements on the whole display or particular parts of it. To be able to distinguish or compare what and where captured one's attention, usually, certain *areas of interest* (e.g. a person or an object) are defined based on their on-screen coordinates. Areas of interest (AOIs) can be described as the areas of a display or visual environment that are of interest to, and thus defined by, the research team (Jacob & Karn, 2003). It is important to note, however, that a wide array of metrics is possible given the information produced by the eye-trackers. Thus, it remains unclear which measures are most suitable as representation of different cognitive processes.

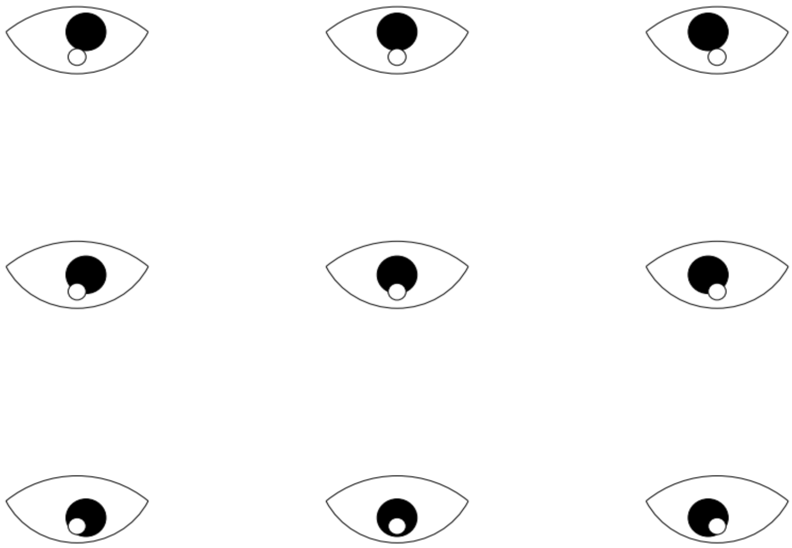

Figure 2.2. Relationship between the pupil and the corneal reflection across different points of reference as seen by the eye tracker. Reprinted from *Eye Tracking Methodology: Theory and Practice* (p. 58), by A. Duchowski, 2007, London: Springer. Copyright 2007 by Springer-Verlag London Limited.

Jacob and Karn (2003) reviewed a number of human-computer interaction and usability studies for eye-tracking and attempted to define the characteristics of the most commonly used metrics. For example, they have observed that the larger number of fixations overall seem to represent a less efficient search, which could be resulting from a poor arrangement of display elements. Overall mean fixation duration, on the other hand, may indicate difficulty in extracting information from a display. Similarly, regarding the AOI analysis, larger mean visit (dwell) duration (i.e. time spent within a certain AOI including both fixation and saccades) would reflect difficulty extracting or interpreting information from that display element. A larger number of fixations and/or a larger proportional visit duration (i.e. time spent looking at that AOI in proportion to the overall looking time) on a particular AOI indicates the importance of that element (Jacob & Karn, 2003). Total visit or fixation duration per AOI, as opposed to a mean fixation or visit durations indicating difficult processing, are also often used to compare the importance of elements on display in ASD research as they indicate increased attention (e.g. Freeth et al., 2010; Riby & Hancock, 2008). In other words, a larger sum of all visit or fixation durations (e.g. more time spent exploring) on a specific AOI would represent more attention paid to that object, but a longer average fixation duration (e.g. the length of one gaze) on a certain AOI would most likely indicate additional time needed to process the information observed. Finally, orienting, which can be defined as the aligning of attention with a source of sensory input (Posner, 1980), has been measured using time to first fixation and saccadic latencies (e.g. Fletcher-Watson et al., 2009; van der Geest et al., 2001; Williams, Porter, & Langdon, 2013).

Eye-tracking procedure. The general eye-tracking procedure can be divided into four main stages: set-up, adjustments, calibration, and monitoring (Nevalainen &

Sajaniemi, 2004). The participant set-up stage involves seating of the participant in front of the eye-tracker and adjusting their location in relation to the eye-tracking device. The adjustment stage involves adjusting the settings of the eye-tracking program, detecting and ensuring the recognition of the participant's eyes, and opening the file used for the recording of the eye-tracking data. The third step includes the calibration procedure, during which a calibration pattern consisting of a number of calibration points (e.g. red dots or a butterfly in toddler research) is shown to the participant. The participant is asked to direct their gaze to each of the calibration points (Nevalainen & Sajaniemi, 2004). This type of calibration procedure is crucial for accurate eye modelling to be performed. During calibration, the eye-tracker measures characteristics of participant’s eyes at different angles. The collected data are then integrated with the 3D model of an eye including information on shape, light refraction and reflection properties of the different parts of the eye (e.g. cornea, placement of the fovea, etc.). The combination of these data enables the eye-tracker to predict a point of reference on the screen based on the changing characteristics of a participant’s eyes (Holmqvist et al., 2011). Finally, the monitoring stage consists of viewing the status of the eye-tracking during data collection and readjusting the settings when and if necessary (Nevalainen & Sajaniemi, 2004).

Stimulus Presentation

A combination of the E-prime 2.0 stimulus presentation package (Psychology Software Tools Inc., 2012) and a Tobii x120 eye-tracker (Tobii Technology AB, 2010) was used to present stimuli and record the data during the experiments in the current thesis. A two computer-based stimulus presentation/data collection interface was set up with one computer running E-prime and the other running Tobii Studio 3.3.1 (Tobii Technology AB, 2015). This arrangement allowed for the stimuli to be presented via

E-prime and recorded as external source video through Tobii Studio. Stimulus events (e.g. trial start and end notifications) are sent from the E-prime to Tobii Studio during the data recording, which then enables splitting of the recordings into scenes (e.g. a part of the recording representing a trial). Such an interface offers multiple benefits. For example, these include the ability to collect gaze information on complex experimental paradigms with precise stimulus timing and randomized trials, which would not be possible using eye-tracking software alone. Furthermore, it also enables the collection of manual reaction time and gaze data simultaneously.

Eye-Tracking Setup

As observed by Klin et al. (2002a), eye-tracking offers many advantages for the researchers investigating visual social attention in ASD. Because of the precise measurement of temporal and spatial accuracy of eye movements, eye-tracking allows researchers to more objectively evaluate where, when, and for how long overt attention is deployed to. Eye movements are also faster and precede directed motoric movement as measured in reaction time approach (e.g. Crippa, Forti, Perego, & Molteni, 2013). Therefore, the automatic nature of these movements should allow for even fewer artefacts of higher order cognitive processes (e.g. social desirability effect) than analysis of motor responses. The ability to define areas of interest within social scenes and video stimuli is a further benefit of an eye-tracking approach, as it offers the optimal balance between ecological validity and methodological constraints (Guillon et al., 2015). The availability of remote eye-tracking technology (i.e. table-top set up without direct contact with a participant) is also a great asset as it enables testing of almost all participants (Tobii Technology AB, 2010). This non-intrusive and non-constraining nature is particularly relevant for ASD participants whose diagnostic characteristics include hyper-sensitivity to touch and often stimming behaviour (American Psychiatric Association, 2013).

A Tobii x120 eye-tracker with Tobii Studio 3.3.1 (Tobii Technology AB, 2010) interface was utilized to record eye-tracking movements in the experiments within the current thesis. Tobii x120 is a remote, thus completely non-invasive, infra-red tracking-based system. It provides little indication that eye movements are being tracked and has no need to artificially constrain head or body movements. All eye movements in the current thesis were recorded binocularly, with a sampling rate of 120 Hz (i.e. 120 samples per second) and accuracy of up to 0.4 degrees (Tobii Technology AB, 2012).

Data pre-processing. Before extraction, all eye-tracking data was pre-processed in Tobii Studio (Tobii Technology AB, 2010). Specifically, a fixation filter was applied to identify fixations in the raw eye-tracking data. A fixation filter in the analysis of eye movements is a commonly used umbrella term encompassing a few pre-processing steps. Among the choice of fixation classification algorithms available, the Velocity-Threshold Identification (I-VT) fixation classification algorithm is among the most popular as it is fairly easy to understand and implement (Salvucci & Goldberg, 2000). In the Tobii I-VT filter, the available steps are velocity calculator, I-VT classifier, noise reduction, gap fill-in, eye selection, merge adjacent fixations, and discard short fixations (Olsen, 2012).

Velocity calculator. To render gaze velocity independent of the image and screen resolution, angular velocity is calculated to represent eye movement speed. An intuitive approach would suggest a calculation of velocity based on change in the position from one sample of gaze data (i.e. Tobii x 120 recording rate is 120 samples per second) to the next one. Yet, the higher the sampling frequency, the shorter the distance that the gaze must move to achieve higher velocity. Thus, it becomes sensitive to even small distortion due to noise. The Tobii I-VT filter addresses this issue by providing an option to calculate the velocity as an average of the velocity for a period of time around each sample instead of just between two consecutive samples. A window length in milliseconds can be specified to apply a particular time window around the current sample that the velocity is calculated for. The window length applied in this research was set to the default value of 20 milliseconds, which has been shown to produce more accurate performance across eye movements of varying velocity (Tobii Technology AB, 2012).

I-VT classifier. As a velocity-based classification algorithm, I-VT classifies directional shifts based on the velocity threshold set. If the eye movement reaches a velocity over the specified threshold, it is classified as a saccade. If the movement is slower than the specified velocity, it is classified as a fixation. A velocity threshold of 20^{o}/s has been specified for all the experiments in the current thesis, as that is a speed reached at the start and the end of the saccade (B. Fischer, Gezeck, & Hartnegg, 1997).

Eye selection. Both eyes do not move in exactly the same way. For example, the eye moving away from the nose usually travels a shorter distance towards a target and thus achieves a lower velocity than the eye moving towards the nose (see Holmqvist et al., 2011). Therefore, either monocular (left or right) eye movement data has to be used, or the spatial coordinates of the eye movements have to be averaged across both eyes. However, gaps in the data may also differ between the eyes due to, for example, blinks or vision obstruction (Duchowski, 2007). The strict average function in Tobii Studio discards all samples where only one eye has been detected, whilst the average function utilizes monocular information as long as the eye is successfully identified (see Olsen, 2012). To avoid data loss a non-strict average function was applied, so both binocular and monocular information was used depending on availability.

Gap fill-in. It is almost unavoidable that some of the data loss that occurs during eye-tracking is due to blinks, obstructed view, or looking away. Yet, shorter breaks in data recording may also occur due to technical issues, such as delays in data transfers within the hardware systems, temporary malfunctions of hardware, time out issues, and temporary reflections in prescription glasses that make it impossible for the eye-tracker to identify the eyes (Munn, Stefano, & Pelz, 2008). Such gaps in the data, if unattended, may distort the accuracy of eye movement classification by, for example, splitting a longer fixation into two shorter ones. A gap fill-in function is available in Tobii Studio for the interpolation of this missing data using a linear algorithm (see Olsen, 2012). It is important that the distinction is made between the short and long interruptions in the sampled data as the latter is more likely to reflect meaningful interruptions in data collection (e.g. not looking at the screen). The current study utilized a default maximum gap length value of 75 milliseconds, which is shorter than a typical blink (Komogortsev & Gobert, 2010). This means that gaps in data longer than that were kept in as missing, whilst gaps that were shorter than that were automatically interpolated (see Olsen, 2012).

Noise reduction. All measurement systems, including eye-trackers, experience noise. Some of the noise may stem from the imperfections in the system setup, while other noise may reflect natural small eye movements like drift, tremors, and microsaccades (Duchowski, 2007). Noise in the data may result in artificially short saccades or fixations due to sudden changes in eye movement velocity (Salvucci & Goldberg, 2000). Tobii Studio provides two (optional) noise reduction functions: moving average and median based corrections (see Olsen, 2012). Yet, for velocity thresholds between 20º/s and 40º/s and window length of 20 ms, the merge adjacent fixations function has also been observed to address the noise issues when merging short fixations that are close in time (Tobii Technology AB, 2012). Given that the parameters in the current research fell within specified range, no additional noise reduction functions were applied to the data to avoid potential artificial distortion.

Merge adjacent fixations. As mentioned, noise in the sampling or other disturbances may cause a long fixation to be divided into several short ones with very short saccades or gaps in between. Merging adjacent fixations addresses this issue by combining fixations that are close in time and position. It is important that the gaps in fixations occurring due to blinks or short saccades, however, are not artificially merged (Olsen, 2012). Default values for the maximum time (75 ms) and angle (0.5º) between fixations were used to determine which fixations should be merged together (Komogortsev & Gobert, 2010).

Discard short fixations. After all previously described steps, the I-VT classifier defines all samples, where the positional data is available and velocity is under 20º/s, as fixations. However, very short fixations are not possible as the eye and brain require some time to process the perceived information (Munn et al., 2008). With this in mind, a default minimum fixation duration parameter of 60 milliseconds was used, where fixations below this threshold are discarded (Olsen, 2012).

Manual Reaction Time

As mentioned, eye-tracking metrics, and saccadic latencies in particular, can offer a rudimentary measure of reaction time in terms of attentional shifting. Eye movements have been shown to precede other directed actions and are less susceptible to control by higher cognition (Crippa et al., 2013). Nevertheless, manual reaction time (RT) as a measure has its uses. While eye movement measures offer a better insight into temporal aspects of attention deployment, they do not directly reflect a start or finish of higher cognition tasks, which require a response. Thus, manual reaction time and response accuracy were both collected using a response box in tasks that required a task completion (Chapter 3 and Chapter 7). The recording of manual data was done via E-prime 2.0 data collection software (Psychology Software Tools Inc., 2012).

During some of the studies described in the current thesis, the goal was to estimate how quickly participants could deliver an answer to tasks that are simple enough to provide a correct answer. Therefore, only reaction times to correct trials have been used in those analyses. Although individuals may differ in their processing speed due to the differences in the speed-accuracy trade-off (Kyllonen & Zu, 2016), erroneous responses were discarded in current research for two main reasons. Firstly, inaccurate responses are likely to reflect outside interruptions or multiple underlying processes including not knowing the answer, not spending enough time to process the information fully, or having gotten confused while answering and quitting (Kyllonen & Zu, 2016). Secondly, the tasks used were relatively simple and thus had low error rates. Moreover, hierarchical models automatically deal with data dependence (see the Data Analysis section). Thus, it was assumed that these factors should minimize the potential effects of different processing approaches (Field & Wright, 2011) and thus not require an analysis of inaccurate responses.

Background Noise Manipulation

Audio stimuli were used as distractors in most of the experiments described in the current thesis. Three noise conditions were utilized: control (no noise), low-intelligibility noise, and high-intelligibility noise. The low-intelligibility track was an audio recording of students coming into a classroom, whilst the high-intelligibility track included the same background noise as the low-intelligibility track merged with somewhat intelligible speech. The no noise condition did not include an audio stimulus. This manipulation allowed evaluating the effect that the presence and/or intelligibility of background noise may have on the performance of adults with ASD.

In order to achieve ecological validity and similarity of the noise tracks, both the recording of the background noise and that of intelligible speech were made in the same environment. To be precise, the recordings were made in one of the lecture rooms at the University of Roehampton during the psychology undergraduate induction. They were recorded while the students were entering the room and during the induction speech, respectively. The recordings were made using Olympus WS-811 digital voice recorder in a Window Media Audio (WMA) format at standard 44.1 kilohertz (kHz) sampling rate. The noise tracks were then trimmed, matched and overlaid (when needed) using a free, open source Audacity audio editor (Audacity Team, 2014). Final recordings were similar in length (low-intelligibility – 9 min 59 s, and high-intelligibility – 9 min 36 s) and bit rate (1411 kbps). During testing, both low- and high-intelligibility noise stimuli were presented through a pair of closed headphones (Sennheiser HD 205), but participants were requested to wear the same headphones during the no noise condition, too. Intensity of both of the noise tracks was evaluated and matched using a sound level meter (Tecpel DSL-330). The noise was controlled to not exceed 65 dB SPL at its peak, which is the level commonly found in many classrooms (Jamieson, Kranjc, Yu, & Hodgetts, 2004).

Data Analysis

Introduction to Multilevel Modelling

Multilevel modelling (also known as hierarchical linear models or mixed-effect models) is a versatile statistical approach for analysing data that has a hierarchical data structure or for which assumptions of independence are likely to be violated (Field & Wright, 2011). A lot of the data in social (and other) sciences is collected using nested sampling techniques. For example, an educational psychologist might randomly select a number of schools, in which they will select a few classes, and then will test a few children from them. Such sampling suggests a three-level hierarchical structure where variability is present at each level: between pupils, between classes, and between schools. In other words, children from the same class will probably behave more similarly than children from another class, which will further differ based on the school they come from. Multilevel analysis allows modelling of relations between variables measured at different levels of the hierarchical data structure.

Multilevel modelling is also known as mixed-effects modelling because of its differentiation between fixed and random effects. Fixed effects are effects of variables that are specified to be constant over all cases (e.g. regression weights or mean differences). In contrast, random effects are effects of variables that are specified as varying across cases (Hoffman & Rovine, 2007). For example, in the previously described example of pupils in schools we may want to predict children's mathematics scores based on the number of pupils in the class. In that case, we would collect their scores on the first level and specify a fixed effect of the number of pupils at the second level. Yet, by allowing a random intercept to vary across schools, we would ensure that the prediction is not confounded by, for example, teaching quality across different schools. Thus, essentially multilevel models are a multilevel version of the familiar multiple regression model where parameters are calculated at different levels (Hox, 2010).

As an extension of multiple regression modelling, multilevel models are also very versatile. Similarly to the former, using dummy coding for categorical variables enables the use of analysis of variance (ANOVA) type models, where predictors can be modelled at different levels of the hierarchical structure (Maas & Hox, 2005). This, in turn, means that the mixed-effect models are useful not only for scenarios where individuals are nested within contexts, but also for longitudinal (Hox, 2010) or experimental (Field & Wright, 2011; Hoffman & Rovine, 2007) repeated measures designs. In contrast to the previously described design, individuals now would be modelled at the highest level (e.g. level three). The second level then could include the types of questionnaires (i.e. longitudinal design) or trials (i.e. experimental design), with observed repeated measures scores nested at the first level. These types of multilevel models may sound somewhat less intuitive. They often consist of crossed (i.e. every individual responds on every item) rather than fully nested (i.e. each individual responds on different items) designs (Hoffman & Rovine, 2007). The data, however, is still organised in a hierarchical fashion with variability at different levels, where individuals may, for example, differ in their general reaction time. Mixed-effect modelling, therefore, provides a very useful alternative to standard ANOVA techniques by taking the said variability into account.

Benefits of multilevel modelling. Historically, due to the complexity of multilevel models and lack of powerful and/or accessible software, multilevel modelling was not readily achievable. Therefore, more traditional methods such as ordinary multiple regression or ANOVA had to be utilized as alternatives instead. Nevertheless, mixed-effect modelling offers many advantages over the use of standard methods when it comes to analysis of hierarchically structured data. In terms of experimental designs, it is particularly useful for small sample studies with large amounts of missing data as seen in eye-tracking research involving clinical populations.

Hierarchical structure. Analysing hierarchically structured variables as if they are all on the same level leads to both interpretational and statistical errors. If traditional approaches are used to analyse hierarchical data, scores often have to be falsely disaggregated or aggregated in order to fit the single-level concept (Hox, 2010). Disaggregation of scores refers to one higher-level value being assigned to a few lower-level scores (e.g. each child is assigned a school's teaching quality score). This approach gives rise to *atomistic fallacy*. In other words, assigning one value to several lower-level units falsely increases the sample size of that measure and thus leads to the inflation of chance findings. The aggregation approach, where lower-level variables are used at the higher-level (e.g. each individual is assigned a mean score for their reaction time across different trials), causes *ecological fallacy*. Conducting analysis on averaged scores at the higher-level results in a loss of variance and thus statistical power, whilst also distorting standard errors and thus results (Hox, 2010). Therefore, multilevel modelling allows for a more accurate analysis where the degrees of freedom at each level are representative of actual observations.

Independence of errors. This assumption states that the cases or observations are selected at random and thus their values on the dependent variable are independent of each other (Tabachnick & Fidell, 2007). Differently from other regression-based techniques, multilevel modelling does not require independence of errors. Indeed, one of the main purposes of multilevel modelling is to account for this violation of independence via a hierarchical structure (Hox, 2010). As previously mentioned, mixed-effect modelling bypasses the issues of error dependence by inclusion of the random effects across levels (Hoffman & Rovine, 2007).

Assumptions of homogeneity of variance or sphericity. This refers to the requirement for the structure of residual variance and covariances to be equal between groups (homogeneity of variance) and pairs of conditions (sphericity), respectively (Field, Miles, & Field, 2012). Violation of these assumptions may result in incorrect tests of the fixed effects in ANOVA models. Multilevel modelling, for example, can be used as an alternative to repeated measures ANOVA when the assumption of sphericity is likely to be violated (Hoffman & Rovine, 2007). Thus, mixed-effect models have an advantage over more traditional approaches as assumptions about the structure of residual variances and covariances are not required.

Missing data. Another strength of multilevel modelling is that it does not require balanced data (Hox, 2010). Thus, the number of available measurements does not have to be the same for all individuals (Tabachnick & Fidell, 2007). Differently from the traditional approach to repeated measures ANOVA, mixed-effect modelling does not require an equal number of individuals within experimental groups (Field et al., 2012). This is particularly beneficial when collecting psychophysiological measurements, such as eye-tracking data, that are sensitive to technical interferences or working with vulnerable samples (Field & Wright, 2011).

Multilevel modelling is also able to deal with the missing data without listwise deletion, which would result in the loss of information, or imputation (Tabachnick & Fidell, 2007). Instead, utilization of the long format (i.e. where each case represents a measurement point) allows for the parameters to be estimated successfully with only the available data. To achieve that an estimation of parameters (regression coefficients and variance components) is conducted via the use of maximum likelihood methods. The maximum likelihood method (e.g. full-information maximum likelihood) is a general estimation procedure that produces parameter values that maximize the likelihood of making the observations in the population given the parameters of the model (Hox, 2010). This way, mixed-effect modelling is able to bypass the issue of unbalanced data and provide unbiased and efficient estimates.

Data Extraction

Tobii Studio. Several standard AOI based metrics are easily obtained via Tobii Studio (Tobii Technology AB, 2015). Three metrics provided by Tobii Studio were utilized in the current research.

Time to first fixation. *Time to First Fixation – seconds* is a Tobii Studio provided metric that measures how long it takes before the gaze is fixated on a particular AOI (Tobii Technology AB, 2015). The time to first fixation is expressed in seconds as the difference between when the relevant stimulus appears on the screen and when the first fixation occurs. In the research described in the current thesis, this metric was utilized in Chapter 5 as a representation of attentional capture by and disengagement from social information in naturalistic scenes.

Fixation duration. *Total Fixation Duration (zeros) – seconds* metric in Tobii Studio has been used to extract fixation durations for the current research. This metric provides a measure of the sum of all fixation durations on a certain AOI. If at the end of the recording the gaze has not been fixated on the AOI, the fixation duration for that particular AOI was recorded as zero (Tobii Technology AB, 2015). This Tobii Studio provided metric has been applied in the Chapter 7 of the current thesis, when comparing visual attention to interactive and non-interactive faces in patterns.

Visit duration. *Total Visit Duration (zeros) – seconds* is another standard metric in Tobii Studio measuring the sum of all the visits on a certain AOI (Tobii Technology AB, 2015). A visit, or a dwell, refers to the time spent exploring a certain AOI expressed as a time difference between when the gaze enters and exits that AOI.

It is usually measured as the interval between the first fixation on a specific AOI and the end of the last fixation within it, when there have been no fixations outside the said AOI (Tobii Technology AB, 2015). Thus, a visit duration includes not only fixation durations, but also the duration of saccadic movements falling within the boundaries of said AOI (Holmqvist et al., 2011). Similarly to fixation duration, if the gaze has not been fixated on the AOI at all, the zero value is recorded for the relevant visit duration (Tobii Technology AB, 2015). In the research described in the current theses, the visit duration metric has been used twice. For example, in Chapter 6, it was used to compare visual attention to different parts of social scenes. In Chapter 5, the total visit duration metric was used to calculate the proportional dwell time, instead. The proportional dwell time was used as an expression of the time spent looking at social information in relation to the whole scene.

Matlab. Although Tobii Studio provides easy access to several standard metrics, the available range of measures is still limited. To be precise, the available metrics in Tobii Studio are based on two basic events, namely, fixations and mouse clicks, and only available in connection with an AOI analysis (Tobii Technology AB, 2015). Definition of dynamic AOIs on a keyframe (i.e. a certain point on the timeline of the media) by keyframe basis is now available in Tobii Studio. Yet, the system remains incompatible with randomised trial presentation, as only processing of linear dynamic recordings (i.e. movies or animations that are of a fixed length and viewed in the same order and with the same timing by all participants) are possible. In light of these constraints, several scripts for new measures were custom-built using Matlab programming language and numerical analysis environment (The MathWorks Inc., 2013).

Saccadic latencies. Although Tobii Studio uses a velocity-based algorithm, it does not provide any data directly related to saccadic movements. Therefore, a metric of saccadic latency was created for the use in the current research. Saccadic latency refers to the time taken from the appearance of a target to the beginning of a saccade in response to that target. This measure was built for and utilized in Chapter 4 of the current thesis, where it served as a representation of saccadic reaction time to a peripherally appearing stimulus (see Chapter 4 and Appendix B for more details on the script). This has allowed a comparison of how fast participants shifted their attention towards social and non-social stimuli under different disengagement conditions.

Fixation duration. A measure, similar to that of fixation duration in Tobii Studio, was devised using the Matlab script. This metric also provides a measure of the sum of all fixation durations on a certain AOI during the recording. Use of Matlab, however, allowed processing of the data on a trial basis and thus enabled randomised presentation of the tasks. This script was specifically created for the experiment described in Chapter 8 (see Chapter 8 and Appendix C for more details on the script). Fixation durations extracted using this script were utilized to compare visual attention to different parts of dynamic socially relevant information in video recordings.

Statistical Approach

As previously discussed, multilevel or mixed-effect modelling has many advantages over more traditional statistical approaches. Those include addressing of hierarchical structure of the data, robustness against missing values, and exemption from the homoscedacity and sphericity assumptions (see Hox, 2010). Therefore, linear mixed-effect (multilevel) modelling was applied to the data analyses across the studies described in the current thesis. The modelling was carried out using the nlme package (Pinheiro, Bates, DebRoy, & Sarkar, 2016) in R (R Development Core Team, 2015).

Model building. To develop a final model, multiple models with fixed effects were created by adding predictor variables one by one and comparing the current model with the previous one. In order to be able to make such comparisons between the models, a full maximum likelihood estimation (ML) had to be used (Field et al., 2012), which also enabled us to account for the missing data when calculating the final parameters of the model (Field & Wright, 2011). As multilevel modelling in the current research was used as an alternative to repeated measures ANOVA rather than multiple regression, no predictors were excluded from the model due to lack of significance. Once main fixed effects were included, interaction terms for the predictor variables were added to the model one by one. After that the anova.lme function from the nlme package (Pinheiro et al., 2016) was used to obtain relevant statistics for the main and interaction effects of the final model.

The significant main effects of variables with three or more levels, as well as significant interaction effects were followed up with post-hoc comparisons. Post-hoc comparisons were used instead of planned contrasts due to technical constraints of the statistical package used. The planned contrasts in this case could only be specified for the main effects of variable with three or more levels and not for any interaction (Field et al., 2012). In turn, the further comparisons could provide only limited information. Therefore, pairwise post-hoc comparisons on all available combinations of significant categorical variables were carried out. To avoid spurious findings due to a Type I error, a Tukey HSD correction was applied to all the comparisons (Tabachnick & Fidell, 2007).

Outliers. In his seminal paper on dealing with outliers, Ratcliff (1993) cautions that a single extreme outlier can distort the mean, the standard deviation, and the shape of the distribution and thus care must be taken to minimise their effect. For instance, mean trimming based on certain percentage of the data or the width of distribution around the mean (as indicated by SD) is a common, although not perfect, approach to dealing with outliers (Miller, 1991). It has also sometimes been applied in previous studies on attention in ASD (e.g. Ballantyne & Núñez, 2016; Mann & Walker, 2003; Wainwright & Bryson, 1996). A priori treatment of outliers, such as mean trimming, may be necessary for classic ANOVA, which heavily depends on means aggregated over subjects or conditions (Baayen & Milin, 2010). However, trimming the means in the distribution poses a risk of over- or under-estimating the true average of the population (Ratcliff, 1993). In turn, if the effect of interest is dependent on group differences in breadth of the data (i.e. occurs in the tails of distribution), removing certain responses could artificially negate or weaken the said effect (Baayen & Milin, 2010). This is particularly risky for the skewed data and samples including more than 10 cases (Miller, 1991). As multilevel modelling does not depend on the same restrictions as classic ANOVA approaches, a need to optimise central values through the large loss of data diminishes (Baayen & Milin, 2010).

In the current research the data was, nevertheless, pre-screened for the true outliers on the case-by-case basis by removing trials obviously contaminated by interruptions or technical issues. This was not common, other than couple of cases (e.g. Chapter 7) where participants obviously (based on video recording information) did not follow instructions. Secondly, a few impossible values were batch removed for the saccadic latencies in Experiment 2 and 3 (c.f. B. Fischer et al., 1997) and for gaze data in Experiment 5 and 7 (c.f. Fletcher-Watson et al., 2009). The impossible values in gaze data in Experiment 4 and 6 were both automatically discarded due to the proportional expression of viewing time. Surprisingly, the reaction time data in Experiment 1 and 6 did not require any additional attending to as the shortest reaction times recorded (281 ms and 2.56 s, respectively) were well above the previously indicated cut-offs for pre-emptive response times (e.g. 5 s; Baayen & Milin, 2010; e.g. 100; Casey, Gordon, Mannheim, & Rumsey, 1993). After that, the steps outlined by Tabachnick and Fidell (2007) to ensure the most efficient way of dealing with the outliers through correction of distribution were utilized.

Normal distribution of residuals. Multilevel modelling is an extension of generalised linear models and thus is susceptible to assumption of normality. This assumption of normality states that the error terms at every level of the model are normally distributed.

Statistical normality tests and graphical examination of residual values for the final model were used to assess the normality of residual distribution. Given that multilevel modelling allows for the analysis of raw rather than averaged scores, it resulted in a relatively large sample of data points in all the studies reported here. This is important for two reasons. Firstly, statistical normality tests are oversensitive in large samples. In other words, statistically significant deviations from normality in large samples often represent deviations that are not substantive enough to make a difference in the analysis (Tabachnick & Fidell, 2007). The second issue refers to the choice of statistical test used to evaluate the distribution of residuals in the current research. The Shapiro-Wilk test was the primary choice for normality testing, as it is more powerful than the Anderson–Darling, Lilliefors, and Kolmogorov–Smirnov tests, respectively (Razali & Wah, 2011). Availability of the Shapiro-Wilk test, however, is constrained by the size of the data sample (< 5000). Hence, when the

Shapiro-Wilks test was not available due to technical constraints, the Anderson–Darling test was used instead (Razali & Wah, 2011).

If the deviations from normality appeared to be substantial, corrections were applied to avoid distortion of the findings. Guidelines proposed by Tabachnick and Fidell (2007) for dealing with outliers and non-normality of the data were followed.

Removal of cases. According to Tabachnick and Fidell (2007), firstly, the data should be checked for any inaccurately entered values, which should be subsequently removed, if found. Secondly, the cases producing outliers may be removed, if they are judged not to be representative of the population (Tabachnick & Fidell, 2007). Given the heterogeneity in ASD presentation, most of the outliers across the studies described in the current thesis have been judged to be mostly meaningful and thus not excluded beyond obviously invalid or otherwise impossible values (see Outliers).

Transformation of the data. Transformation of a dependent variable can be used to improve normality via a change to the shape of the distribution (Tabachnick & Fidell, 2007). The effects of transformation on multilevel modelling do not really differ from the principles of transformation in single-level approaches (Hox & van de Schoot, 2013). Log, square root, and reciprocal transformation were all independently applied to the data in the current research when considerable deviations from normality were observed (see Field, 2009 for a non-technical review). A transformation that improved the normal distribution of residuals around the final model the most was then utilized.

Changing of the scores. If transformation fails, multiple score replacement techniques may be used, yet they were not required in the current research. In other words, the outlying scores can be adjusted so that they are deviant, but not as deviant as they were before (Tabachnick & Fidell, 2007). The most common approaches involve treating all the values that differ from their means by 2 or 3 standard deviations as outliers and replace them with the highest value within that range (Field, 2009). In none of the studies described in the current thesis, changing of the scores resulted in larger improvements of normality distribution than data transformation.

Statistical power. The issue of statistical power in mixed-effect modelling is complex. On the one hand, ability to model the data at the observed level allows for a more accurate statistical power at each level. Indeed, as disaggregation does not have to be used, a limited number of higher order observations is not repeated across the multiple lower level items thus artificially increasing the power. At the same time, the available power is maximised due to raw data being analysed at the lowest level. As aggregation is not needed, the loss of variance and, consequently, power does not occur. The power is also maximised because listwise deletion is not required and thus all the observed cases can be modelled (Hoffman & Rovine, 2007). On the other hand, multilevel models are complex and require greater power for all parameters to be calculated (Hox, 2010). As in most types of analyses, mixed-effect models, too, gain power with increases in sample size, whereas smaller effect sizes and larger standard errors decrease power (Tabachnick & Fidell, 2007).

Simulation studies have been conducted and attempts at power calculation software have been made (e.g. Kreft & De Leeuw, 1998; Maas & Hox, 2005; Snijders, 2005). In general, they show that power is greater with more higher level units and fewer items at the lowest level than the converse, although more of both leads to increased power (Tabachnick & Fidell, 2007). It is near impossible, however, to devise a meaningful rule of thumb or universal power calculator, as there are many unique factors involved in every multilevel analysis (Twisk, 2006). Nevertheless, it is suggested that at least 20 units at the highest level with a ‘not too small’ number of observations at the lowest level are required for sufficient statistical power, if cross-level interactions are estimated (Kreft & De Leeuw, 1998). In the research described in the current thesis, the highest level of the model always referred to the overall number of participants. The power was thus maximised by testing as many individuals as possible (53 in Phase 1 and 35 in Phase 2) and collecting their responses on multiple trials.

CHAPTER 3

GLOBAL AND LOCAL PROCESSING IN HIGH-FUNCTIONING ADULTS WITH ASD

Summary

Previous research has suggested that individuals with ASD differ from TD individuals by exhibiting an atypical processing of hierarchical stimuli (e.g. Mottron, Burack, Stauder, & Robaey, 1999). This has been interpreted as potentially resulting from a more locally oriented processing style or having difficulty integrating local and global processing. Yet, most of the previous research has been conducted on children. Moreover, the few existing studies on adults have used different versions of hierarchical processing tasks than the studies on children. Thus, it is difficult to directly compare the previous findings concerning adults to the findings of studies on children. The main aim of Experiment 1 was to investigate the presence of atypical local or global processing in high-functioning adults with ASD using a traditional divided attention task with Navon's (1977) hierarchical figures. This allowed more direct evaluation of whether hierarchical processing atypicalities observed in children with ASD persist into adulthood. Manual reaction time data of 27 high-functioning adults with ASD and 25 age and IQ matched TD adults was analysed using multilevel modelling. The results revealed that adults with ASD, like TD adults, experienced a global precedence effect. Moreover, both participants with ASD and TD experienced not only global, but also local, interference effects. These findings imply that high-functioning adults with ASD exhibit a typical, albeit unexpected, hierarchical processing style. Theoretical implications and potential explanations are discussed.

Introduction

Despite deficits often associated with ASD, individuals with it also excel at certain tasks. For example, above typical performance in ASD has been observed during embedded figures (e.g. Cribb, Olaithe, Lorenzo, & Dunlop, 2016; Shah & Frith, 1983) and block design tasks (e.g. Ropar & Mitchell, 2001; Shah & Frith, 1993). Similarly, individuals with ASD exhibit superior abilities in copying impossible figures (Mottron et al., 2003), and detecting local targets (Plaisted et al., 1998) or ignoring an increasing numbers of distractors (O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001) in visual search tasks. However, individuals with ASD also often self-report fragmented perception (Bogdashina, 2003), appear to be less efficient when utilizing gestalt grouping rules (Brosnan, Scott, Fox, & Pye, 2004), and succumb less to visual illusions (Happé, 1996). Taken together, these findings indicate that individuals with ASD may focus more on the components of a stimulus than on the global entity or whole. Thus, it has been suggested that this atypical local focus may also be underlying social difficulties, especially face processing, seen in ASD (e.g. Behrmann et al., 2006).

This atypical perception of hierarchical structures has been primarily addressed by two theories: Weak Central Coherence (Frith, 1989; WCC; Frith & Happé, 1994; Happé & Frith, 2006) and Enhanced Perceptual Functioning (EPF; Mottron & Belleville, 1993; Mottron et al., 2006). WCC originally posited that individuals with ASD are best characterized by a detail-focused processing style, which comes from a specific imbalance in integration of information at different levels (Frith, 1989). A later version of the theory accommodated the new evidence of, for example, susceptibility to illusions (e.g. Ropar & Mitchell, 2001) and typical global advantage in ASD (Mottron et al., 1999). The new theory suggested that the detail-processing style may reflect a bias towards local processing, rather than a weakness in global processing (Happé & Frith, 2006). EPF, in contrast, has suggested that atypical behaviour exhibited by individuals with ASD comes about not due to a weakness in global perception, but rather a superiority in low-level perception (Mottron & Belleville, 1993). It also proposed the notion of atypical hierarchical organisation when processing information. For example, whilst higher-order processing may be mandatory in TD, it appears to be optional (i.e. moderated by instruction; Ropar & Mitchell, 2001) in ASD (Mottron et al., 2006).

The notion of atypical hierarchical perception can be tested using stimuli that can be analysed at both the global (i.e. the overall shape) and local level (i.e. individual elements). The most frequently used example of such stimuli is the Navon's (1977) hierarchical figures task with two stimulus levels comprising of large shapes made up from the smaller ones (e.g. an H composed of small Es). The stimuli can be congruent (e.g. E at both levels) or incongruent (e.g. big H composed of small E's), and have the target letter presented at both, or only the local or global level, respectively. Typical performance on this task usually results in two effects. Firstly, participants experience a global interference effect where an incongruent large letter slows down the identification of the target letter presented locally when compared to the congruent stimuli. When the target is presented at the global level, on the other hand, a global advantage effect occurs because a comparable interference from the incongruent local letter does not take place. Hence, this task is thought to represent a global precedence effect where global information is processed faster and is therefore available earlier than local information.

Research utilizing Navon's or Navon's-like hierarchical figures in ASD has so far produced mixed results. In general, some studies find atypical local processing occurs in children and adolescents with ASD (Mottron et al., 1999; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000), while others do not (Mottron et al., 2003; Ozonoff, Strayer, McMahon, & Filloux, 1994). These inconsistencies are likely to have been due to methodological differences across studies. For example, Plaisted, Swettenham, and Rees (1999) observed that attention can determine the performance of individuals with ASD in tasks involving hierarchical stimuli. They found that the instructions provided could moderate performance on this task in children with ASD. To be specific, atypical processing occurred only in the divided attention task where participants were asked to monitor both levels of the hierarchical figures and respond when the target letter appeared. The alternative, a selective attention version of the task required participants to focus only on the local or global level of the figure at the time and identify which letter appeared. In contrast to a divided attention task, selective attention tasks did not yield atypical performance. Therefore, it appears that children and adolescence with ASD demonstrate atypical hierarchical processing, but only on divided, and not selective, attention tasks.

In respect to hierarchical processing atypicalities in adults with ASD, the existent research has, so far, used variations rather than more standard approaches to the Navon’s task. This overlap between the choice of the Navon’s-like task utilized and the age group studied further interferes with the development of a more comprehensive view of hierarchical figure perception in ASD. Indeed, beyond the previously mentioned divided and selective attention hierarchical figures tasks, other variations exist. For example, a preference task where participants are required to sort the figures sharing similarities at either the global or local level has been often used to study hierarchical perception in adults with ASD (e.g. Rondan & Deruelle, 2007). Other variations have included a divided attention task lacking a congruent condition

(Hayward et al., 2012) or a free-choice naming task, where participants have to name a figure they see without explicit instruction to focus on different levels (Wang, Mottron, Peng, Berthiaume, & Dawson, 2007). This versatility and adaptability of the task administration, undoubtedly, is a strength of the Navon's (Navon, 1977) task. Nevertheless, it is important to note that these studies on adults with ASD have also yielded inconsistent findings. Indeed, some show a global preference (Rondan & Deruelle, 2007) and interference (Hayward et al., 2012) comparable to that of controls, whilst others reported faster responses to local elements (Wang et al., 2007). Thus, it further increases the difficulty of understanding hierarchical processing in ASD as these studies differ from the previously described ones not only in an age of the sample used, but also the task chosen.

In summary, Plaisted et al. (1999) revealed that the task demands can moderate the presence of atypical hierarchical processing in children with ASD with only the divided attention task revealing a lack of global advantage. Yet, none has established whether the existence of this atypical processing in a divided attention task extends to adults with ASD. This is especially surprising, given that studies examining hierarchical processing in adults with ASD using other Navon's-like tasks have reported inconsistent results. Notwithstanding the insight previous research can provide into compound stimulus processing in adults with ASD, it remains unclear whether their tasks tap into the same processes as seen in children and adolescents with ASD when using a more common take on the task (e.g. Plaisted et al., 1999) or represent some other underlying perceptual processes.

Aims

The primary aim of the present study was to investigate local and global processing in high-functioning adults with ASD. The divided attention Navon's

(1977) hierarchical figures task, albeit popular in hierarchical processing research in ASD, to the knowledge of the current researcher, has not been previously used to examine these processes in a high-functioning adult sample. This represents a gap in understanding of perception in ASD, specifically whether the same atypicality seen in children with ASD is present in adults. After all, atypicalities seen in previous studies using younger samples may have been tapping into delayed development of hierarchical processing in ASD rather than a pervasive and universal deficit. Therefore, the current study, firstly, aimed to confirm the presence of a global advantage and global interference effects in TD adults. Then, it aimed to evaluate how, if at all, this differs in adults with ASD.

With regard to typical performance, researchers have previously observed that there are other methodological aspects that may influence TD participants' performance on tasks involving hierarchical figures (see Navon, 2003). For example, the global advantage effect is less likely to occur if the size of the global stimulus exceeds 7^{o}, consists of a few or sparse elements, is presented centrally or otherwise predictable, and requires selective attention (see Kimchi, 2015). Variations in these parameters also seem to be influencing participants' performance in previous ASD studies using Navon-like stimuli (e.g. Behrmann, Thomas, et al., 2006; Wang et al., 2007). Hence, Experiment 1 described in the current chapter also aimed to address these methodological concerns through a carefully considered design. Firstly, the perceived stimulus size was similar to that used by Navon (1977) in the original study (3.12^{o} x 3.47^{o} at the global level) and smaller than critical size of 7^{o} (Kinchla & Wolfe, 1979). Secondly, even though the number of elements varied per type of global letter (e.g. 26 for big S, but 40 for big H), it corresponded to studies using denser (e.g. 56 in Plaisted et al., 1999; 14-21 in Rinehart et al., 2000) rather than sparse (e.g. 8 in Rondan

& Deruelle, 2007) stimuli arrays. The location of stimulus presentation was varied on the vertical axis (i.e. presented above or below the centre of the screen) rather than presented centrally to avoid predictability (Pomerantz, 1983). Finally, a divided attention task was employed, in which participants had to monitor both the local and global level of the figure and respond whether the target was present or absent.

Hypotheses

It was hypothesised that TD adults will exhibit typical performance on the Navon's (1977) hierarchical figures task. To be precise, it was expected that TD participants will respond to the incongruent stimuli containing a target letter at the local level slower than the congruent stimuli, thus exhibiting a global interference effect (Hypothesis 1). As per typical performance, it was also expected that a global advantage effect, represented by the comparable performance in congruent and global target trials, will occur in the TD sample (Hypothesis 2). In contrast to TD participants, for high-functioning adults with ASD it was hypothesised that a local interference effect will occur. In other words, it was expected that adults with ASD will respond to incongruent trials with a global target slower than congruent trials (Hypothesis 3). Regarding their performance on incongruent trials with the target letter at the local level, two competing hypotheses were formed. According to WCC (Frith, 1989; Frith & Happé, 1994; Happé & Frith, 2006), it was expected that the local advantage effect will occur in adults with ASD resulting in similar performance in congruent and incongruent trials with local target (Hypothesis 4a). EPF theory (Mottron & Belleville, 1993; Mottron et al., 2006), however, would posit that similarly to TD participants a global interference effect would occur in the ASD participants as well. Thus, trials with a local target and incongruent global letter would result in slower responses than trials where the target letter was congruent across levels (Hypothesis 4b).

EXPERIMENT 1

Methods

Participants

All the participants (see Chapter 2) completed Experiment 1 of the current thesis. One participant's data were, however, omitted from the sample due to testing session issues[1]. Therefore, the final sample consisted of 27 high-functioning adults with ASD (14 females) and 25 TD adults (13 females). The mean chronological age of the individuals with ASD was 38 years and 2 months, ranging between 18 years 5 months and 63 years 3 months. For TD participants, the mean chronological age was 36 years and 7 months with a range from 19 years 11 months to 64 years. No significant differences in gender ($\chi^2(1) < 0.01$, $p = .991$) and age, as well as full, verbal, or performance IQ as estimated by the full Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), were observed between the groups (see Table 3.1). Scores on the Autism Spectrum Quotient (Baron-Cohen et al., 2001) in the TD sample were significantly lower than the ASD group (Table 3.1).

Stimuli and Apparatus

Monochrome stimuli were presented on a 40 x 30 cm (1152 x 864 px) CRT monitor with a white background. Navon's hierarchical figures (Navon, 1977) with two stimulus levels comprising of large shapes made up from the smaller ones were used as the stimuli. To be precise, 16 different stimuli were constructed from four letters (A, H, S, X; Figure 3.1). Four of the stimuli were congruent (e.g. A at both levels) and 12 were incongruent (e.g. big H made up of smaller X's; Appendix D). The letters used measured at 3.43 x 5.01 cm (2.44^o x 3.55^o) for the global level and

[1] The excluded participant belonged to the TD group and did not differ from other TD participants on any of the background information (*p*s > .090).

approximately 0.39 x 0.39 cm (0.27^{o} x 0.27^{o}) for the local level. A number of letters at the local level varied (from 26 to 40 small letters) between the global letter types. The task was designed and presented using E-prime experimental software (Psychology Software Tools Inc., 2012). Reaction time (i.e. time to a press of the button) and accuracy data were also logged using E-prime.

Table 3.1

Participant Comparison on Age, IQ, and AQ per Diagnosis

	ASD (n = 27)			TD (n = 25)			t(50)	p
	M	*SD*	Range	*M*	*SD*	Range		
Age	38.22	13.87	18-63	36.61	13.84	19-64	-0.42	.677
FSIQ	110.33	14.44	77-134	110.68	11.19	83-125	0.10	.924
VIQ	107.59	14.64	71-129	109.04	10.72	81-127	0.40	.688
PIQ	111.00	14.05	80-136	110.32	12.65	84-138	-0.18	.856
AQ	34.93	6.72	21-48	18.64	5.95	5-29	-9.22	<.001

Note. FSIQ = full scale IQ, VIQ = verbal IQ, PIQ = performance IQ, and AQ = Autism Spectrum Quotient.

Figure 3.1. Example stimuli used in the Navon's hierarchical figures task. A congruous stimulus is presented on the left and incongruous stimulus is presented on the right.

Procedure

The task was presented in a 4x2x3 within-subject design, where one factor was the target letter-based block (A, H, S, or X), the other was the presence of the target letter (present or absent), and the third factor was the target presentation level (congruent, global, or local). Participants were presented with 144 trials in total. In each letter block participants responded to 36 trials, 18 of which had the target letter present and 18 which did not. Of target present trials, six had a congruent hierarchical figure, six had an incongruent hierarchical figure with the target letter at the global level, and six had an incongruent stimulus with the target letter at the local level. Similarly, in target absent trials, six stimuli were congruent and 12 were incongruent. The whole procedure took around 10 minutes per participant.

Each participant received on-screen and verbal instructions regarding the procedure. Participants were instructed in each trial to decide, as quickly as possible, if the stimulus contained a pre-determined target letter. They were instructed to input their answer using the stimulus response keyboard by pressing key 8 (if target present) or 9 (if target absent). There were four target letter based experimental blocks (A, H, S, or X). Prior to the actual testing, a feedback-based training session with the target letter T was conducted. As the Navon's task (Navon, 1977) concerns the principle of global precedence in terms of speed rather than error rate, the training block was repeated until the participant achieved 80% accuracy. After that the rest of the blocks were presented at random. Each letter block started with instructions indicating which letter the participant should respond to. At the beginning of each trial, a fixation cross appeared in a middle of the screen for 1000 ms. Once the fixation cross disappeared, the participant was presented with one of the stimuli. The vertical position of the stimulus was randomised to appear either at 5.37^{o} (7.56 cm) above the fixation point or below it. Each stimulus remained on the screen until the participant responded using the stimulus response keyboard.

Data Analysis

Manual reaction time (RT) data was analysed to see whether different stimuli conditions affected participants' performance. Only responses to trials encompassing a target letter (72 trials) were included in the analysis. Due to technical issues, participants with ASD were missing reaction time data on 2% (*M* = 1.41, *SD* = 4.80) of trials, whilst TD participants did not have any missing data Yet, the amount missing responses did not significantly differ between groups, *t*(26) = -1.52, *p* = .140[2].

Even though participants had to complete the training trials to the accuracy of 80% before they could proceed to the actual experiment, some errors still inevitably occurred. Participants with ASD made errors in 8% (*M* = 5.56, *SD* = 7.39) of trials on average. TD individuals in this study made errors on 6% (*M* = 4.04, *SD* = 6.96) of trials. The number of incorrect responses also did not differ between participant groups, *t*(50) = -0.76, *p* = .451. Therefore, incorrect trials were also excluded from the analyses.

The Shapiro-Wilk normality test and graphical examination of residual values revealed that the reaction time data was positively skewed in both participant groups, TD: *W* = .72, *p* < .001, ASD: *W* = .74, *p* < .001. Thus, a log-transformation with the basis of 10 was applied to the data. The graphical examination of log-transformed data confirmed that the distribution of residual values was sufficiently improved, although Shapiro-Wilk normality test remained significant in both groups, TD: *W* = .94, *p* < .001, ASD: *W* = .94, *p* < .001. It should be noted, however, that the Shapiro-Wilk normality test is biased by sample size (Field et al., 2012). Therefore, it may be over

[2] Levene's test revealed that the homogeneity of variance between groups could not be assumed. Hence, the Welch-Satterthwaite adjustment of the degrees of freedom was applied.

sensitive to slight variations in normality when a large sample of measurements, like in the current study, is concerned.

The reaction time data was then analysed using linear mixed-effect (multilevel) modelling with 2x3 design as an alternative to ANOVA (see Chapter 2). Participant information including their diagnostic details (ASD or TD) was modelled at the second level of the multilevel analysis. Reaction time for each trial was modelled at the first level, nested within each participant. The first level also included information on the condition (congruent, global target, or local target).

Results

The mean reaction times in milliseconds for both groups of diagnosis per condition are shown in Table 3.2.

Table 3.2

Means (M) and Standard Deviations (SD) of Reaction Time (ms) per Diagnosis and Condition

	ASD (*n* = 27)		TD (*n* = 25)	
	M	*SD*	*M*	*SD*
Congruent	723.45	373.49	687.75	288.17
Global target	838.33	423.15	784.82	321.65
Local target	930.87	433.46	861.93	304.72

Note. The average scores for each condition are presented here. For subsequent analyses, log-transformed data were used.

Results of the multilevel model building revealed that the main effect of condition was significant (Figure 3.2), $F(2,3399) = 253.37$, $p < .001$, $\eta^2_p = .13$. RTs in the congruent condition ($M = 706.15$, $SD = 335.21$) were shorter than RTs in incongruent trials where the target letter was presented at the global level ($M = 811.76$, $SD = 376.98$) or the local level ($M = 896.77$, $SD = 376.75$). These observations were confirmed with post-hoc Tukey's HSD pairwise comparisons (p < .05). Tukey's HSD pairwise comparison also showed a significant difference between the RTs to incongruent trials with the target letter presented at the global and local levels.

The analysis, however, also showed that neither the main effect of diagnosis on participants' RTs, nor its moderating effects on condition reached significance. In other words, participants with an ASD diagnosis ($M = 827.76$, $SD = 418.43$) did not differ on average RT from those with TD ($M = 776.80$, $SD = 313.05$), $F(1,50) = 0.56$, $p = .457$, $\eta^2_p = .01$. Having a diagnosis also did not change the effect that the incongruent conditions had on participants' RTs, $F(2,3399) = 1.11$, $p = .329$, $\eta^2_p < .01$.

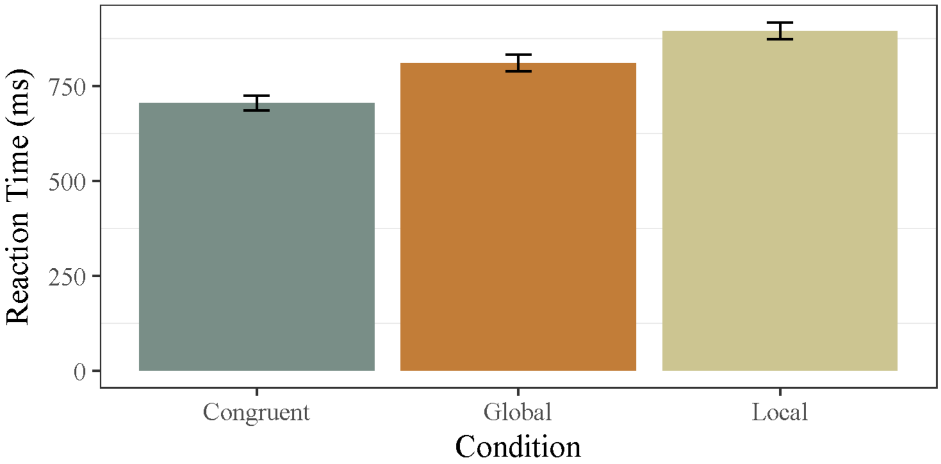

Figure 3.2. Mean reaction time per condition. Congruent label refers to trials where the target letter was presented at both global and local levels. Global label refers to incongruent trials where the target level appeared at the global level (the big letter) only. Local label includes incongruent trials where the target letter appeared only at the local level (the small letter). Error bars represent 95% CI.

Discussion

Experiment 1 described in the current chapter is the first study using a traditional divided attention Navon's (1977) hierarchical figures task to examine whether local and global processing atypicalities exist in high-functioning adults with ASD. In line with Hypothesis 1, a global interference effect occurred in TD adults as their responses to incongruent trials with a local target were slower than in congruent trials. High-functioning adults with ASD, however, also experienced a global interference effect as was posited in Hypothesis 4b. This means that Hypothesis 4a, which proposed a local advantage effect in ASD, was not supported. In line with Hypothesis 3, a local interference effect occurred in adults with ASD. Surprisingly, however, a local interference effect also occurred in TD adults. This contradicted Hypothesis 2 which posited that TD participants would exhibit a global advantage effect.

The main aim of the present study was to investigate local and global processing in high-functioning adults with ASD. Albeit inconsistently, previous research has suggested that individuals with ASD differ from TD individuals by exhibiting atypical processing of hierarchical stimuli (Mottron et al., 1999; Plaisted et al., 1999; Rinehart et al., 2000; Wang et al., 2007). To be precise, children and adolescents with ASD appeared to experience higher interference from detailed information and /or less advantage from the globally presented information. This was explained as potentially resulting from having a more locally oriented processing style (WCC; Frith, 1989; Frith & Happé, 1994; Happé & Frith, 2006) or having difficulty integrating local and global processing (EPF; Mottron & Belleville, 1993; Mottron et al., 2006). The current study shows that adults with ASD experienced both local and global interference when processing hierarchical stimuli. At a first glance, this could be interpreted as support for the EPF theory that posits that individuals with ASD process information at the global level typically, but exhibit superiority at the local level (Mottron & Belleville, 1993; Mottron et al., 2006). Nevertheless, it is crucial to note that both local and global interference was exhibited not only by the adults with ASD, but also TD adults. Thus, although in line with the prediction, this finding contradicts EPF by showing that high-functioning adults with ASD do not exhibit superior local processing in comparison to TD adults.

Thus, whilst adults with ASD indeed experienced local interference, such a processing pattern was not ASD specific. This finding of typical performance by individuals with ASD contradicts some of the previous research utilizing the Navon's hierarchical figures paradigm in children and adolescents with ASD (Mottron et al., 1999; Plaisted et al., 1999; Rinehart et al., 2000), but is in keeping with others (Mottron et al., 2003; Ozonoff et al., 1994). Also, similarly to the study by Hayward et al. (2012), the current findings confirm a global interference effect in adults with ASD. Yet, due to the methodological differences it is hard to say whether this interference represents the global preference effect seen in the study by Rondan and Deruelle (2007) or the local interference reported in (Wang et al., 2007). Without the congruent comparison condition in the study by Hayward et al. (2012), it is also hard to confidently say that a local interference would have not occurred in their study. Utilization of a traditional divided attention task in the current study, however, allows for making more direct comparisons with previous studies on younger samples.

One of the several plausible explanations for the inconsistent findings between the current and previous studies, indeed, involves a potential developmental trend. For instance, studies using the same paradigm have previously found atypical hierarchical processing in samples of children and adolescents with ASD (Mottron et al., 1999;

Plaisted et al., 1999). Yet, previous studies focusing on adolescent only samples - did not (e.g. Mottron et al., 2003). Similarly, the current study testing adult participants also failed to reveal diagnostic differences in hierarchical processing. Thus, this could indicate that this processing atypicality lessens with age in ASD. For example, Gadgil, Peterson, Tregellas, Hepburn, and Rojas (2013) conducted an fMRI study where adult participants were asked to focus on either the local or global level of hierarchical targets and found increased activation in the right superior frontal gyrus during locally directed attention and greater right lateral occipital activation during globally directed attention in the ASD group. Although they did not collect behavioural responses during the task, one could speculate that atypical processing remains while the behavioural presentation decreases with age. Indeed, past research shows that whilst high-functioning adults with ASD do not always directly exhibit, for example, speech encoding abnormalities, their performance is more dependent on other characteristics like age or self-reported sensory atypicalities (Mayer & Heaton, 2014). Therefore, the current findings do not necessarily exclude the possibility of atypical hierarchical processing in ASD overall, but rather may indicate that the pervasiveness of such issues might lessen with development. Longitudinal studies, however, are needed to confirm the existence of these developmental pathways.

Developmental changes in hierarchical processing are further supported by research showing that older TD adults process information at the local level faster than the global level (Lux, Marshall, Thimm, & Fink, 2008). Therefore, in TD there appears to be a change in adulthood from primarily global to more local processing. This is in line with current findings showing unexpected local interference in the TD participants. Yet, if so, one would expect a similar process with the local processing bias, or superiority, increasing with age in adults with ASD (Happé & Charlton, 2012).

Therefore, the lack of age matched group differences in hierarchical processing shown in the current study further indicates that its development may follow a different trajectory in TD and ASD.

The second explanation derives from research, that questions what is really measured by the Navon’s hierarchical figures task (see Kimchi, 2015). A distinction is proposed between global and configural processing. The suggestion is that hierarchical figures may be processed differently depending on whether local elements are perceived more as a texture or parts of the whole. To be precise, global processing as measured using the Navon’s figures concerns processing at the highest level of a hierarchical structure. Configural processing taps into processing of the interspatial relationships of elements where the presence and correct arrangement of all the elements is necessary for the global shape to be perceived (e.g. schematic faces). Rondan and Deruelle (2007) have suggested that atypical configural processing rather than global processing may also be characteristic of ASD. Their study supported this notion by finding a local preference in adults with ASD and no preference in TD adults when using the inter-elemental spatial relationships task. This distinction of configural global processing and the presence of its atypicalities in ASD opens an interesting avenue for future research especially when considering atypical facial processing in ASD. Yet, Navon’s (1977) hierarchical figures are created to specifically tap into the precedence of global processing when stimuli are presented at both levels of a hierarchical structure. Therefore, a distinction between the two global processing types does not fully explain why configural processing differences would occur in some studies using Navon’s (1977) hierarchical figures, but not others. Future research is needed to disentangle the relative contribution of these two global processing types.

Limitations and Future Directions

As previously mentioned, the unexpected performance by TD adults in terms of local interference and thus the absence of a global advantage may be accounted for by the developmental changes in hierarchical processing during adulthood. Yet, methodological differences that could potentially explain this finding should also be addressed. As previously discussed, special care was taken when designing this experiment to attend to potential issues that could diminish a global advantage effect. Nevertheless, a global advantage effect did not occur.

Jolliffe and Baron-Cohen (1997) previously proposed prolonged stimulus presentation as a potential explanation for the similar lack of global advantage in individuals with ASD in some of the previous studies (i.e. Ozonoff et al., 1994). They speculated that if atypical processing in ASD is the result of a reduced speed of processes involved in central coherence, prolonged stimulus duration may allow sufficient time for such processes to occur. Yet, while that may explain why performance of participants with ASD did not differ from that of TD individuals in research by Ozonoff et al. (1994) or the current study, it does not directly explain why a global advantage effect did not occur in either of the groups. If the suggestion is meant to reflect ceiling performance, where all the levels of the hierarchical information are sufficiently processed, such a hypothesis would predict a lack of local or global interference at prolonged exposure times as well. In other words, none of the differences would have occurred between the conditions in the current experiment. Yet, it may be that a global advantage effect occurs only when the stimuli are presented for a limited amount of time. Therefore, future studies may want to consider varying the stimulus exposure time to see whether the cut-off point for a global advantage effect differs between TD individuals and those with ASD.

Conclusion

The experiment described in the current chapter is the first study using the traditional divided attention tasks with Navon's (1977) hierarchical figures and showing the presence of a global precedence with both global and local interference effects in high-functioning adults with ASD. As both effects were also exhibited by TD adults, however, these results could not be explained by either the WCC, or the EPF theories of atypical hierarchical processing. Therefore, it appears unlikely that the presence of atypical hierarchical processing was characteristic of high-functioning adults with ASD in the current sample. Atypical attentional shifting, however, has also been proposed to explain atypical visual behaviour and social stimuli processing difficulties in ASD. Hence, attentional capture and disengagement processes will be considered in the next chapter.

CHAPTER 4

ATTENTIONAL SHIFTING DEFICITS IN ASD: DOMAIN GENERAL, DOMAIN SPECIFIC, OR ABSENT?

Summary

Although not a diagnostic characteristic, atypical attention is considered to have an important role in the development of ASD. Due to inconsistent findings (e.g. J. Fischer, Koldewyn, Jiang, & Kanwisher, 2014; van der Geest et al., 2001), it remains unclear whether these attentional difficulties are domain general, existing across domains, or specific to the social domain. The present study utilized an eye-tracking methodology and a modified gap-overlap task to examine attentional orienting in ASD from and to non-social (i.e. a rectangle or a house) and social (i.e. face) stimuli. Saccadic latencies of adults with ASD and TD adults were compared in Experiment 2 using relatively simple schematic images (ASD = 27, TD = 26) and Experiment 3 using photographs (ASD = 18, TD = 17). Adults with ASD, just like TD adults, exhibited both gap and overlap effects and shifted their attention faster towards a social stimulus. However, adults with ASD exhibited a combination of subtle domain general and social domain specific impairments. Thus, the current study challenges the accounts that argue that either a domain general or social domain specific view can solely account for attentional disengagement in ASD. It also weakens the prevailing notion that attentional difficulties are pervasive by showing their dependence on the ecological validity of the stimuli used.

Introduction

Experiment 1 described in the previous chapter examined the presence of hierarchical processing atypicalities that been previously suggested to be a core deficit in ASD (Frith, 1989; Frith & Happé, 1994; Happé & Frith, 2006). Atypical attention is also considered to have an important role in the development of ASD (e.g. Mottron et al., 2006). Attention can broadly be defined as the process of focusing on certain aspects of the environment and excluding others (Pashler, 1998). However, some aspects of attention are more relevant for ASD than others. For example, attention orienting is thought to act in three steps: disengagement from its current focus, capture by a target (i.e. shift), and engagement of the target (Posner, Walker, Friedrich, & Rafal, 1984). It is further proposed to be controlled by two mechanisms: exogenous (e.g. reacting to a sudden change in luminance), which is a relatively reflexive response to the external stimulus; and endogenous (e.g. reporting the colour of the presented word), which depends on internal, volitional, or central executive control (Posner, 1980). Attentional orienting is also fundamental in the social domain, which results in preferential selection of social information (Ames & Fletcher-Watson, 2010). Attentional atypicalities in ASD, especially in relation to social contexts, are likely to have an impact on the development of other social and cognitive skills (Luyster, Kadlec, Carter, & Tager-Flusberg, 2008), such as joint attention (Mundy & Newell, 2007) or Theory of Mind (Baron-Cohen, 2000). Research findings (e.g. J. Fischer et al., 2014; Kawakubo et al., 2007; Kikuchi et al., 2010; Landry & Bryson, 2004; van der Geest et al., 2001) regarding these attentional differences in ASD are, however, relatively inconsistent.

Recent debates have focused on whether attentional difficulties in ASD are domain general, suggesting attentional atypicalities exist across domains, or whether these difficulties are specific to the social domain (see Ames & Fletcher-Watson, 2010). On one hand, ASD is often referred to as a social disorder (e.g. Klin et al., 2002a). In support of this, research to date shows that individuals with ASD orientate less to social stimuli (e.g. Klin, Jones, Schultz, & Volkmar, 2003; Riby & Hancock, 2008; Riby, Whittle, & Doherty-Sneddon, 2012; Swettenham et al., 1998). This has led some researchers to suggest that individuals with ASD have particularly impaired attention within the social domain, failing to prioritize social information (Klin et al., 2002a; Mundy & Newell, 2007). Others, however, propose that these attentional deficits are not specifically social in nature, but domain general (Behrmann, Thomas, et al., 2006; van der Geest et al., 2001). To be precise, individuals with ASD may have atypical attention mechanisms resulting in difficulty shifting attention between a range of different social or non-social stimuli (Courchesne et al., 1994). Researchers ascribing to this view suggest that social orienting difficulties are not a reflection of social attention deficits, but are in fact caused by domain general abnormalities in visual attention (van der Geest et al., 2001). An alternative position is that both domain general and social domain specific deficits are present in individuals with ASD. In other words, they have general impairments disengaging and shifting attention, but these impairments are more evident for social stimuli (Dawson et al., 1998).

The majority of evidence for attentional differences in ASD pertaining to the social domain comes from observational (Dawson et al., 1998; Swettenham et al., 1998), scene viewing (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Riby & Hancock, 2008), or other viewing time-based paradigms (Riby & Hancock, 2009). Findings from these studies show, for example, that children with ASD often fail to orient to both social and non-social sounds produced by the examiner or at least do so more slowly, especially for social stimuli, relative to TD children (Dawson et al., 1998). Infants with ASD also shift their gaze between objects more often than from an object to a person or from a person to another person in free play situations (Swettenham et al., 1998). Eye-tracking studies show that children and adolescents (Riby & Hancock, 2008, 2009) as well as adults (Klin et al., 2002a) with ASD tend to spend less time than is typical viewing people and faces in natural scenes. However, although these findings support atypical social processing, they may also be indicative of domain general attentional difficulties in ASD. These studies have utilized paradigms with high ecological validity, which reflect the attentional demands required in real-life situations, where the information is complex, dynamic, and occurs across multiple sensory modalities. Yet, to distinguish domain general and social specific attention atypicalities from one another and from contextual effects, it is crucial to investigate social and non-social components of attention in controlled experimental studies (Ames & Fletcher-Watson, 2010).

The examination of saccadic eye movements in gap-overlap tasks has been deployed to measure attention processes described by Posner (1980). In gap-overlap tasks participants are shown a central fixation point, or other stimulus, which precedes the appearance of a stimulus presented to either side of the screen (B. Fischer et al., 1997). Manipulation of the interval between the central and peripheral stimulus presentation allows for the observation of both exogenous (i.e. having an external cause or origin) and endogenous (i.e. having an internal cause or origin) disengagement. In the gap condition the central fixation point is removed before the peripheral stimulus appears (exogenous disengagement). In the baseline condition the peripheral stimulus is shown at the same time as the central fixation point disappears. In the overlap condition the central fixation point remains on the display when the peripheral stimulus is presented; thus, attention has to be disengaged intentionally (endogenous disengagement). Saccadic reaction time tends to be faster in the gap condition and slower in the overlap condition, because attention is already disengaged when the peripheral stimulus is presented in the former condition, but still engaged in the latter one (e.g. B. Fischer & Weber, 1993; Saslow, 1967). Furthermore, eye movement analysis enables removal of the confounds of higher-order cognitive processes present in motor (e.g. manual reaction time; see Chapter 2) responses (see Ames & Fletcher-Watson, 2010). Thus, such a task allows examination of experimentally controlled attentional processes. In addition, when combined with social and non-social stimuli it can provide an insight into domain general and social specific processing by revealing whether attentional shifting atypicalities in ASD differ based on stimulus type.

Proponents of the domain general deficit view often use gap-overlap tasks to investigate attention from and to non-social stimuli to show that attentional atypicalities in ASD are independent of social contexts. Yet, these studies do not produce consistent results. For example, Landry and Bryson (2004) found that children with ASD were slower to disengage their attention in overlap trials in comparison to children with Down’s syndrome or TD children. They suggested that this finding is similar to “sticky” attention previously described in typical 2-month olds, where infants were unable to endogenously disengage from a central stimulus at all (Hood & Atkinson, 1993). According to such an interpretation, this inability to disengage attention would not only indicate a domain general attentional deficit, but could also account for pervasive, restricted and repetitive interests seen in ASD. Indeed, this effect has been shown to apply to motor responses (Todd, Mills, Wilson, Plumb, & Mon-Williams, 2009) and has also been observed in adults with ASD (Kawakubo et al., 2007). Kawakubo et al. (2007) also demonstrated heightened presaccadic positivity in event-related potentials of ASD participants during the overlap condition. In other words, a higher level of activity is necessary to execute eye movements in ASD than TD, thus, suggesting that disengagement in ASD requires more resources. By finding slower disengagement in infant siblings of children with ASD, Elsabbagh et al. (2009) have shown that this effect is also characteristic of the broader autism phenotype.

In contrast, van der Geest et al. (2001) claimed that attentional engagement, but not disengagement, deficits were present in their sample of children with ASD because the difference between saccadic reaction times in the gap and overlap conditions was smaller in the ASD than control group. It should be noted, however, that the ASD and control groups in their study did not differ directly on mean reaction times in either the gap or overlap condition separately, which suggests such an interpretation should be applied with caution. In other words, a smaller difference between the performance in gap and overlap conditions in ASD without the clear indication whether the difference occurred due to exogenous or endogenous disengagement should not be over-interpreted. Furthermore, other researchers using the gap-overlap task have not found attentional differences between children (Crippa et al., 2013; Mosconi et al., 2009), adolescents (Goldberg et al., 2002) or adults (Kawakubo, Maekawa, Itoh, Hashimoto, & Iwanami, 2004) with and without ASD. This in turn challenges studies finding group differences and thus suggests that domain general attentional difficulties may not be universal in ASD. Hence, it remains unclear whether individuals with ASD have domain general attentional deficits and what has led to inconsistencies in previous studies.

Only the studies directly comparing both social and non-social attention can actually offer an insight into whether attentional shifting deficits in ASD, if present at all, are domain general or specific to the social domain. Yet, such research is scarce as most of the previous studies utilized non-social stimuli only (e.g. Crippa et al., 2013; Kawakubo et al., 2007, 2004; Landry & Bryson, 2004; van der Geest et al., 2001). To the current researcher's knowledge, only two studies thus far (J. Fischer et al., 2014; Kikuchi et al., 2010) have used a gap-overlap task to directly investigate both social and non-social attention differences in ASD. For example Kikuchi et al. (2010) compared disengagement from social and non-social stimuli in children with and without ASD. They found that children with TD responded slower in the overlap condition when the central stimulus was a face compared to when it was a house. However, slowed disengagement from the social stimulus was not present in the ASD group whose responses did not differ based on the social or non-social nature of the central stimulus. They did not find any differences between groups or type of central stimulus in the gap condition. The lack of group difference when the central stimulus was non-social seems to suggest that children with ASD do not have domain general attentional difficulties. Yet, in line with social attention domain deficits, they exhibit atypical social attention by disengaging from social stimuli faster than TD children. This may indicate a weaker engagement with social stimuli in ASD. However, J. Fischer et al. (2014) included social stimuli for both the central and the peripheral target, when investigating disengagement and social capture in children with ASD and found no differences in comparison with the TD children. In their study children with ASD disengaged from the central social stimulus similarly to TD children. They also shifted their attention towards social peripheral stimuli faster than non-social stimuli as did TD children. This indicates a lack of impairment in both domain general and social domain specific attention in ASD. Therefore, as well as being scarce, the findings comparing general or social domain specific disengagement or engagement issues in ASD are inconsistent as well.

There may, however, be methodological or sampling inconsistencies (e.g. the lack of control task, age and functioning of participants) that could explain the discordant findings of the previous research. One review of experimental publications examining attentional engagement and disengagement in ASD (Sacrey, Armstrong, Bryson, & Zwaigenbaum, 2014) attempted to address the issue of the lack of significant findings in some studies using a gap-overlap task. For example, the review suggested that individuals with ASD are slower to disengage when the interval between the presentation of the central and peripheral stimulus is short (<500 ms), but not long (>800 ms). If disengagement requires additional resources and time in ASD, indeed a shorter interval to do so would be more likely to expose such a delay. Therefore, the lack of differences in some studies (e.g. J. Fischer et al., 2014; Kawakubo et al., 2004; Mosconi et al., 2009) could be accounted for by a prolonged (> 1000 ms) inter-stimulus interval. Sacrey et al. (2014) also proposed that discordant findings could be explained by the diversity of the methods employed to determine saccadic reaction times. Indeed, a few of the previous studies used electrooculography (EOG; Kawakubo et al., 2004; Kawakubo et al., 2007; Kikuchi et al., 2010; Mosconi et al., 2009; van der Geest et al., 2001); some used image-based methods (Elsabbagh et al., 2009; Landry & Bryson, 2004), while others used infra-red oculography (Crippa et al., 2013; J. Fischer et al., 2014; Goldberg et al., 2002) to measure the saccadic latencies in the gap-overlap task. Yet, as previously discussed (see Chapter 2), methods of EOG or recording-based techniques cannot provide information about the point of regard and thus may be less precise when determining relevant saccades. Furthermore, EOG is a relatively intrusive method, which requires placement of electrodes on one's face (Hunnius, 2007), and thus may cause additional anxiety for persons with ASD. Hence, as inconsistencies in previous research may at least partly be explained by available measures and a lack of uniform design, additional research is necessary to examine whether these explanations are viable.

Aims

The two studies presented in the current chapter aim to expand previous knowledge on domain general and social domain specific attentional atypicalities in ASD by conducting a comprehensive examination of attentional engagement and disengagement of non-social and social stimuli in high-functioning adults with and without ASD. Firstly, a gap-overlap task (B. Fischer et al., 1997; Saslow, 1967) was utilized in order to directly compare the presence of domain general and social domain specific deficits in ASD. Similar to a previous study on children with ASD (J. Fischer et al., 2014), a typical gap-overlap task was modified in the current study to create three additional conditions to involve not only shifting attention from non-social to non-social, but also from non-social to social, from social to non-social, and from social to social, stimuli. This was done in order to determine whether any attentional orienting difficulties in ASD are specific to social stimuli. The comparison of trials where both stimuli are non-social to those involving social stimuli allowed us to determine the presence of domain general (i.e. deficits in all trials) or social domain specific (i.e. deficits in social trials) impairments in ASD. In contrast, impairments in general and the social domain would be supported if ASD participants experienced attentional shifting difficulties with all stimulus conditions, but they were more pronounced with social stimuli.

A second aim of the research described in the current study was to evaluate whether attentional deficits in ASD persist to, or possibly emerge, when ecological validity of stimuli used is increased. If attentional disengagement issues are indeed a pervasive characteristic of ASD, differences should also occur independent of stimulus complexity. Thus, Experiment 2 was conducted using relatively simple monochrome shapes as stimuli (i.e. a rectangle and a schematic face). Previous research indicates that individuals with ASD may respond to, for example, static graphical representations of social stimuli differently than to more socially realistic images (Riby & Hancock, 2008). Thus, Experiment 3 addressed the possibility that attentional disengagement atypicalities in ASD may be dependent on ecological validity by including colour photographs of houses (non-social) and faces (social) stimuli.

Also, as previously discussed, it has been suggested that other methodological differences may account for the non-significant findings of some previous studies using the gap-overlap task with ASD samples (Sacrey et al., 2014). Both of the current studies addressed these methodological inconsistencies through a carefully considered design. First, a short inter-stimulus interval (200 ms) suggested by B. Fischer et al. (1997) and fitting within Sacreys et al.'s (2014) proposed range was used in the current study. Secondly, given the abnormally elevated saccadic frequency found in individuals with ASD, even in the absence of a stimulus (Kemner, Verbaten, Cuperus, Camfferman, & van Engeland, 1998), accurate measures of saccadic latencies may be especially important. Therefore, an infra-red eye-tracking with the best available spatial and temporal resolution (Knox, 2004 cited in Brenner, Turner, & Müller, 2007) was used to record eye movements in the current study. It is also imperative to define saccades accurately, exclude directional errors, and anticipatory or late saccades (see B. Fischer et al., 1997). This is because blinks or other artefacts can disturb the signal such that a proper and timely identification of saccades is impossible. Due to technical limitations, such data screening was rarely available in the previous studies, but can be achieved with current technology. Additionally, previous studies (e.g. Kawakubo et al., 2007; Kikuchi et al., 2010; Landry & Bryson, 2004; van der Geest et al., 2001) often included only gap and overlap conditions and calculated *gap effect* as a difference between reaction times in those conditions. However, to control for participants' typical attentional performance the current study included a baseline condition, where the central stimulus disappeared at the same time as the peripheral appeared. In turn, a comparison between the performance in gap and baseline conditions was used to define the *gap effect* and a comparison between the baseline and overlap conditions represented the *overlap effect*. Inclusion of the baseline leads to a more accurate distinction between endogenous and exogenous disengagement processes and can provide additional insight into determining which of the processes is impaired in ASD.

Hypotheses

Based on the inconsistency in previous research, three possible outcomes were formed for atypical attentional orienting in ASD. Individuals with ASD will possibly differ from TD individuals either by: (a) taking longer to disengage in the overlap condition irrespective of whether the central stimulus was social or non-social (Hypothesis 1a: domain general deficit hypothesis); (b) showing faster disengaging from and slower attentional capture by a social stimulus, but responding similarly to TD participants when disengaging from a non-social to a non-social stimulus (Hypothesis 1b: social domain specific hypothesis); or (c) taking longer to disengage in the overlap condition, but especially in case of attentional capture by a new social stimulus (Hypothesis 1c: domain general and social domain specific deficit hypothesis). Secondly, saccadic latency differences were expected to occur across different conditions (Hypothesis 2). To be more precise, it was predicted that individuals in both groups will, in general, respond faster when the central stimulus disappears before the appearance of peripheral stimulus (i.e. exogenous disengagement) and slower when the stimuli overlap (i.e. endogenous disengagement) as seen in previous studies (e.g. Kawakubo et al., 2004; van der Geest et al., 2001). Furthermore, it was expected that attention capture and disengagement in TD individuals will be, respectively, faster towards and slower from the social stimulus in comparison to the non-social stimulus (Hypothesis 3). Finally, certain moderation effects were also expected. For instance, for TD individuals the social peripheral stimulus will produce faster saccadic latencies in the gap condition than corresponding non-social stimuli, whereas the social central stimuli will result in slower response rates in the overlap task (Hypothesis 4).

EXPERIMENT 2

Methods

Participants

All 53 participants (see Chapter 2) completed this experiment. Hence, the sample for Experiment 2 consisted of 27 high-functioning adults with ASD (14 females) and 26 TD adults (13 females).

Stimuli and Apparatus

Monochrome stimuli were presented on a 40 x 30 cm (1024 x 768 px) CRT monitor with a white background. The stimuli measured 1.33 cm by 1.88 cm (0.95^o by 1.34^o of visual angle)[3]. Stimulus was either a non-social (rectangle), or social (schematic face; Figure 4.1). Therefore, two types of stimuli were used to create four engagement/disengagement conditions based on stimulus pairs: social to non-social, non-social to non-social, social to social, and non-social to social. An interface of the E-prime stimulus presentation package (Psychology Software Tools Inc., 2012) and a Tobii x120 eye-tracker (Tobii Technology AB, 2010) was used to present the stimuli and record the data (see Chapter 2).

Procedure

The task was presented in a 3x2x2 within-subject design, where one variable was the condition (gap, baseline, or overlap), the other was the type of the central stimulus (social or non-social), and the third one was the type of peripheral stimulus

[3] The stimulus size used in the previous studies varied from 0.1^o for central stimulus and 0.2^o for peripheral stimulus (e.g. van der Geest et al., 2001) to 12^o for both (e.g. Elsabbagh et al., 2009). Yet, B. Fischer et al. (1997) recommended using a fixation stimulus of 0.1^o and the peripheral of 0.2^o in the original gap-overlap task with non-social stimuli. Thus, the current study aimed to not increase the stimulus size more than necessary, whilst also ensuring the social stimuli was not indistinguishable.

(social or non-social). The experiment encompassed 72 trials in total (6 per condition). Trial order was fully randomised to prevent subjects from predicting the upcoming stimulus. The task took around 15 min to complete.

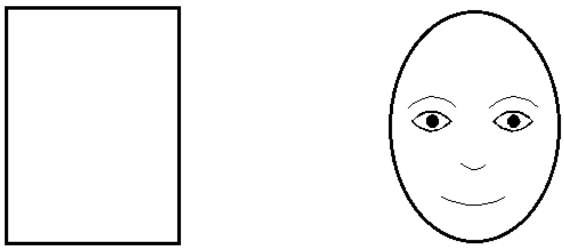

Figure 4.1. Enlarged stimuli used in the gap-overlap task. Non-social stimulus is presented on the left and social stimulus is presented on the right.

Each participant received on-screen and verbal instructions to look at the central stimulus and shift gaze to the peripheral stimulus as soon as it appeared. At the beginning of each trial a social or non-social central stimulus was presented in the middle of the screen. The peripheral social or non-social stimulus was then presented to the right or the left of the central stimulus for 1500 ms. In the baseline condition (Figure 4.2b), the central fixation disappeared at the same time as the peripheral stimulus appeared. In the gap condition (Figure 4.2a), on the other hand, the peripheral stimulus appeared 200 ms after the central fixation disappeared (exogenous disengagement), whilst in the overlap condition (Figure 4.2c) the peripheral stimulus appeared 200 ms before the central fixation disappeared (endogenous disengagement). After each trial the screen went blank for 200 ms before the next trial started. The peripheral stimulus was presented 7.13^{o} (10 cm) away from the central stimulus. To minimize the possibility of anticipating the timing of the peripheral stimulus onset, the interval of the central stimulus presentation was randomised (1500, 3000, or 4500 ms). An inter-stimulus interval of 200 ms was chosen in accordance with the protocol for the gap-overlap paradigm (B. Fischer et al., 1997).

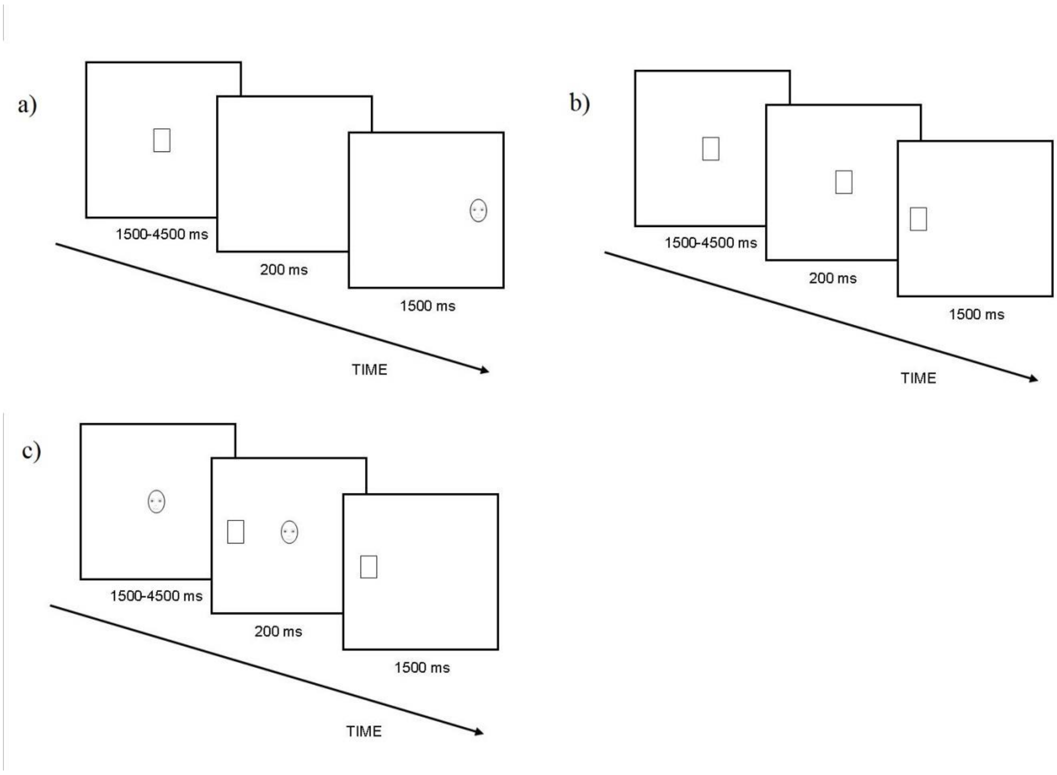

Figure 4.2. Schematic presentation of the sample stimulus sequence: a) gap condition for disengagement from non-social to social stimulus; b) baseline condition for disengagement from non-social to non-social stimulus; and c) overlap condition for disengagement from social to non-social stimulus.

Data Analysis

The sampled values of eye position were utilized to compute eye velocity, which were subsequently used to determine relevant saccadic latencies (Tobii Technology AB, 2010). A custom-built Matlab (The MathWorks Inc., 2013) script was then used to calculate the saccadic latencies in each trial. Saccades during stimulus presentation were detected by a saccadic velocity criterion of 20°/s and duration threshold of 15 ms (B. Fischer et al., 1997; B. Fischer & Weber, 1993). The start and the end of a saccade were defined as the time when average eye velocity passed the 20°/s mark. When tracking a light spot occurring in unpredictable positions, the typical mean saccadic latency is observed in a range of 180-250 ms (Saslow, 1967). B. Fischer et al. (1997) suggests that in gap-overlap tasks the saccadic response should occur in a range of 80-699 ms. Thus, anticipatory saccades (defined by RT < 80 ms), late responses (defined by RT > 699 ms), as well as saccades made in the wrong direction (direction errors) were excluded from analysis. Also, trials where the number of artefacts, due to blinks or head movements, made it impossible to determine the start and the end of saccadic responses were eliminated. The amount of incorrect or missing responses did not significantly differ between groups, $t(42.87) = -1.21$, $p = .233$. On average participants with ASD were missing data on 24% ($M = 17.00$, $SD = 22.14$) of trials, whilst TD participants were missing data on 15% ($M = 10.96$, $SD = 13.30$) of trials.

The Shapiro-Wilk normality test and graphical examination of residual values revealed that the saccadic latency data was slightly positively skewed in both participant groups, TD: $W = .92$, $p < .001$, ASD: $W = .90$, $p < .001$. Thus, a log-transformation with the basis of 10 was applied to the data. The graphical examination of log-transformed data confirmed that the distribution of residual values was sufficiently improved, although the Shapiro-Wilk normality test remained significant in both groups, *W*s = .99, *p*s < .001.

The saccadic latency data was then analysed using linear mixed-effect (multilevel) modelling with 2x3x2x2 design as an alternative to ANOVA (see Chapter 2). Participant information including their diagnostic details (ASD or TD) was modelled at the fourth level of multilevel analysis. Nested within each participant, trial type with the information of condition (gap, baseline, or overlap) was modelled at the third level. On the second level of the model, within trial information with central (social or non-social) and peripheral (social or non-social) stimulus type as predictors were modelled. Repeated measures of saccadic latencies for each trial were modelled at the first level, nested within each trial.

Results

The mean saccadic latencies in milliseconds of all three conditions per stimulus combination for both groups are shown in Table 4.1.

Table 4.1

Means (M) and Standard Deviations (SD) of Saccadic Latencies (ms) per Diagnosis and Condition

	ASD (*n* = 27)			TD (*n* = 26)		
	Gap	Baseline	Overlap	Gap	Baseline	Overlap
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Social to Social	150.44 (49.55)	174.85 (79.98)	204.47 (85.86)	143.77 (44.23)	165.22 (54.64)	204.24 (88.46)
Social to Non-Social	162.71 (56.61)	183.84 (90.51)	235.76 (103.21)	161.34 (57.56)	171.89 (66.52)	222.15 (99.59)
Non-Social to Social	152.15 (41.33)	172.98 (61.35)	204.26 (88.80)	153.49 (62.17)	165.09 (59.27)	192.29 (87.98)
Non-Social to Non-Social	158.90 (48.67)	177.15 (62.64)	232.02 (108.62)	156.28 (56.92)	173.25 (60.88)	221.20 (102.82)

Note. The average scores for each condition are presented here. For subsequent analyses, log-transformed data were used.

Results of the multilevel model building (Table 4.2) revealed that the main effect of diagnosis was not significant, $F(1,51) = 0.75$, $p = .391$, $\eta^2_p = .01$. In other words, participants in the ASD ($M = 184.63$, $SD = 81.27$) and TD ($M = 177.37$, $SD = 76.37$) groups did not differ on average saccadic latencies.

Nevertheless, the analysis revealed a significant main effect of condition on participants' saccadic reaction times (Table 4.2), $F(2,100) = 88.38$, $p < .001$, $\eta^2_p = .64$ (Figure 4.3). Further contrasts indicated that saccadic latencies were significantly shorter in the gap ($M = 154.81$, $SD = 52.85$) than baseline ($M = 172.82$, $SD = 67.68$)

condition. The overlap condition produced significantly longer saccadic latencies (*M* = 214.32, *SD* = 96.64) than baseline trials. The presence of both the gap and overlap effects were confirmed with post-hoc Tukey's HSD pairwise comparisons ($p < .05$).

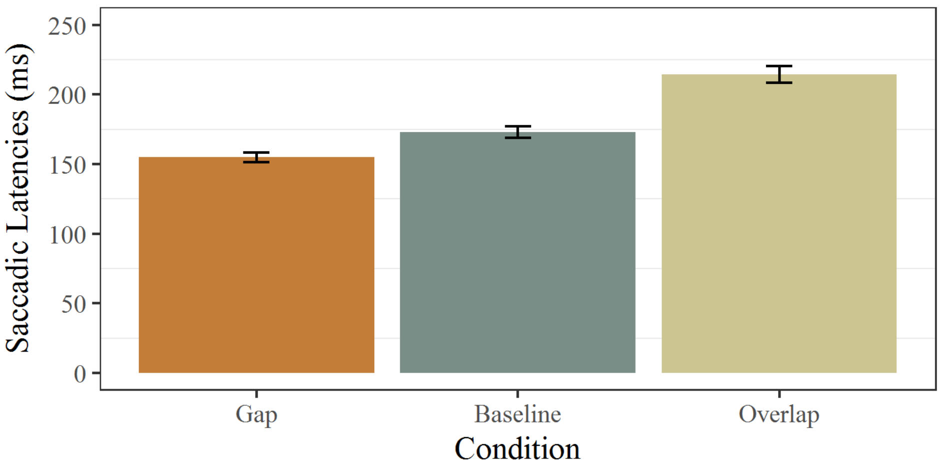

Figure 4.3. Mean saccadic latencies for each condition. Error bars represent 95% CI.

There was also a significant main effect of peripheral stimulus type on the participants' saccadic latencies (Table 4.2), $F(1,431) = 29.52$, $p < .001$, $\eta^2_p = .06$. Saccadic latencies towards a social stimulus (*M* = 173.84, *SD* = 72.44) were shorter than towards a non-social stimulus (*M* = 188.13, *SD* = 84.35; Figure 4.4). Yet, saccadic latencies from a social (*M* = 181.66, *SD* = 80.12) and non-social (*M* = 180.09, *SD* = 77.54) central stimulus were, in general, the same (Table 4.2), $F(1,431) = 0.06$, $p = .810$, $\eta^2_p < .01$. Similarly, the interaction between central and peripheral stimulus type on participants' saccadic latencies was further moderated by the condition (Figure 4.5), $F(2,431) = 3.91$, $p = .021$, $\eta^2_p = .02$. Indeed, only in the overlap condition saccadic latencies towards the social stimuli (*M* = 159.81, *SD* = 55.11) were significantly shorter than towards non-social stimuli (*M* = 201.38, *SD* = 87.70). Saccadic latencies to social and non-social stimuli in both the gap (social: *M* = 149.87, *SD* = 50.09; non-social: *M* = 159.81, *SD* = 55.11) and baseline (social: *M* = 169.37, *SD* = 64.15; non-social: *M* = 176.40, *SD* = 71.05) conditions were similar, however. These observations were confirmed with post-hoc Tukey's HSD pairwise comparisons ($p < .05$). None of the other main or interaction effects in the model yielded significance (Table 4.2).

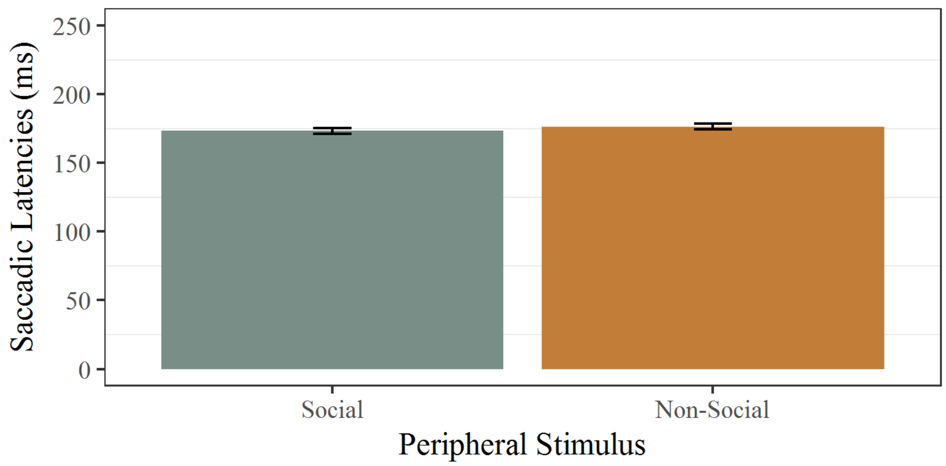

Figure 4.4. Mean saccadic latencies for each peripheral stimulus type. Error bars represent 95% CI.

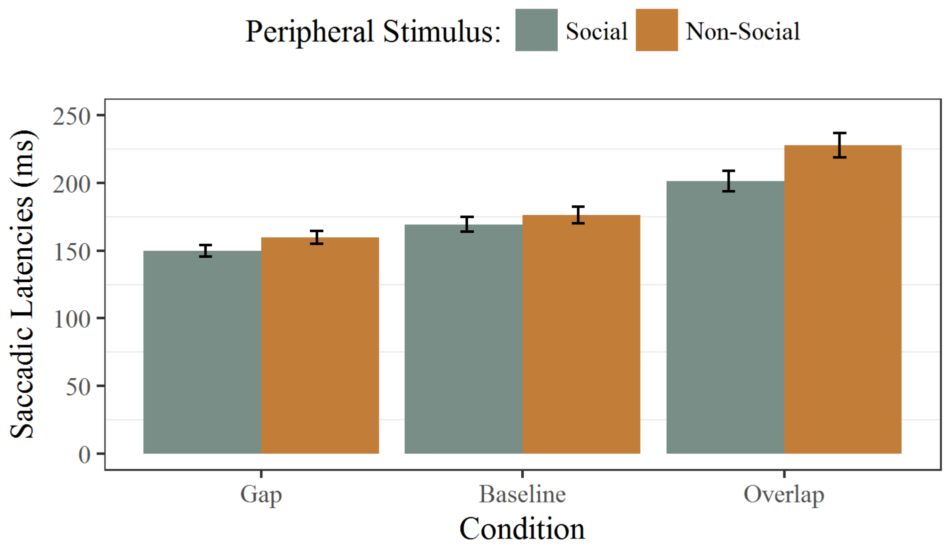

Figure 4.5. Mean saccadic latencies for each condition and peripheral stimulus type. Error bars represent 95% CI.

Table 4.2

Saccadic Latency Model Summary of the Main Effects and Interactions

	df	df_{error}	*F*	*p*	η^2_p
Condition	2	100	88.38	<.001	.64
Central stimulus	1	431	0.06	.810	<.01
Peripheral stimulus	1	431	29.52	<.001	.06
Diagnosis	1	51	0.75	.391	.01
Condition * Central stimulus	2	431	0.75	.475	<.01
Condition * Peripheral stimulus	2	431	3.91	.021	.02
Condition * Diagnosis	2	100	0.21	.808	<.01
Central stimulus * Peripheral stimulus	1	431	0.10	.747	<.01
Central stimulus * Diagnosis	1	431	0.02	.891	<.01
Peripheral stimulus * Diagnosis	1	431	<0.01	.946	<.01
Condition * Central stimulus * Peripheral stimulus	2	431	1.32	.269	.01
Condition * Central stimulus * Diagnosis	2	431	0.14	.870	<.01
Condition * Peripheral stimulus * Diagnosis	2	431	0.14	.868	<.01
Central stimulus * Peripheral stimulus * Diagnosis	1	431	0.34	.559	<.01
Condition * Central stimulus * Peripheral stimulus * Diagnosis	2	431	0.50	.607	<.01

Note. Condition = gap, baseline, or overlap; Central stimulus = social or non-social; Peripheral stimulus = social or non-social; Diagnosis = ASD or TD.

Experiment 2 Summary

Experiment 2 investigated attentional capture by and disengagement from simple non-social and social stimuli in high-functioning adults with ASD in comparison to TD individuals. Contrary to predictions, there was no difference in the pattern of saccadic latency responses between the ASD and TD participants. Instead, high-functioning adults with ASD performed very similarly to age and IQ matched TD adults. They responded faster in the gap than baseline condition and slower in the overlap than baseline condition. In particular, a gap between stimuli presentation facilitated participants' responses, whereas stimulus overlap slowed them. This indicates a lack of universal domain general attentional deficits in ASD, as both exogenous and endogenous disengagement appeared intact in the current study. In addition, none of the social domain specific attentional deficits were observed. Participants with ASD responded faster when shifting attention towards faces, just like TD individuals. Therefore, no support was found for either domain general or social domain specific attentional atypicalities in ASD when using simple monochrome drawings as stimuli in Experiment 2.

These findings are consistent with some previous research using non-social gap-overlap task on children (Crippa et al., 2013; Mosconi et al., 2009), adolescents (Goldberg et al., 2002), and adults (Kawakubo et al., 2004) with ASD. Yet, a few of the previous studies that found differences in ASD attentional disengagement used more complex stimuli: e.g. dynamic cartoons (Elsabbagh et al., 2009), illustrations (Kawakubo et al., 2007), dynamic patterns (Landry & Bryson, 2004), or photographs (Kikuchi et al., 2010). Thus, Experiment 3 was designed to replicate and further explore the findings of Experiment 2 by improving the ecological validity of the paradigm. This was achieved by utilizing photographs of faces and houses as social and non-social stimuli and introducing different background noise conditions.

EXPERIMENT 3

In general, the aim of Experiment 3 was to replicate and potentially expand on the findings of Experiment 2 using more ecologically valid photographic stimuli. As mentioned, it is possible that, for example, atypical social domain specific attentional capture or disengagement processes in ASD would not occur if the stimuli were not realistic enough to be perceived as socially relevant (see Riby & Hancock, 2009b). Therefore, the ecological validity of the paradigm was increased by using photographs of faces and houses rather than schematic representations as stimuli and by introducing background noise.

The ecological validity of the stimuli was increased in order to see whether such changes would induce group differences that were not present in Experiment 2. To allow a comprehensive comparison between the experiments the same hypotheses as those examined in Experiment 2 were raised for Experiment 3. To be precise, it was expected that with increased ecological validity of the stimulus individuals with ASD will: (a) exhibit domain general deficits (Hypothesis 1a); (b) show social domain specific atypicalities only (Hypothesis 1b); or (c) experience both domain general and social domain specific attentional shifting differences (Hypothesis 1c). It was also expected that Experiment 3 will replicate Experiment 2 by showing that individuals in both groups will, in general, respond faster in exogenous and slower in endogenous disengagement conditions (Hypothesis 2). It was also still expected that attention capture and disengagement in TD individuals will remain, respectively, faster towards and slower from a social stimulus in comparison to a non-social stimulus (Hypothesis 3). Despite the findings of Experiment 2, attentional capture by a social stimulus in TD individuals was expected to be faster than a non-social stimulus in the gap condition, whereas in the overlap condition disengagement from a social central stimulus was expected to be slower than a non-social stimulus (Hypothesis 4).

In addition to the previously raised main hypotheses, one of the overarching aims of the current thesis has been to investigate potential intersensory integration issues in ASD via the interference of background noise on visual attention (see Chapter 1). Thus, in Experiment 3 the possibility that the presence and intelligibility (low and high) of the background noise might affect attentional capture and disengagement processes was explored as well. To be precise, it was predicted that all participants will react more slowly in the background noise conditions compared to the no noise condition (Hypothesis 5a). It was further hypothesised that saccadic latencies will be even slower in the high-intelligibility noise (i.e. noise of students entering a room overlaid with speech) condition rather than the low-intelligibility noise (i.e. noise of students entering a room) (Hypothesis 5b). Additionally, interference by background noise was expected to be stronger for the participants with an ASD diagnosis (Hypothesis 6).

Methods

Participants

All 35 participants, who took part in the second testing phase (see Chapter 2), completed this experiment. Thus, the Experiment 3 sample included 18 high-functioning adults with ASD (8 females) and 17 TD adults (10 females), all of whom previously took part in Experiment 2.

Stimuli and Apparatus

The stimuli were presented on a 40 x 30 cm (1280 x 1024 px) CRT monitor with a white background. Photographs of two houses and two faces (one male and one female) were used as stimuli. Thus, the stimulus was either non-social (house), or social (face; Figure 4.6). Photographs of faces with neutral expressions from the NimStim facial stimulus set were used (Tottenham et al., 2009). Different stimuli were matched on colour and size, measured 2.97 cm by 2.78 cm (2.13^{o} by 2.00^{o}). Similarly to Experiment 2, two types of stimuli were again used to create four capture/disengagement conditions based on stimulus pairs: social to non-social, non-social to non-social, social to social, and non-social to social.

Figure 4.6. Enlarged example stimuli used in the gap-overlap task. Non-social stimulus is presented on the left and social stimulus is presented on the right.

In addition to visual stimuli, audio stimuli were used as distractors in Experiment 3. There were three noise conditions delivered via headphones: control (no noise), low-intelligibility noise, and high-intelligibility noise. The low-intelligibility track was an audio recording of students coming into the class, whilst the high-intelligibility track included the same background noise as a low-intelligibility track merged with somewhat intelligible speech (see Chapter 2). As in Experiment 2, a Tobii x120 eye-tracker placed below the monitor and interfaced with the E-prime stimulus presentation package was used to record participants' eye movements.

Procedure

The task was presented in a 3x2x2x3 within-subject design, where one independent variable was condition (gap, baseline, or overlap), the second one was central stimulus type (social or non-social), the third one was peripheral stimulus type (social or non-social), and the last was noise condition (no noise, low-intelligibility, or high-intelligibility). There were 12 trials per condition, which were presented in three separate noise-based blocks (144 trials each). Thus, each participant was presented with 432 trials in total. Both the order of the blocks and the trials within them were fully randomised to prevent fatigue effects and predictions of the upcoming stimulus. Each block took the participants around 15 min to complete.

Similarly to Experiment 2, participants first received on-screen and verbal instructions to look at the central stimulus and shift their gaze to the peripheral stimulus as soon as it appeared. At the beginning of each trial a social or non-social central stimulus was presented in the middle of the screen for 1500, 3000, or 4500 ms. The peripheral social or non-social stimulus was then presented 7.13^{o} (10 cm) to the right or to the left of the central stimulus for 699 ms. The inter-stimulus interval between the central and peripheral stimuli (200 ms, 0 ms, or -200 ms) again was varied to represent the different conditions (Figure 4.7).

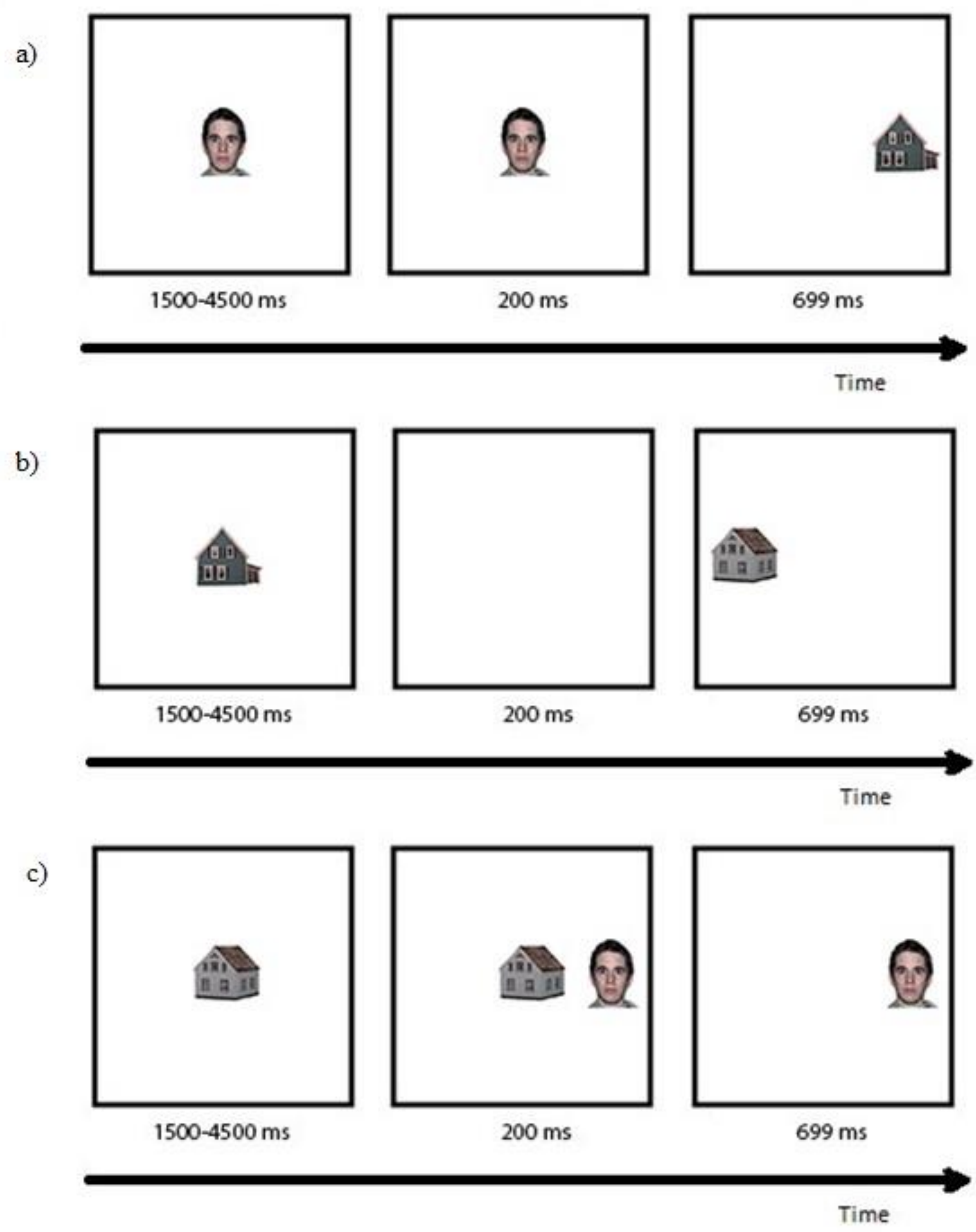

Figure 4.7. Schematic presentation of the sample stimulus sequence: a) baseline condition for disengagement from social to non-social stimulus; b) gap condition for disengagement from non-social to non-social stimulus; and c) overlap condition for disengagement from non-social to social stimulus.

Data Analysis

The same Matlab script and criteria, as in Experiment 2, was used to extract saccadic latencies for each trial in Experiment 3. On average participants with ASD were missing saccadic latency data for 39% (M = 168.50, SD = 95.27) of trials, whilst TD participants were inaccurate or missing data on 31% (M = 134.76, SD = 73.86) of trials. The amount of incorrect or missing responses did not significantly differ between groups, $t(33) = -1.17$, $p = .252$.

Due to the technical constraints of the Shapiro-Wilks normality test (i.e. not possible for a sample size over 5000), the Anderson-Darling normality test was applied to the Experiment 3 data, instead. In combination with the graphical examination of residual values, it showed that the saccadic latency data was positively skewed in both participant groups, TD: $A = 85.51$, $p < .001$, ASD: $A = 80.06$, $p < .001$. Thus, a log-transformation with the basis of 10 was applied to the data. The graphical examination of the log-transformed data confirmed that the distribution of residual values was sufficiently improved, although the normality test remained significant in both groups, TD: $A = 9.03$, $p < .001$, ASD: $A = 10.24$, $p < .001$.

The saccadic latency data was then analysed using a linear mixed-effect (multilevel) modelling with a 2x3x2x2x3 design as an alternative to ANOVA (see Chapter 2). Participant information including their diagnostic details (ASD or TD) was modelled at the fourth level of the multilevel analysis. Nested within each participant, trial type with the information on condition (gap, baseline, or overlap) and noise type (high-intelligibility, low-intelligibility, or no noise) were modelled at the third level. Within trial information with central (social or non-social) and peripheral (social or non-social) stimulus type as predictors were modelled at the second level. Repeated measures of saccadic latencies for each trial were then modelled at the first level, nested within each trial.

Results

The mean saccadic latencies of all three conditions per stimulus combination, noise type, and diagnosis for both groups are shown in Table 4.3. Results of the multilevel model building (Table 4.4) yielded a non-significant main effect of diagnosis, $F(1,33) = 2.60$, $p = .116$, $\eta^2_p = .07$. Thus, participants in the ASD (M = 182.47, SD = 78.93) and TD (M = 167.68, SD = 71.68) groups did not differ on average saccadic latencies. The main effect of noise type also did not reach significance, $F(2,264) = 1.48$, $p = .229$, $\eta^2_p = .01$. Therefore, given the presence of other interactions in the model, average fixation durations were similar when no noise (M = 174.69, SD = 79.96) was played or low- (M = 176.73, SD = 74.28) and high-intelligibility (M = 173.09, SD = 72.92) background noise was presented.

The analysis, nevertheless, showed a significant main effect of condition on participants' saccadic latency (Figure 4.8), $F(2,264) = 176.29$, $p < .001$, $\eta^2_p = .57$. Tukey HSD paired comparisons confirmed that saccadic latencies were significantly different ($p < .05$) in the overlap (M = 206.95, SD = 92.39) and the baseline (M = 161.57, SD = 55.00) conditions. The saccadic latencies in the gap condition (M = 149.57, SD = 54.02) were also significantly different from the saccadic latencies in both the baseline and overlap conditions ($p < .05$). Thus, both gap and overlap effects occurred.

Table 4.3

Means (M) and Standard Deviations (SD) of Saccadic Latencies (ms) per Diagnosis and Condition

	ASD (n = 18)			TD (n = 17)		
	Gap	Baseline	Overlap	Gap	Baseline	Overlap
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
High-Intelligibility Noise						
Social to Social	152.06 (52.04)	165.73 (45.62)	220.22 (88.89)	141.67 (51.26)	150.06 (51.53)	194.38 (83.77)
Social to Non-Social	164.42 (66.81)	169.82 (53.07)	214.77 (86.20)	145.69 (50.16)	164.66 (70.10)	207.79 (85.92)
Non-Social to Social	148.21 (62.75)	164.08 (64.42)	201.52 (95.98)	151.25 (47.38)	150.35 (39.07)	184.48 (80.85)
Non-Social to Non-Social	161.04 (65.04)	174.98 (67.82)	205.43 (83.94)	138.22 (33.04)	156.96 (55.34)	197.13 (88.96)
Low-Intelligibility Noise						
Social to Social	157.06 (69.58)	167.77 (55.03)	229.46 (87.40)	147.96 (56.28)	153.98 (43.86)	194.90 (82.21)
Social to Non-Social	156.85 (49.44)	176.38 (61.76)	229.22 (113.99)	146.97 (43.24)	154.60 (49.83)	188.05 (78.84)
Non-Social to Social	146.81 (41.98)	176.22 (62.96)	220.56 (93.14)	141.50 (39.27)	150.82 (44.54)	197.33 (80.78)
Non-Social to Non-Social	167.71 (66.34)	161.32 (48.03)	212.44 (92.36)	146.63 (36.05)	165.05 (55.12)	205.50 (88.74)
No Noise						
Social to Social	149.31 (66.92)	166.46 (53.35)	228.73 (97.74)	141.65 (45.76)	152.52 (40.37)	204.25 (102.85)
Social to Non-Social	149.35 (50.27)	171.05 (61.51)	218.73 (98.73)	141.59 (49.57)	157.74 (45.01)	205.89 (113.53)
Non-Social to Social	151.69 (56.26)	163.75 (58.74)	211.22 (95.06)	147.41 (74.15)	147.18 (51.34)	194.74 (88.65)
Non-Social to Non-Social	150.65 (46.41)	168.23 (65.54)	211.18 (89.20)	143.98 (43.33)	152.32 (52.68)	197.80 (100.25)

Note. The average scores for each condition are presented here. For subsequent analyses, log transformed data were used.

Table 4.4

Saccadic Latency Model Summary of the Main Effects and Interactions

	df	df_{error}	F	p	η^2_p
Noise type	2	264	1.48	.229	.01
Condition	2	264	176.29	<.001	.57
Central stimulus	1	877	3.46	.063	<.01
Peripheral stimulus	1	877	7.27	.007	.01
Diagnosis	1	33	2.60	.116	.07
Noise type * Diagnosis	2	264	0.75	.473	.01
Condition * Diagnosis	2	264	0.54	.585	<.01
Central stimulus * Diagnosis	1	877	3.49	.062	<.01
Peripheral stimulus * Diagnosis	1	877	0.79	.375	<.01
Noise type * Condition	4	264	0.20	.938	<.01
Noise type * Central stimulus	2	877	1.55	.212	<.01
Noise type * Peripheral stimulus	2	877	1.38	.252	<.01
Condition * Central stimulus	2	877	3.90	.021	.01
Condition * Peripheral stimulus	2	877	1.33	.265	<.01
Central stimulus * Peripheral stimulus	1	877	1.04	.308	<.01
Noise type * Condition * Diagnosis	4	264	0.10	.981	<.01

	df	df_{error}	F	p	η^2_p
Noise type * Central stimulus * Diagnosis	2	877	0.70	.497	<.01
Noise type * Peripheral stimulus * Diagnosis	2	877	0.07	.936	<.01
Condition * Central stimulus * Diagnosis	2	877	2.29	.102	.01
Condition * Peripheral stimulus * Diagnosis	2	877	6.13	.002	.01
Central stimulus * Peripheral stimulus * Diagnosis	1	877	0.70	.404	<.01
Noise type * Condition * Central stimulus	4	877	1.28	.276	.01
Noise type * Condition * Peripheral stimulus	4	877	1.41	.228	.01
Noise type * Central stimulus * Peripheral stimulus	2	877	0.91	.403	<.01
Condition * Central stimulus * Peripheral stimulus	2	877	1.17	.309	<.01
Noise type * Condition * Central stimulus * Diagnosis	4	877	1.28	.278	.01
Noise type * Condition * Peripheral stimulus * Diagnosis	4	877	0.86	.486	<.01
Noise type * Central stimulus * Peripheral stimulus * Diagnosis	2	877	3.08	.047	.01
Condition * Central stimulus * Peripheral stimulus * Diagnosis	2	877	0.52	.593	<.01
Noise type * Condition * Central stimulus * Peripheral stimulus	4	877	0.79	.532	<.01
Noise type * Condition * Central stimulus * Peripheral stimulus * Diagnosis	4	877	1.03	.389	<.01

Note. Noise type = no noise, low-intelligibility, or high-intelligibility; Condition = gap, baseline, or overlap; Central stimulus = social or non-social; Peripheral stimulus = social or non-social; Diagnosis = ASD or TD.

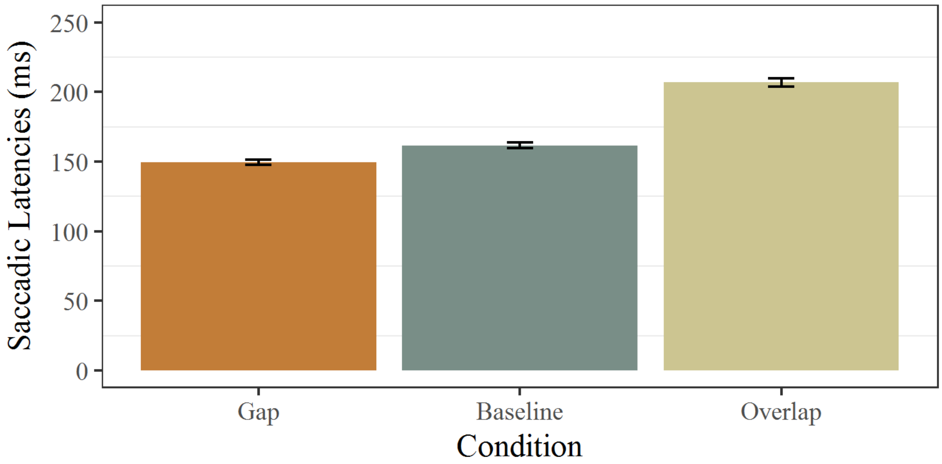

Figure 4.8. Mean saccadic latencies for each condition. Error bars represent 95%

Peripheral stimulus type also had a significant main effect on participants' saccadic latencies (Figure 4.9), $F(1,877) = 7.27$, $p = .007$, $\eta^2_p = .01$. Reactions towards a social stimulus ($M = 173.25$, $SD = 74.81$) were shorter than towards a non-social ($M = 176.49$, $SD = 76.45$) stimulus. Yet, the central stimulus type on its own was not a sufficient predictor to yield a significant main effect (Table 4.4), $F(1,877) = 3.46$, $p = .063$, $\eta^2_p < .01$.

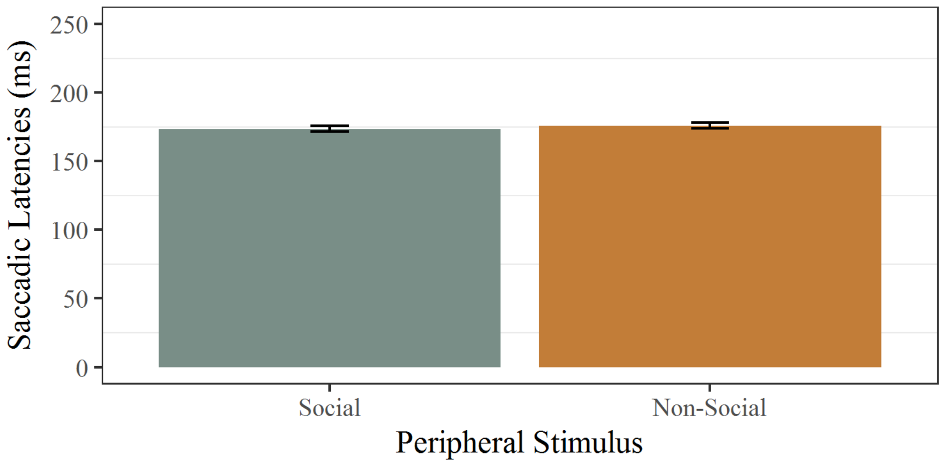

Figure 4.9. Mean saccadic latencies for each peripheral stimulus type. Error bars represent 95% CI.

There was, nevertheless, a two-way interaction effect between central stimulus type and condition of the trial (Figure 4.10), $F(2,877) = 3.90$, $p = .021$, $\eta^2_p = .01$. Least square comparisons based on Tukey HSD showed a significant difference between saccadic latencies in the overlap condition when disengaging attention from social ($M = 210.94$, $SD = 94.51$) stimuli in comparison to non-social ($M = 202.87$, $SD = 90.02$) stimuli ($p < .05$). However, there were no differences between saccadic latencies from social or non-social stimuli in the gap (social: $M = 149.47$, $SD = 55.09$; non-social: $M = 149.66$, $SD = 52.96$) or baseline (social: $M = 162.32$, $SD = 53.57$; non-social: $M = 160.84$, $SD = 56.38$) conditions ($p > .05$).

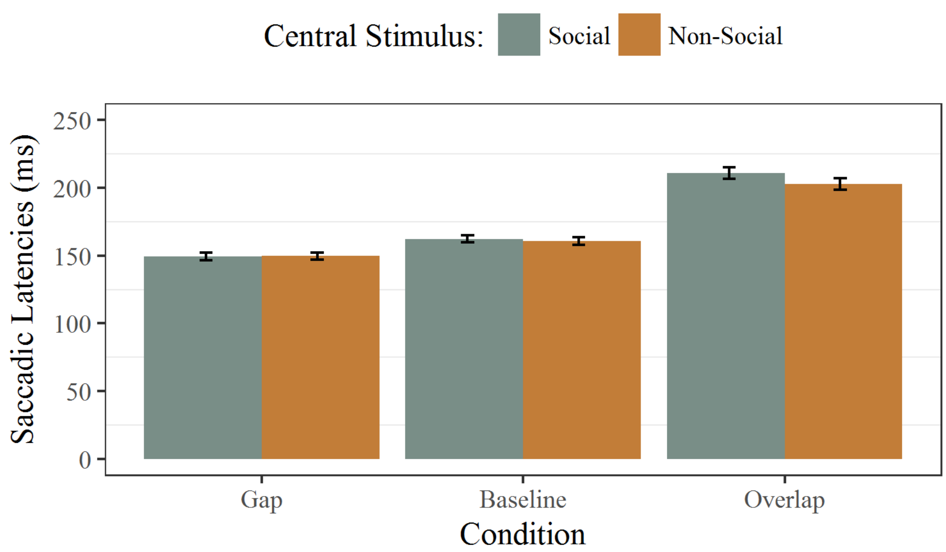

Figure 4.10. Mean saccadic latencies for each condition and central stimulus type. Error bars represent 95% CI.

The effect of peripheral stimulus type on participants' saccadic latencies was also further moderated by the condition and participants' diagnosis (Figure 4.11), $F(2,1141) = 3.54$, $p = .029$, $\eta^2_p = .01$. To be precise, the gap effect only occurred in TD participants when the peripheral stimulus was non-social (gap: $M = 143.87$, $SD = 42.96$; baseline: $M = 158.69$, $SD = 55.61$), but not when it was social (gap: $M = 145.34$, $SD = 53.27$; baseline: $M = 150.86$, $SD = 45.20$). For participants with ASD, however, the moderation of the gap effect was opposite, occurring when shifting attention towards social (gap: *M* = 150.90, *SD* = 59.10; baseline: *M* = 167.72, *SD* = 57.01), but not non-social information (gap: *M* = 158.73, *SD* = 58.53; baseline: *M* = 170.27, *SD* = 59.90). These observations were confirmed using Tukey HSD pairwise comparisons ($p < .05$). The post-hoc comparisons further confirmed that the overlap effect occurred in both groups independently from whether the peripheral stimulus was social (ASD overlap: *M* = 218.74, *SD* = 93.25; TD overlap: *M* = 194.92, *SD* = 86.68) or non-social (ASD overlap: *M* = 215.51, *SD* = 94.94; TD overlap: *M* = 200.30, *SD* = 92.95).

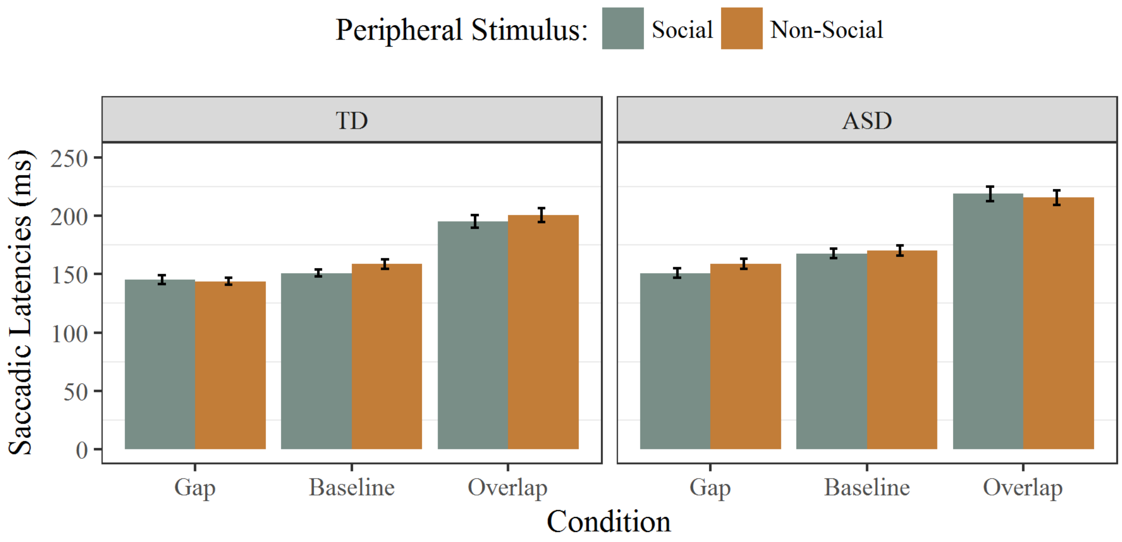

Figure 4.11. Mean saccadic latencies for each condition, peripheral stimulus type, and diagnosis. Error bars represent 95% CI.

Finally, there was a four-way interaction between the background noise presented, combination of the central and peripheral stimulus type, and participants' diagnosis (Figure 4.12), $F(2,877) = 3.08$, $p = .047$, $\eta^2_p = .01$. Tukey HSD corrected post-hoc comparisons were carried out to investigate the difference, yet they failed to reveal any significant differences between the estimated least square means ($p > .05$). None of the other main or interaction effects in the model yielded significance (Table 4.4).

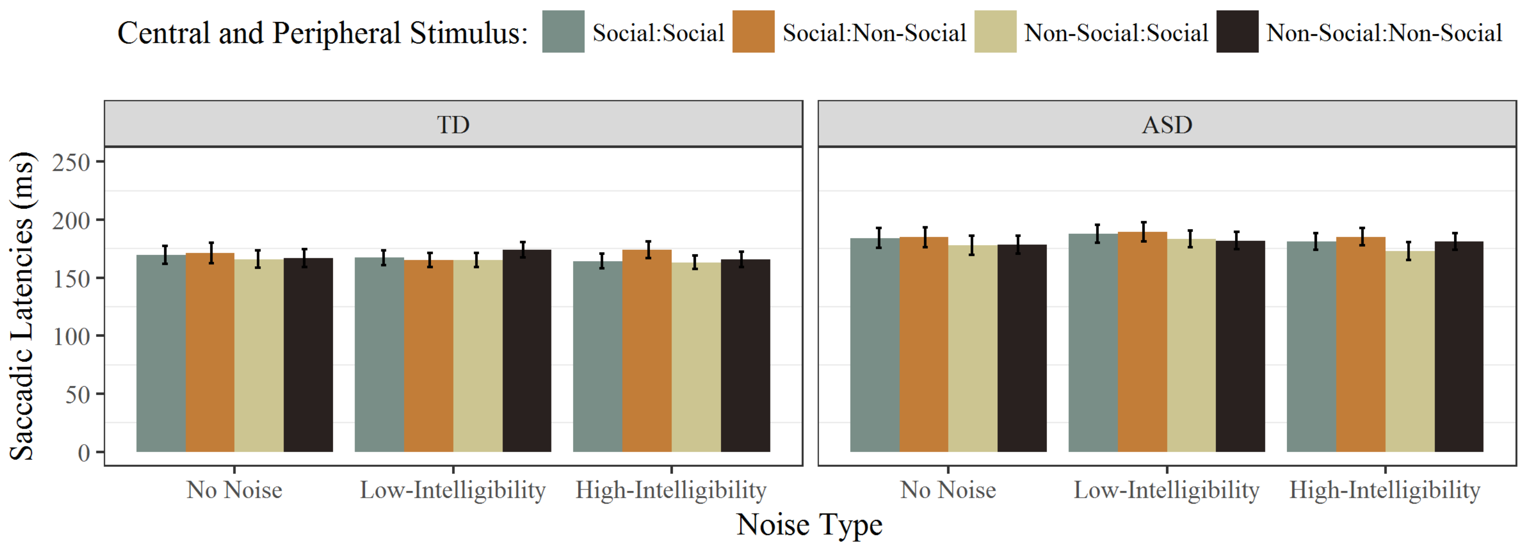

Figure 4.12. Mean saccadic latencies for each noise condition, central and peripheral stimulus type combination, and diagnosis. Error bars represent 95% CI.

Experiment 3 Summary

The aim of Experiment 3 was to replicate and expand on the findings of Experiment 2 by utilizing more ecologically valid stimuli. Some subtle domain general and social domain specific atypicalities in high-functioning adults with ASD have been observed. Yet, it differed from Hypothesis 1c, which predicted that individuals with ASD will take longer to disengage in the overlap condition, but especially so when shifting attention to a social stimulus. The diagnostic differences in the current study occurred only in the exogenous disengagement condition. To be precise, only individuals with ASD exhibited a facilitating gap effect in attentional capture by social stimuli, whilst TD participants did not. Regarding capture by non-social information the pattern was opposite with TD adults, but not those with ASD, benefiting from the gap between stimuli presentation. Hypothesis 2, however, was consistently supported across both experiments. As predicted, individuals in both groups responded faster when the central stimulus disappeared before the appearance of a peripheral stimulus and slower when the stimuli overlapped. It was found that overall stimulus type had a similar effect on both participants with and without ASD. Partially in line with Hypothesis 3, the appearance of a social rather than non-social stimulus as a new target, overall, facilitated attentional capture. Responses in both groups were slower if attention had to be shifted from a social, rather than non-social, stimulus. This was especially true, if that stimulus was still present on the screen when the new target stimulus appeared, as proposed in Hypothesis 4. Finally, the presence of different types of background noise had a marginal effect on participants' attentional shifting, which was moderated by diagnosis. This effect, however, was not strong enough to clearly provide support for either of the relevant hypotheses.

Discussion

These are the first studies using a modified gap-overlap task to comprehensively examine attentional capture by and disengagement from social and non-social stimuli in high-functioning adults with ASD. This was done in order to investigate whether domain general or social domain specific attentional shifting atypicalities are present in high-functioning adults with ASD. Moreover, the current study also aimed to evaluate whether attentional deficits in ASD persist to, or possibly emerge, when ecological validity of stimuli used is increased. This was achieved by examining individuals' saccadic latencies to relatively simple schematic stimuli (Experiment 2) and more ecologically valid photographic stimuli (Experiment 3).

In short, Experiment 2 failed to find any differences in the pattern of saccadic latency responses between ASD and TD participants. Therefore, neither Hypothesis 1a, nor 1b or 1c regarding domain general or social domain specific attentional deficits in ASD were supported. In line with Hypothesis 2, however, both adults with ASD and TD adults responded faster in the gap than baseline task and slower in the overlap than baseline task. Attention of both adults with ASD and TD adults was also captured by schematic faces faster than rectangles as predicted in Hypothesis 3. Contrary to Hypothesis 4, Experiment 2 revealed that attentional shifting to faces, rather than rectangles, had the biggest effect in the overlap condition where endogenous disengagement was required.

Experiment 3, in general, produced similar finding to Experiment 2. To be specific, just like in Experiment 2, neither Hypothesis 1a, 1b, nor 1c regarding domain general or social domain specific attentional deficits in ASD were directly supported. Furthermore, findings of Experiment 3 supported Hypothesis 2 by showing both gap (i.e. faster responses in the gap than baseline condition) and overlap (i.e. slower responses in the overlap than baseline condition) effects in adults with ASD and in TD individuals. Moreover, similarly to Experiment 2, Experiment 3 also supported Hypothesis 3 by showing that attention of both adults with ASD and TD adults was captured by photographs of faces faster than houses. Contrary to Experiment 2, but in line with Hypothesis 4, Experiment 3 revealed slower disengagement from faces, rather than houses, in the overlap condition, however. Additionally, the presence of different types of background noise, which was not examined in Experiment 2, had an effect on participants' attentional shifting in Experiment 3. This effect was moderated by participants' diagnosis. Yet, it was too marginal to provide any support for either Hypothesis 5 or Hypothesis 6.

It should be noted that the domain general and social domain specific deficit predictions that adults with ASD would take longer disengage in the overlap condition, but especially so when shifting attention to a social stimulus (Hypothesis 1c) was not supported by either Experiment 2 or 3 of the current study. Nevertheless, atypical social and non-social orienting in individuals with ASD, indeed, took place during the gap condition in Experiment 3 utilizing more ecologically valid photographs of faces and houses. Unexpectedly, only individuals with ASD, but not TD participants, experienced a gap effect in attention capture by social information in Experiment 3. At the same time, only TD individuals and not those with ASD exhibited a gap effect in attention capture by non-social information in Experiment 3. These findings suggest that a combination of subtle domain general and social domain specific atypicalities in attentional shifting of high-functioning adults with ASD occurred when using more ecologically valid stimuli, albeit not in the pattern predicted.

Attentional Shifting Differences Between Adults with ASD and TD Individuals

Domain general vs. social domain specific deficits. The main aim of the current study was to investigate whether domain general or social domain specific attentional deficits are present in adults with ASD in comparison to TD individuals. Both attentional disengagement and social capture were previously implicated in ASD (e.g. Courchesne et al., 1994; Dawson et al., 1998; van der Geest et al., 2001). Instead, in the current studies, high-functioning adults with ASD, for the most part, performed very similarly to age and IQ matched TD adults. They responded slower in the overlap than baseline condition and faster in the gap than baseline condition across the stimulus types. This indicates a lack of pervasive domain general attentional deficits in ASD, as in general both exogenous and endogenous disengagement appeared intact. In addition, pervasive social domain specific attentional difficulties also did not occur. Participants with ASD responded faster when shifting attention towards faces than non-social stimuli, just like matched controls. They also exhibited slower endogenous disengagement from photographs of faces rather than houses just like TD peers. These findings are consistent with some previous research using non-social gap-overlap task on children (Crippa et al., 2013; Mosconi et al., 2009), adolescents (Goldberg et al., 2002), and adults (Kawakubo et al., 2004) with ASD. They are also consistent with some research using a gap-overlap task to examine social orienting in children with ASD (J. Fischer et al., 2014).

Even though neither the domain general view, nor the social domain specific perspective was exclusively supported, current findings indicated more subtle differences in exogenous disengagement of individuals with ASD and TD. To be precise, TD adults experienced a gap effect only when orienting towards houses rather than faces, whereas adults with ASD exhibited the opposite pattern benefiting from exogenous disengagement when shifting attention towards social, but not non-social information. In other words, only for individuals with ASD attentional capture by social information was facilitated by the gap in stimulus presentation when more realistic photographs were used. One could speculate that TD individuals already experience a social bias when shifting attention towards a social stimulus that appears at the same time as the currently engaged information disappears, thus diminishing the facilitation effect of the increased inter-stimulus interval. Given that the difference between reaction times in gap and baseline conditions is usually smaller than the difference between overlap and baseline conditions (e.g. Goldberg et al., 2002); faster attentional shifting in the baseline condition could diminish the said gap effect. Yet, such an interpretation would also indicate that individuals with ASD may have a comparative bias towards non-social information, in turn, not benefiting from exogenously disengaged attention. The presence of a non-social bias in ASD has been previously proposed as a potential explanation for reduced social attention (e.g. Tager-Flusberg, 2010). Yet, participants with ASD just like those with TD exhibited an overall social bias rather than non-social bias in attention capture in both currently discussed experiments. Hence, a conclusive observation regarding a non-social bias in ASD cannot be currently made and should be further investigated in future studies.

Social bias. The overall bias towards social rather than non-social information, indeed, occurred in individuals with ASD and TD alike. It is not surprising that TD individuals responded faster when orienting towards faces rather than rectangles or houses. Fitting with previous literature (e.g. Botzel & Grusser, 1989), this confirms that socially salient stimuli draw one’s attention more than non-social stimuli. Yet, unexpectedly, adults with ASD also shifted attention to faces faster than houses. This partially contradicts the general view and previous research indicating that individuals with ASD orientate less to social stimuli (Klin et al., 2003; Riby & Hancock, 2008; Riby, Whittle, et al., 2012; Swettenham et al., 1998). In contrast to these previous studies we, however, did not measure the length of attentional engagement by social targets, in general, but rather how quickly attention was captured by it. Furthermore, to the knowledge of the current researcher, none of the studies to date explicitly compared exogenous disengagement from social and non-social stimuli in individuals with and without ASD. Thus, it is possible that even though individuals with ASD orient to novel social stimuli faster than non-social stimuli, they end up engaging with the social stimulus less. This might especially be true if faces are perceived as threatening or otherwise stress inducing. The faster capture by a social stimulus could then simply be a reflection of a threat-detection advantage (Krysko & Rutherford, 2009; Rosset et al., 2011).

Exogenous disengagement. Nevertheless, differently from TD individuals, adults with ASD benefited from forcefully disengaged attention when shifting attention to social information. This suggests that a typical social bias may not be present in adults with ASD and thus exogenous disengagement is required to facilitate attentional capture. This inability to easily disengage from a central stimulus when a new target appears supports the previously suggested concept of “sticky” attention (Landry & Bryson, 2004). Additionally, the current findings show that this “sticky” attention in adults with ASD, whilst stronger when engaged with complex social stimuli just like in TD individuals, presents itself via an obstruction of social bias. In other words, whilst TD individuals exhibit faster attentional capture by social information even if their attention is already engaged with it, a similar bias fails to occur in individuals with ASD unless their attention is already disengaged and freely available for capture. This effect only appeared when more realistic photographic stimuli were used rather than simple schematic images. Thus, it seems that attentional atypicalities in ASD depend on how ecologically valid or otherwise engaging the stimulus is, not only on whether it is social or not. Thus, current results are partially consistent with other studies finding slower disengagement in infant siblings of children with ASD (Elsabbagh et al., 2009), as well as children (Landry & Bryson, 2004; Todd et al., 2009) or adults (Kawakubo et al., 2007) with ASD. Yet, they contradict findings of faster disengagement from social stimuli in youth with ASD and TD (Kikuchi et al., 2010).

Endogenous disengagement. Interestingly, within the current sample, individuals with ASD exhibited typical endogenous orienting. Just like TD individuals, they took longer to disengage from photographs of faces than houses and were faster to orient to schematic faces than rectangles. This counters some previous studies in children (Landry & Bryson, 2004; Todd et al., 2009) and adults (Kawakubo et al., 2007) with ASD claiming that atypical orienting occurs due to delayed endogenous disengagement. Yet, it should be noted that these studies excluded participants' baseline disengagement, defining the gap effect as a difference in reaction time between the gap and overlap conditions. The lack of comparison to a baseline condition, however, makes it difficult to distinguish whether the group differences are occurring due to facilitation by exogenous disengagement or the lag in endogenous disengagement. Current findings including the comparison to a baseline condition, consequently, suggest that atypical attentional orienting in ASD may actually be better observed during exogenous disengagement.

General Attentional Processes

The current study also extends prior knowledge on general attentional processes in ASD and TD by confirming effects of exogenous and endogenous disengagement and differential effects of non-social and social stimuli on attentional capture and disengagement. Indeed, shorter saccadic latencies in the gap relative to the baseline condition confirm that the removal of the old stimulus facilitates exogenous orienting towards the new stimulus (B. Fischer & Weber, 1993). In other words, a person's attention is forcefully disengaged when the target is removed and thus it can be captured by a new target faster. Longer reaction times in the overlap condition show that it is harder to disengage from the stimulus which is still present when the new stimulus appears (endogenous orienting). The lack of external interference in stimulus removal requires an individual to intentionally disengage attention using internal, volitional, or central executive mechanisms (Posner, 1980). That in turn takes longer than exogenous disengagement. Both of these effects are consistent with findings of the previous studies (e.g. Hood & Atkinson, 1993; Kopecz, 1995). Yet, the current study demonstrates that these effects occur in adults regardless of whether social stimuli are used or the presence of an ASD diagnosis.

Both participants with ASD and TD also responded slower when shifting attention from faces rather than houses. This also fits with previous literature indicating that social stimuli retain one's attention (e.g. Bindemann, Burton, Hooge, Jenkins, & de Haan, 2005). It is not surprising that it would take longer to disengage one's attention from a face. However, the absence of this effect in Experiment 2 suggests that the target has to be realistic or complex enough for such an effect to occur. Furthermore, the overlap effect was stronger when shifting attention from faces and weaker when shifting attention towards them. The latter was true for all participants in the experiment using simple stimuli and for TD participants when using photographic images as stimuli. It seems intuitive that endogenous rather than exogenous orienting would be more obviously affected by the social bias. After all, as attention is already disengaged by the time that the new target stimulus appears in the gap condition, it is readily available to be captured by the new stimulus independent of its type. Thus, these findings further support the importance of ecological validity in attentional orienting.

Effects of Background Noise

Background noise had a marginal effect on the speed of attentional disengagement and capture, which was moderated by diagnosis. Yet, neither further analysis, nor graphical examination presented a clear pattern. Ultimately, it is the combination of task demands and the environmental stimulations that determines the extent to which the person's performance might be affected (Hancock & Warm, 1989). Given that gap-overlap tasks demand rudimentary attentional responses rather than higher order cognition, they may thus be less susceptible to such environmental influences as background noise. Indeed, in their meta-analysis Szalma and Hancock (2011) concluded that the detrimental effects of noise are stronger in psychomotor and communication tasks rather than perceptual or attention tasks. Furthermore, the current study focused on ecological validity and thus utilized a type of noise that is often encountered in an everyday environment. This was achieved by using a recording of students gathering into the room for the low-intelligibility condition and then overlaying it with speech for the high-intelligibility condition. It is possible that adults in the current study have already learned to adapt to the distracting nature of such noises due to previous exposure or training. If a different type of noise (e.g. shorter and more intense noise recordings presented intermittently; Szalma & Hancock, 2011) was used, more pronounced effects may been observed.

Limitations and Future Directions

The current study has several strengths such as the inclusion of a baseline condition to control for participants' typical responses, careful data screening with removal of various artefacts (e.g. anticipatory saccades and directional errors), and a novel well controlled design. It does, however, have limitations. First, the sample used was relatively small. Therefore, some weaker effects may have failed to manifest themselves due to the lack of power. Multilevel modelling does not allow for simple power calculations and existent techniques often yield very inconsistent results (Field et al., 2012). Yet, Kreft and de Leeuw (1998) suggest that at least 20 cases at the highest level are necessary for sufficient power, which is the case for both of the experiments in this study. Also, previous studies finding attentional capture or disengagement deficits in ASD commonly utilized similar or even smaller sample sizes (see Sacrey et al., 2014). Yet, small power could explain the lack of significance in post-hoc tests, indicating that the noise effects seen in Experiment 3 were, indeed, weak. Thus, future studies should aim to utilize larger samples in order for the weaker effects to emerge.

Secondly, characteristics of the sample used in current experiments make a comparison with previous studies, as well as the generalisation of findings, uncertain. Indeed, the majority of the previous studies examined either younger (Elsabbagh et al., 2009; Goldberg et al., 2002; Kikuchi et al., 2010; Landry & Bryson, 2004; Todd et al., 2009; van der Geest et al., 2001) or lower functioning individuals (Kawakubo et al., 2007), whilst the current sample included only high-functioning adults. Some previous studies examining auditory abnormalities in high-functioning adults with ASD have also failed to uncover expected group differences (Mayer & Heaton, 2014), yet demonstrated a different path of underlying mechanisms including age and sensory symptomology influencing performance. This could offer an alternative explanation to why attentional atypicalities seen in previous studies (e.g. Elsabbagh et al., 2009; Kawakubo et al., 2007; Kikuchi et al., 2010; Landry & Bryson, 2004; Todd et al., 2009) were not present in the current sample when relatively simple stimuli were used. After all, the severity of some symptoms in ASD generally decreases in high-functioning individuals and increases in low-functioning individuals as they grow older (see Levy & Perry, 2011). It is possible that high-functioning individuals with ASD have a different developmental trajectory which allows them to deal with increasingly higher cognitive load as they mature and, subsequently, in some conditions shift attention faster (Mayer, Hannent, & Heaton, 2014). Therefore, it is possible that the current findings would have been different if younger or lower functioning individuals were included. Yet, given that ASD is a pervasive developmental disorder, its core deficits should, to some degree, persist across development and symptom severity.

Conclusion

Participants with ASD exhibited intact exogenous and endogenous disengagement, slower disengagement from faces, and faster social capture similarly to controls. Thus, results of the current study could not be explained by either a domain general or social domain specific view only. Instead, evidence for a combination of subtle domain general and social domain specific impairments emerged. Surprisingly, exogenous disengagement of attention facilitated social capture only in high-functioning adults with ASD, but not TD individuals. The opposite pattern was observed in exogenous capture by non-social information. Yet, this occurred only when more ecologically valid stimuli were used. Therefore, the current studies partially support the presence of “sticky attention” in ASD and suggest an obstruction of social orienting. However, they challenge the belief that either a domain general or social domain specific view can solely account for attentional disengagement in ASD. They also weaken the prevailing notion that attentional difficulties are pervasive by showing their dependence on ecological validity of the stimuli used.

Albeit findings of Experiment 2 and Experiment 3 in the current chapter were relatively consistent, diagnosis-based differences occurred only in Experiment 3. This finding supports the notion that ecological validity of the stimulus used is imperative for atypical social attention in ASD to occur. Nevertheless, it should be acknowledged that the group differences observed in Experiment 3 were very subtle. Experiment 4 described in Chapter 5, thus, will investigate attentional capture and disengagement by social information further by utilizing even more ecologically valid photographs of naturalistic scenes.

CHAPTER 5

ENGAGEMENT TO AND DISENGAGEMENT FROM SOCIAL INFORMATION OF HIGH-FUNCTIONING ADULTS WITH ASD IN NATURALISTIC PHOTOGRAPHS OF SCENES

Summary

Delayed social orienting or slower attentional disengagement could be underlying atypical attention to social information often seen in individuals with ASD (e.g. Courchesne et al., 1994). Most of the eye-tracking paradigms distinguishing between attentional capture and disengagement utilize simple stimuli in isolation (e.g. van der Geest et al., 2001). Yet, information is rarely encountered on its own in in everyday life. Experiment 4 aimed to bridge this gap by examining attention shifting in photographs of complex, naturalistic scenes. Manipulating the location of social information (i.e. a human figure) in photographs allowed distinguishing between attentional engagement with (i.e. proportional dwell time), attention capture by (i.e. time to first fixation on off-centre located figure), and attentional disengagement from (i.e. time to first fixation away from centrally located figure) social information. Data was collected from 18 high-functioning adults with ASD and 17 TD adults. Participants with ASD spent proportionally less time than TD participants viewing social information in the scenes. Yet, the groups did not differ on speed of either social attentional capture, or disengagement. These findings imply that adults with ASD look at, and away from, social information just as fast as TD adults. The pattern of missing data, however, suggests that a lack of engagement with some of the social information, rather than the speed of attentional mechanisms, may play a role in atypical social attention in ASD. The effects of the presence and intelligibility of background noise on these processes are also discussed.

Introduction

Research shows that individuals with ASD view social stimuli, and faces in particular, less than TD individuals (Klin et al., 2003; Riby & Hancock, 2008, 2009a). Individuals with typical development exhibit attentional bias towards socially relevant information from birth (Farroni et al., 2005). Whereas infants with ASD tend to shift their gaze between two objects, rather than people more often, compared to TD infants (Swettenham et al., 1998). Children with ASD also appear to be less distracted by faces than TD children (Riby, Brown, Jones, & Hanley, 2012). This has led some researchers to suggest that the lack of attentional bias to socially relevant information may reflect atypical attention mechanisms with difficulty in attentional disengagement.

Studies examining attentional disengagement and social capture (e.g. J. Fischer et al., 2014), however, have mostly utilized paradigms with relatively simple stimuli in isolation (see Chapter 4). This is a useful approach allowing one to better examine the influence that a certain stimulus or manipulation has without interference from uncontrolled background information. However, in everyday life one rarely encounters stimuli in isolation. Furthermore, researchers argue that individuals with ASD may respond to, for example, static graphical representations of social stimuli differently than to more socially realistic images (Riby & Hancock, 2008). Indeed, when utilizing a gap-overlap paradigm in Chapter 4, it was found that using photographic stimuli instead of simple schematic stimuli yielded differential diagnostic effects. To be precise, exogenous disengagement of attention resulted in the facilitation of attention capture by photographs of faces for high-functioning adults with ASD, but not TD individuals. These group differences observed in Chapter 4 were subtle when using more realistic stimuli (i.e. photographs of faces) and not present at all when using less ecologically valid stimuli (i.e. schematic faces). Therefore, even more ecologically valid stimuli (e.g. photographs of scenes rather than faces in isolation) may be necessary for atypical attentional disengagement in general and/or social orienting more specifically to emerge.

Several studies have previously compared participants with and without ASD on the speed of first fixation to socially relevant information in naturalistic scenes. For example, Freeth et al. (2010) showed that high-functioning adolescents with ASD take longer to fixate on faces than TD adolescents. Lower functioning children and adolescents with ASD, also, took longer than matched controls to detect faces embedded within scenes and faces in scrambled pictures (Riby & Hancock, 2009a). These findings support the claim that shorter social viewing in ASD (e.g. Klin et al., 2002b) could stem from delayed attentional capture by social information. Yet, only the study by Freeth et al. (2010) ensured that social information would not be appearing at the centre of the screen. If social information is presented at the initial point of fixation, no capture of attention from elsewhere is required or can be measured. Furthermore, research shows that foveal focus is automatically drawn to the centre of an image, where the fixation point is usually placed (Tatler, 2007). Thus, if social information is also presented centrally, it may be hard to differentiate whether one's attention is drawn to the centre of the image by the socialness of the information presented, the confounding effect of the fixation cross, or simply lower order processing.

Williams et al. (2013) were the first to devise a paradigm using eye-tracking to distinguish between the processes of attentional capture and disengagement in naturalistic scenes. They achieved this by manipulating the location of socially relevant information across naturalistic, although relatively high in valence and arousal, scenes. Participants' gaze can be guided to the centre of the screen via the use of a fixation cross prior to the stimulus presentation. To measure attentional capture, the fixation cross then can be followed up with a scene with off-centre located social information. Time taken to fixate on the social information can be used as a representation of the time taken for attention to be captured by it. Yet, to measure attentional disengagement from social information, the fixation cross should be followed up by a scene with centrally located social information. That would force participants' attention to be automatically (i.e. exogenously) captured by the social information. Therefore, time taken to shift attention away from the area representing social information would indicate how long it took one to disengage attention before the rest of the scene could be explored (Williams et al., 2013). Such a paradigm is, indeed, unable to provide fair comparisons between attentional shifting to and from social and non-social information due to the lack of an equivalent measure for attentional capture by and disengagement from non-social information. Nevertheless, it can offer an interesting insight into how social information in context captures or holds attention in different groups of people. This is important because research showing reduced attention in ASD often comes from different paradigms than research examining attentional disengagement (see Chapter 4). Therefore, such a paradigm offers insight into whether attentional capture and disengagement atypicalities do indeed occur alongside reduced social attention in naturalistic scenes.

Williams et al. (2013) applied their paradigm to a study investigating participants with Williams and fragile X syndromes in comparison to matched controls. They investigated participants' attentional capture by, disengagement from, and general engagement by, social information in the scene and found that age matched controls oriented to social information faster than either clinical group. Yet, participants with fragile X syndrome disengaged from social information faster than participants with Williams syndrome and chronological or mental age matched controls. Participants with Williams syndrome were the ones who spent most time engaged with centrally located social information in comparison with other groups in the study. In addition to furthering the understanding of attentional atypicalities in both fragile X and Williams syndrome, the findings of Williams et al. (2013) also show that manipulating the location of socially relevant information across scenes can help to distinguish between different attentional processes. The current study aimed to further utilize such a manipulation by being the first to examine attentional capture by and attentional disengagement from naturalistic social information in high-functioning adults with ASD.

Aims

Chapter 4 investigated how ASD and TD participants differed in exogenous and endogenous attentional disengagement from and to social and non-social stimuli in isolation. Thus, the current chapter aimed to further investigate whether attention shifting mechanisms may be underlying atypical attention to social information often seen in ASD samples using naturalistic social scenes (e.g. Klin et al., 2003). This was achieved by manipulating the location of socially salient information, faces and bodies, in natural scenes. A paradigm introduced by Williams et al. (2013), in combination with eye-tracking technology, allows measuring the extent of engagement with socially relevant information in proportion to the rest of the picture, in addition to attention capture by and disengagement from social information within the scene. Hence, the current study aimed to expand on the processes investigated in the experiments discussed in Chapter 4 by increasing the ecological validity of the stimuli through the use of naturalistic scenes.

Additionally, the current study also aimed to further investigate potential intersensory integration difficulties and/or enhanced perceptual load during attentional shifting processes in ASD. In Chapter 4, possibly due to the low perceptual and cognitive demands of the gap-overlap task, the presence of background noise had a minor effect on participants' attentional shifting. The likely explanation is that sufficient cognitive control resources were available to supress the distraction stimulus to an extent (Lavie, 1995). Yet, the higher ecological validity of the stimulus often means a higher perceptual load within the task. Indeed, Bahrick and Todd (2012) proposed that complex and noisy environments, in particular, may be detrimental for capture and disengagement of attention in ASD due to disturbances in intercessory processing in ASD (see Chapter 1). It remains unclear, however, whether task irrelevant background noise does, indeed, have any effect on such rudimentary processes as attentional capture and disengagement and, if so, under what conditions that occurs.

Hypotheses

Both of the experiments in Chapter 4 examined exogenous and endogenous disengagement and capture from and to both social and non-social information. In contrast, Experiment 4 described in the current chapter focused on overall general engagement and more endogenous attentional shifting processes pertaining primarily to social information. In line with previous studies (e.g. Klin et al., 2002b), it was hypothesised that individuals with ASD will show less attentional engagement with social information than TD individuals (Hypothesis 1). Although not observed in Chapter 4, other previous studies indicate that individuals with ASD may orient to social information slower than TD individuals (Freeth et al., 2010; Riby & Hancock, 2008). Therefore, in this experiment, it was expected that social information will capture the attention of ASD individuals slower than TD (Hypothesis 2). In other studies (e.g. Landry & Bryson, 2004), individuals with ASD, to a degree, exhibited ‘sticky attention’ emerging as delayed disengagement. Therefore, it was predicted that individuals with ASD will take longer to disengage from centrally located social information than TD individuals (Hypothesis 3).

Due to the lack of previous empirical research on how the presence and/or intelligibility of the background noise may affect attentional capture, disengagement, and general engagement per se, no a priori hypotheses were formed for each attentional process. However, it was hypothesised that background noise will affect group performances to a different extent (Hypothesis 4). To be precise, it was expected that participants with ASD will be less susceptible than TD participants to the interference of the high-intelligibility noise condition in comparison to the low-intelligibility noise condition. This was posited due to the previous findings showing that individuals with ASD have difficulties perceiving speech if presented in the background noise (e.g. Alcántara et al., 2004)

EXPERIMENT 4

Methods

Participants

All 35 participants who took part in a second testing phase (see Chapter 2) completed this experiment. Thus, the sample for Experiment 4 consisted of 18 high-functioning adults with ASD (8 females) and 17 TD adults (10 females).

Stimuli and Apparatus

Stimuli were presented on a 40 x 30 cm (1280 x 1024 px) CRT monitor with a grey background. Target stimuli included 24 photographs of scenes with one person in each either working or studying in a naturalistic environment (Figure 5.1 and Figure 5.2). All these photographs were selected from the public domain. Distractor stimuli included 15 photographs of scenes with more than one person in each, also either working or studying in a natural environment. All images were matched on their colour scheme and average luminosity (R = 175, G = 170, B = 170), as well as presented at a standard size with a width of 29.45 cm (21.02^{o}) and height of 18.36 cm (13.22^{o}). Target pictures were assigned to two conditions: centrally located social stimuli (i.e. person's face located within 1^{o} of the visual angle from the centre of the image) or off-centre located social stimuli (i.e. person's face located further than 1^{o} of the visual angle away from the centre of the image; Williams et al., 2013). Six of the off-centre located set had a face on the left side of the picture and the other six had the face on the right side of the image.

Similarly to Experiment 3 described in Chapter 4, audio stimuli were used as distractors. There were three noise conditions: no noise, low-intelligibility noise, and high-intelligibility noise (see Chapter 2). As in the previous experiments, a Tobii x120 eye-tracker placed below the monitor and interfaced with the E-prime stimulus presentation package was used to record participants' eye movements.

Figure 5.1. Example stimulus of the disengagement trials with centrally located social information. Adapted from "Businesswoman Sitting at Her Desk Using the Phone and Writing in a Notepad" by Digital Vision, 2008. In the public domain.

Figure 5.2. Example stimuli of capture trials with off-centre located social information. Adapted from [Untitled image] by Chris Schmidt, 2008. In the public domain.

Procedure

The experiment encompassed 39 trials in total, split into three noise-based blocks (no noise, low-intelligibility noise, and high-intelligibility noise). Each block included: four trials with centrally located social information, four trials with off-centre located social information (two with social information appearing on the left and two on the right), and five trials with distractor images. The order of the blocks and trials within them were both fully randomised.

Each participant received on-screen and verbal instructions to focus on the fixation cross, when present, and then simply look at the photograph appearing after it. Each trial included a fixation cross appearing at the centre of the screen for 1000 ms followed by a target or distraction image presented in the centre of the screen for 10000 ms (c.f. Williams et al., 2013). The experiment took around 10 min to complete.

Data Analysis

The 'Draw Polygon' function in Tobii Studio 3.3.1 was utilized to select relevant areas of interest (AOI; Figure 5.3). For each target stimulus, social and non-social AOIs were defined. The former encompassed all the body parts within a scene, whereas the latter included the rest of the scene (c.f. Fletcher-Watson et al., 2009). Three different types of eye-tracking data were extracted using Tobii Studio as measures of general attentional engagement, attention capture, and attentional disengagement (see below). This data was further analysed using linear mixed-effect (multilevel) modelling as an alternative to ANOVA (see Chapter 2).

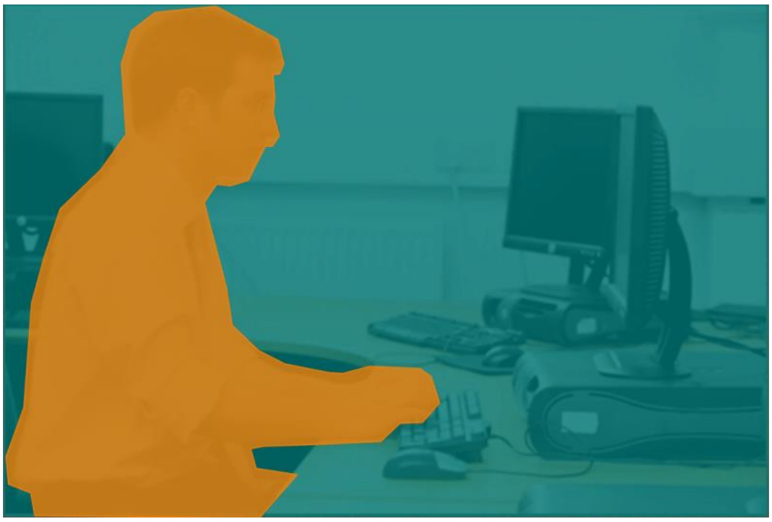

Figure 5.3. Example definition of areas of interest: social (orange) and non-social (green).

General attentional engagement. A proportional dwell time was calculated for both centrally and off-centre located social AOIs as a representation of general attentional engagement with the social stimulus. This measure was devised by dividing visit duration (i.e. dwell time) on a social AOI by the overall visit duration on the stimulus. This way, the final measure represented how much attention was paid to social parts of the scene in relation to how much attention was paid to the scene overall (Williams et al., 2013).

The Shapiro-Wilk normality test and graphical examination of residual values was used to evaluate the violation of normality assumption. The graphical distribution revealed that the proportional dwell time data was sufficiently normally distributed in both participant groups, even though the normality test was significant, TD: $W = .99$, $p = .064$, ASD: $W = .96$, $p < .001$. No transformation was necessary, and thus the raw data could be used for the analysis.

Multilevel modelling with a 2x2x3 design was used. Participants and their diagnostic information (ASD or TD) were modelled at the third level. Nested within each participant, trial type with information on social stimulus location (centre or off-centre) and noise condition (no noise, low-intelligibility, or high-intelligibility) was modelled at the second level. Raw proportional dwell time per stimulus was modelled at the first level, nested within each trial.

Attention capture. Time to first fixation to a social AOI was extracted for the off-centre located social stimuli as a representation of attention capture (Williams et al., 2013). This measure represented how the participant oriented towards the social stimulus.

The Shapiro-Wilk normality test and graphical examination of residual values revealed that the attention capture data was positively skewed in both participant groups, TD: $W = .72$, $p < .001$, ASD: $W = .73$, $p < .001$. Thus, a log-transformation with the basis of 10 was applied to the data. The graphical examination of the log-transformed data confirmed that the distribution of residual values was sufficiently improved, although the Shapiro-Wilk normality test remained significant in both groups, TD: $W = .89$, $p < .001$, ASD: $W = .93$, $p < .001$

Multilevel modelling with a 2x3 design was used to analyse the attention capture data. Again, participants and their diagnostic information (ASD or TD) were modelled at the third level. Then trial type with information on noise condition (no noise, low-intelligibility, or high-intelligibility) was modelled at the second level. Nested within each trial, log-transformed time to first fixation data was modelled at the first level.

Attentional disengagement. Time to first fixation to a non-social AOI was extracted for the centrally located social stimuli as a representation of attentional disengagement. Each stimulus was preceded by the fixation cross, thus participants' gaze automatically landed on the socially relevant information once the stimulus appeared. Consequently, the first fixation outside the social AOI (i.e. on non-social

AOI) was used as an indication of attentional disengagement. However, it is plausible that the person would not be looking at the screen or the fixation cross, despite the instructions, when the image appeared. Thus, to ensure that the data was representative of disengagement from the social stimulus, only the time to first fixation on non-social information since the first fixation on social information was included in the analysis. This allowed for a more representative measure of attentional disengagement from the social AOI.

The attentional disengagement data was also positively skewed in both participant groups based on the Shapiro-Wilk normality test and graphical examination of residual values, TD: $W = .77$, $p < .001$, ASD: $W = .76$, $p < .001$. Thus, a log-transformation with the basis of 10 was also applied to this data, which resulted in sufficient improved in the distribution of residual values, TD: $W = .97$, $p < .001$, ASD: $W = .98$, $p = .092$.

Analysis similar to that of attentional capture was carried out (2x3 design). The participant information including the diagnostic details (ASD or TD) was modelled at the third level of the multilevel analysis and trial type with assignment to noise conditions (no noise, low-intelligibility, or high-intelligibility) was modelled at the second level. Log-transformed attentional disengagement data per trial was subsequently modelled at the first level.

Results

General Attentional Engagement

General attentional engagement was investigated to see whether the amount of attention paid to social information in proportion to the overall image differed based on diagnosis, noise type, or AOI location. The means and standard deviations of a proportional dwell time on centrally and off-centre located social AOI per noise type and diagnosis can be seen in Table 5.1. On average, participants with ASD were missing general engagement data on 18% (*M* = 4.28, *SD* = 6.33) of trials and participants without ASD were missing data on 4% (*M* = 1.06, *SD* = 3.31) of trials, *t*(25.94) = -1.90, *p* = .069.

Table 5.1

Means (M) and Standard Deviations (SD) of a Proportional Dwell Time per Diagnosis, Social AOI Location, and Noise Type

	ASD (*n* = 18)				TD (*n* = 17)			
	Centre		Off-Centre		Centre		Off-Centre	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
High-Intelligibility Noise	0.45	0.30	0.13	0.15	0.52	0.24	0.19	0.24
Low-Intelligibility Noise	0.39	0.30	0.25	0.23	0.56	0.25	0.30	0.16
No Noise	0.46	0.32	0.22	0.24	0.61	0.24	0.34	0.24

Results of the multilevel model building revealed that participants with ASD and TD significantly differed on engagement with social information in the pictures (Figure 5.4), *F*(1,33) = 13.24, *p* = .001, η^2_p = .29. Participants with ASD (*M* = 0.31, *SD* = 0.38) spent proportionally less time looking at social information in comparison to TD participants (*M* = 0.42, *SD* = 0.20).

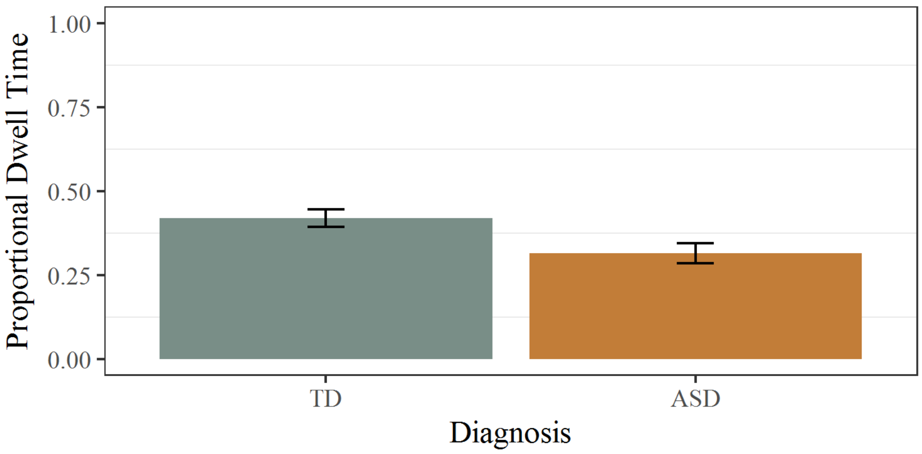

Figure 5.4. Mean proportional dwell time on social information per diagnosis. Error bars represent 95% CI.

The analysis also revealed a significant main effect of noise type on proportional dwell time, $F(2,122) = 9.94$, $p < .001$, $\eta^2_p = .14$ (Figure 5.5). Least square mean comparisons with Tukey HSD correction revealed that proportional dwell time on social information was significantly shorter in the high-intelligibility ($M = 0.32$, $SD = 0.31$) condition than the no noise ($M = 0.40$, $SD = 0.32$) condition ($p < .05$). Dwell time on social information in proportion to the whole picture in the low-intelligibility ($M = 0.38$, $SD = 0.31$) noise condition did not significantly differ from either the high-intelligibility or no noise conditions ($p > .05$).

Location of social AOIs in the image, as well, had a significant effect on the amount of attention participants paid to it, $F(1,33) = 131.00$, $p < .001$, $\eta^2_p = .80$ (Figure 5.6). Centrally located social information ($M = 0.50$, $SD = 0.19$) yielded longer proportional dwell time than off-centre positioned social AOIs ($M = 0.24$, $SD = 0.19$).

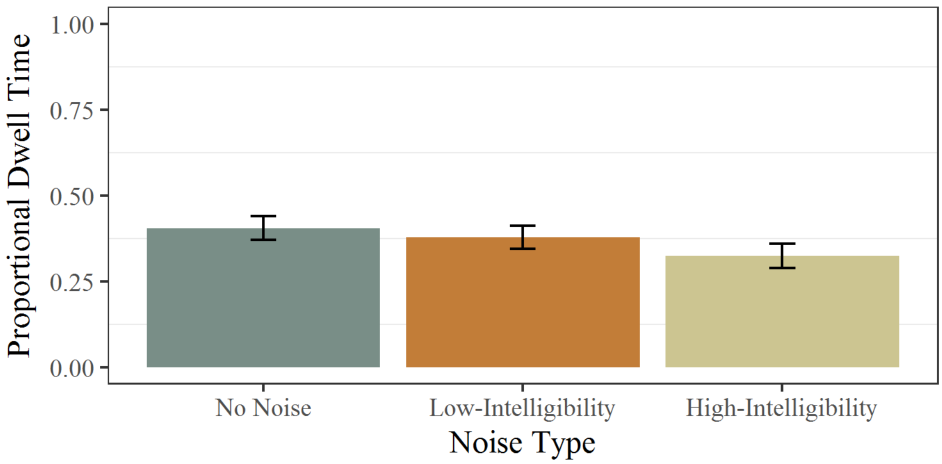

Figure 5.5. Mean proportional dwell time on social information per noise type. Error bars represent 95% CI.

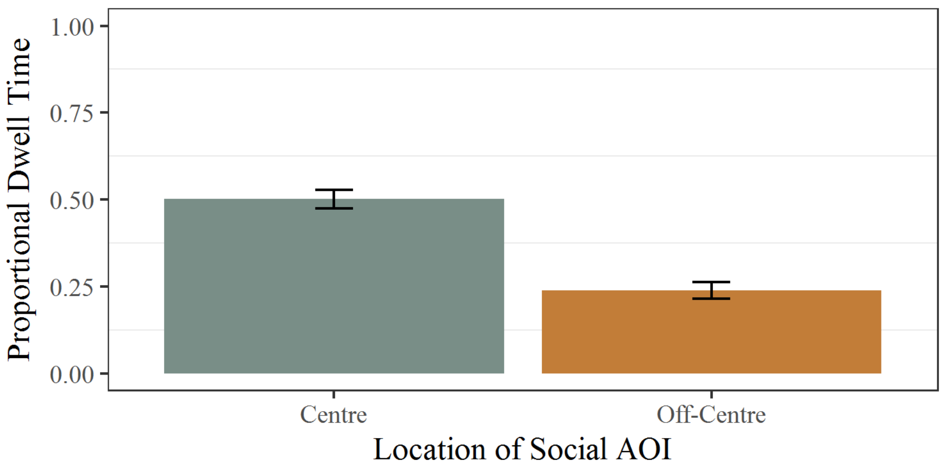

Figure 5.6. Mean proportional dwell time on social information per location of social AOI. Error bars represent 95% CI.

One of the interaction effects was also significant. To be precise, location of social AOIs significantly moderated the effect of noise type on the time spent looking at social AOIs, $F(2,122) = 4.26$, $p = .016$, $\eta^2_p = .07$ (Figure 5.7). Tukey HSD pairwise comparisons confirmed that proportional dwell time to the off-centre social information was still significantly shorter than the centrally located information. Yet, the significant difference in proportional dwell time in between the high-intelligibility condition (*M* = 0.16, *SD* = 0.22) and low-intelligibility (*M* = 0.28, *SD* = 0.22) or no noise (*M* = 0.28, *SD* = 0.24) conditions occurred only towards the off-centre located social information ($p < .05$). If the stimulus was located at the centre of the screen, however, there were no significant differences in proportional dwell time between the noise conditions (no noise: *M* = 0.53, *SD* = 0.26; $p < .05$; low-intelligibility: *M* = 0.47, *SD* = 0.27; high-intelligibility: *M* = 0.49, *SD* = 0.22).

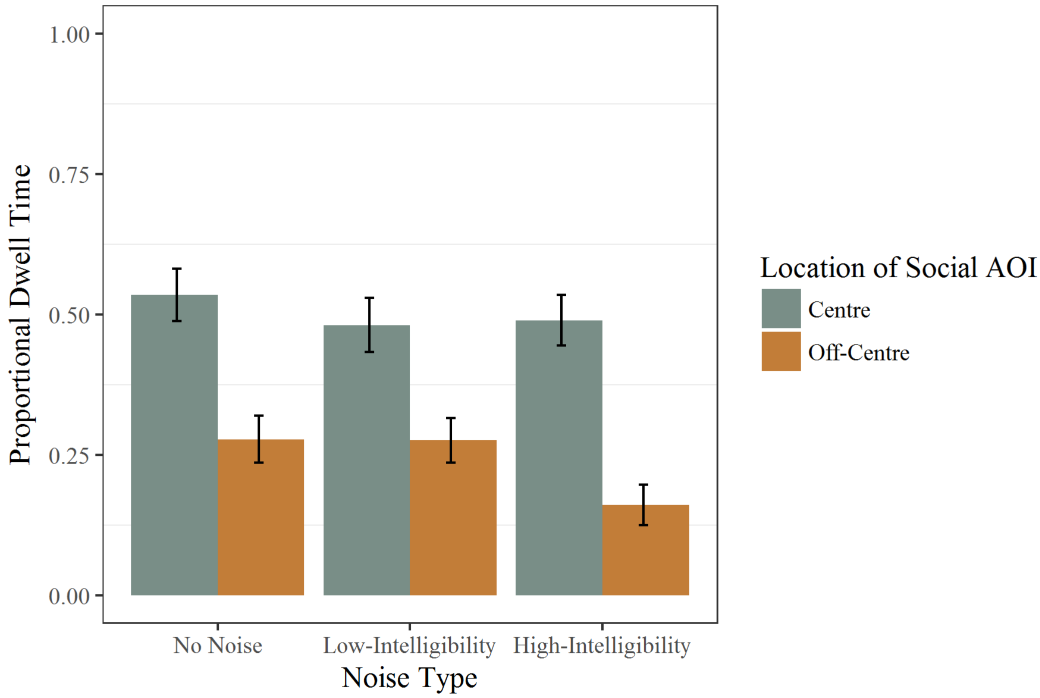

Figure 5.7. Mean proportional dwell time on social information per noise type and location of social AOI. Error bars represent 95% CI.

None of the other interactions in the final model reached significance. Indeed, even though having an ASD diagnosis on average resulted in less attention being paid to the social information in the pictures; it did not moderate any of the other effects in the model. To be precise, there were no group differences in the effect of noise type on a proportional dwell time on social AOIs, $F(2,122) = 1.19$, $p = .307$, $\eta^2_p = .02$. Having a diagnosis also did not change the fact that more attention was paid to centrally, rather than off-centre, located social AOIs, $F(1,33) = 1.68$, $p = .204$, η^2_p =

.05. Finally, the three-way interaction between noise type, location of social AOIs, and diagnosis was not significant, $F(2,122) = 1.07$, $p = .346$, $\eta^2_p = .02$. This indicates both ASD and TD participants paid the least attention to off-centre located social AOIs when listening to high-intelligibility noise and the most attention to centrally located social AOIs when no audio distractions were present.

Attention Capture

The means and standard deviations of the time to first fixation on off-centre located social AOIs per noise type and diagnosis can be seen in Table 5.2. Due to technical issues (e.g. poor eye-tracking signal) or never looking at the social AOI, participants with ASD were missing attention capture data on 32% ($M = 3.83$, $SD = 3.37$) trials compared to TD participants who were missing attention capture data on 10% ($M = 1.18$, $SD = 1.91$). Therefore, there was a significant difference in the amount of missing capture data between the diagnostic groups, $t(27.23) = -2.89$, $p = .007$.

Table 5.2

Means (M) and Standard Deviations (SD) of the Time to First Fixation (s) per Diagnosis and Noise Type

	ASD (*n* = 18)		TD (*n* = 17)	
	M	*SD*	*M*	*SD*
High-Intelligibility Noise	1.95	2.37	1.99	2.45
Low-Intelligibility Noise	1.22	2.00	1.09	1.68
No Noise	2.04	2.48	1.45	1.93

Note. The average scores in seconds for each condition are presented here. For subsequent analyses, log-transformed data were used.

Results of the multilevel model building did not show a significant main effect of diagnosis, $F(1,33) = 1.58$, $p = .218$, $\eta^2_p = .05$. Thus, both participants with ($M = 1.71$, $SD = 2.30$) and without ASD ($M = 1.49$, $SD = 2.03$) were attracted to social information at a similar speed.

The analysis revealed a significant main effect of noise type on the time to first fixation on off-centre located social AOIs, $F(2,61) = 6.79$, $p = .002$, $\eta^2_p = .18$ (Figure 5.8). Tukey HSD pairwise comparisons confirmed that there was a significant difference between the time to first fixation in the high- ($M = 1.97$, $SD = 2.42$) and low-intelligibility ($M = 1.15$, $SD = 1.85$) conditions ($p < .05$). The time to first fixation in no noise ($M = 1.71$, $SD = 2.17$) condition did not differ significantly from either of the conditions with the background noise ($p > .05$). An interaction between noise type and diagnosis was not significant, $F(2,61) = 0.96$, $p = .389$, $\eta^2_p = .03$. This means that having an ASD diagnosis did not moderate the effect that noise type had on participants' attention capture by off-centre social information.

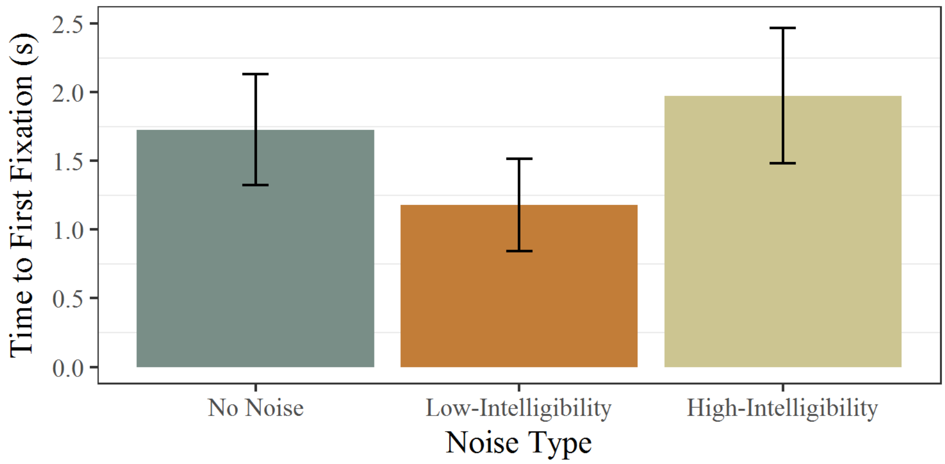

Figure 5.8. Mean time to first fixation on off-centre social AOI per noise type. Error bars represent 95% CI.

Attentional Disengagement

Attentional disengagement away from a social stimulus was investigated using stimuli with centrally located social information. After data cleaning, participants with ASD on average were missing data on 35% ($M = 4.22$, $SD = 3.77$) trials, whilst TD participants were missing data on 17% ($M = 2.00$, $SD = 2.50$) trials, $t(29.70) = -2.07$, $p = .048$. The means and standard deviations of the available data for the time to first fixation outside of centrally located social AOIs per noise type and diagnosis can be seen in Table 5.3.

Table 5.3

Means (M) and Standard Deviations (SD) of Attentional Disengagement (s) per Diagnosis and Noise Type

	ASD (*n* = 18)		TD (*n* = 17)	
	M	*SD*	*M*	*SD*
High-Intelligibility Noise	1.58	1.74	1.46	1.00
Low-Intelligibility Noise	1.66	1.77	1.91	1.86
No Noise	1.82	1.61	1.90	1.23

Note. The average scores in seconds for each condition are presented here. For subsequent analyses, log-transformed data were used.

Unexpectedly, none of the effects in this model reached significance. Participants' speed of disengaging their attention from immediately available social information did not differ based on their diagnosis, $F(1,33) = 3.50$, $p = .070$, $\eta^2_p = .10$. The main effect of noise also was not significant, $F(2,60) = 0.90$, $p = .412$, $\eta^2_p = .03$. Therefore, participants shifted their attention from social to non-social AOIs at a similar speed across the high-intelligibility, low-intelligibility, or no noise conditions. Results also revealed that participants' attentional disengagement was similar across noise type despite the presence of an ASD diagnosis, as the interaction between the noise type and diagnosis was not significant, $F(2,60) = 0.26$, $p = .773$, $\eta^2_p = .01$.

Discussion

The experiment described in the current chapter is the first study of high-functioning adults with ASD to tease apart different attentional shifting processes taking place when viewing naturalistic scenes. To be precise, manipulating the location of socially relevant information by positioning the figure in the centre or off-centre of the scenes allowed evaluating general attentional engagement with social information. Yet, it also allowed differentiating between attention capture by social information and attentional disengagement from social information.

As expected (Hypothesis 1), the findings confirmed that participants with ASD spent proportionally less time engaging with socially relevant information within natural scenes than TD participants. However, opposite to Hypothesis 2, participants with ASD looked at social information in naturalistic scenes just as fast as participants without ASD. Similarly to the findings of both experiments in Chapter 4 using the gap-overlap task with schematic images or photographs of faces in isolation, participants with ASD and TD adults also did not differ on the time taken to endogenously disengage from social information, which contradicted the prediction that they would (Hypothesis 3). Additionally, the hypothesised links between the presence and/or intelligibility of background noise and participants' diagnosis were not found (Hypothesis 4). Noise type affected attention to social information in naturalistic scenes in both groups similarly. To be more precise, the presence of background noise did not affect participants' disengagement from social information. Yet, social information captured participants' attention fastest when listening to the low-intelligibility background noise and slowest when high-intelligibility background noise was present. High-intelligibility noise also yielded the smallest proportions of general engagement with social information, especially when that information was located off-centre. The no noise condition, however, seemed to be associated with the longest proportional dwell time on social, particularly centrally located, AOIs.

Attentional Differences Between Adults with ASD and TD Individuals

General engagement. The main aim of the current experiment was to see whether atypicalities in attention capture by social information and/or disengagement from social information could explain atypical attention to social information seen in previous ASD studies (e.g. Klin et al., 2002; Riby & Hancock, 2009a, 2009b). The current finding that participants with ASD spend proportionally less time than TD individuals looking at social information is in line with the general consensus that individuals with ASD exhibit a lower bias to social information (see Chita-Tegmark, 2016). Therefore, this confirms that atypical attention to social stimuli in ASD was also present in the current sample of high-functioning adults with ASD. The current findings, however, also extend our understanding of atypical social attention in ASD by demonstrating that neither the speed of attention capture by, nor attentional disengagement from, social information in naturalistic scenes differed between TD adults and high-functioning adults with ASD.

Attentional capture and disengagement. The lack of group differences in the speed of attentional capture and disengagement contradicts the notion that atypical social attention in ASD occurs due to delayed attentional disengagement (e.g. Landry & Bryson, 2004) or capture by social information (Freeth et al., 2010; Riby & Hancock, 2009a). It seems intuitive that paradigms with stimuli in isolation (Landry & Bryson, 2004) could reflect different processes than paradigms using more naturalistic scenes. The experiments in Chapter 4 of the current thesis also did not find any clear differences in endogenous disengagement. Furthermore, it is possible that differences in findings of social orienting, at least in part, could be explained by different characteristics of the samples studied. The current sample was older and/or higher functioning than those of previous studies. Indeed, older control participants in the study by Williams et al. (2013) exhibited faster attentional capture than younger controls, whereas others show that global developmental delay is associated with increased failure to disengage (Chawarska, Volkmar, & Klin, 2010). Therefore, it is possible that the disengagement delays in the previous studies also may have been reflective of lower cognitive functioning.

Underlying mechanisms other than attention shifting may be responsible for diminished viewing time of (i.e. general attentional engagement with) social information in ASD. For instance, whilst not the main focus of the current study, the missing data analysis revealed group differences. It is possible that participants with ASD were missing more data due to the eye-tracker having more difficulty tracking their eyes, in general. However, the same differences in missing data were not applicable to the general engagement data in the current experiment. This suggests that participants with ASD differed from TD participants not on the number of scenes attended to, but the number of attended social AOIs instead.

Previous accounts of high-functioning individuals with ASD often include peripheral viewing, where the target (e.g. speaker’s eyes) is not directly looked at, but attended to peripherally (Bogdashina, 2003). This possibility is further supported by enhanced electrophysiological responses to peripheral stimuli seen in children with ASD, which suggests that peripheral information in ASD may be perceived more accurately than TD (Frey, Molholm, Lalor, Russo, & Foxe, 2013). Therefore, if participants with ASD were indeed directly engaging with fewer individuals in the scenes than TD participants, that could be reflected in their general engagement with social information. This further suggests that the answer to atypical social attention in

ASD may lie not in whether they engage less or slower with social information in general, but why certain social information is never directly engaged with.

Effects of Background Noise

Another aim of the current experiment was to evaluate whether the presence or intelligibility of background noise affected attention to social information in participants with ASD in comparison to typical development. The effect of different audio background types did not differ between participants based on their diagnosis. However, the presence and intelligibility of background noise did have an effect on participants' general attentional engagement with social information and attention capture by it.

The finding that the presence of low-intelligibility noise did not affect participants with ASD in a similar fashion as TD is in line with the load theory of selective attention (Lavie, 1995). Indeed, it postulates that, if the perceptual load of the task is low enough, attentional control mechanisms will supress the distractor interference. Yet, the finding that similar interference from high-intelligibility background noise was present for all participants, despite their diagnosis, is less intuitive. Previous research shows that individuals with ASD have difficulties identifying speech presented in noise (e.g. Alcántara et al., 2004). However, the accuracy of speech recognition was not measured in the current study. Therefore, it is possible that while individuals with ASD are poorer than TD individuals at understanding the speech presented in noise, the presence of it is still perceived similarly and thus is just as interfering.

In terms of general engagement, participants' time spent looking at socially relevant information decreased with the presence and intelligibility of noise. Furthermore, all participants paid more attention to centrally, rather than off-centre, located social information. This general tendency to look more at the centrally located AOIs is a novel finding on its own. Indeed, it reveals that this bias towards the centre of the image is present not only in TD individuals (Tatler, 2007), but also in high-functioning adults with ASD. Yet, in addition to that, the location of socially relevant information also moderated the effect of background noise. It appears that the silence increased the general engagement with social information only when it was presented centrally, whereas the increased intelligibility of background noise lead to decreased viewing of only off-centre located social information. It is worth noting that both central and off-centre AOIs were socially relevant and they systematically differed only in position in the scene. This, in turn, could mean that only the intelligibility of background noise decreases the attention paid to social information, while the general presence of any noise makes one focus more on the centre of the image independent from the social relevance of the information presented there. However, future research is required to evaluate such a possibility.

While the background noise did not make a difference in attentional disengagement from social information, it did affect how fast participants looked away from the centre of the scene to a person within it. To be precise, social information captured participants' attention slowest when participants were exposed to high-intelligibility noise. This, in combination with lower proportional engagement to off-centre located social information when high-intelligibility noise is present, indicates that intelligible speech in background noise decreases the social bias in visual attention. The load theory of selective attention suggests that the relatively low perceptual load of the target stimulus requires attentional control mechanisms to supress the perception of distractor stimuli to avoid interference (Lavie, 1995). This seemed to have successfully happened in the current experiment when the distractor was of relatively low perceptual load (i.e. low-intelligibility). The same process, however, did not occur for the distractor with increased perceptual load. From research on effects of noise in open plan offices, we know that increased intelligibility of background noise also interferes with higher cognitive load, such as memory, tasks (Brocolini, Parizet, & Chevret, 2016; Zaglauer, Drotleff, & Liebl, 2017). These findings compliment the load theory of selective attention (Lavie, 1995) by suggesting that not only the perceptual load of the target, but also the distractor itself, may determine how perceptual resources will be allocated and controlled.

Limitations and Future Directions

The current experiment inevitably has unique limitations. Indeed, following the original study by Williams et al. (2013), the tendency to look at the centre of an image (Tatler, 2007) was taken into account when evaluating attentional capture in the current experiment. Yet, the same was not applied for the measure of attentional disengagement. Given that the tendency to process the centre of the image occurred in this experiment and even moderated the effects of background noise on overall general engagement, it may have also influenced attentional disengagement. It is, therefore, possible that were participants' gaze cued to the off-centre location coinciding with the appearance of social information, different disengagement patterns would have occurred.

Conclusion

High-functioning adults with ASD, compared to TD individuals, spent proportionally less time looking at human figures in naturalistic scenes. However, they looked at and away from those figures just as fast as did TD adults, again exhibiting intact social bias in terms of attentional capture and disengagement. Therefore, the current results suggest that neither a delay in social orienting, nor in attentional disengagement can explain the lesser social bias in terms of general attentional engagement for high-functioning adults with ASD. The pattern of missing data seen in the current experiment, however, offers an insight into a possible explanation by suggesting that participants with ASD may simply avoid certain social information. In combination with the previous chapter these findings further confirm that attentional atypicalities in ASD are heavily dependent on tasks utilized and thus ecological validity and complexity of the stimuli. Hence, Experiment 5 described in the next chapter will focus on examining whether stimulus characteristics such as social content and relevance of the information may be moderating reduced social attention (i.e. general engagement) in high-functioning adults with ASD.

CHAPTER 6

VIEWING OF SOCIAL AND NON-SOCIAL INFORMATION IN NATURAL SCENES IN HIGH-FUNCTIONING ADULTS WITH ASD

Summary

Recently, it has been suggested that the content of the scene and the nature of the competing non-social information may moderate reduced attention to social information seen in individuals with ASD (e.g. Chita-Tegmark, 2016). The experiment in the current chapter aimed to evaluate, firstly, whether 24 high-functioning adults with ASD and 26 TD adults differ on attentional engagement with social and non-social information in naturalistic scenes. Secondly, it examined whether social content of the scene (1 - 4 or 6 - 12 people in the scene) and/or subjective relevance (high and low) of the information within the scene, as classified by independent judges, may be explaining these atypicalities in attention. Results revealed that participants with ASD viewed social information and subjectively relevant areas of the scene less than TD adults. However, increased social content affected adults with ASD similarly to TD adults by reducing their attention to the scene overall, to the subjectively more relevant areas, and to the social information in particular. The findings suggest that reduced social attention in ASD occurs due to a lack of social bias seen in TD adults rather than a non-social bias. Furthermore, it provides empirical support for atypical prioritisation of perceived information in ASD by showing that adults with ASD pay less attention to the information judged as relevant by TD adults.

Introduction

Klin and colleagues were one of the first to show that individuals with ASD look at the eye region less than TD individuals and at mouths, bodies, and background more than TD individuals (Klin et al., 2002b). It is generally agreed that individuals with ASD exhibit less attentional engagement with social information than typical and that this tendency persists across ages and levels of functioning (see Chita-Tegmark, 2016). Yet, multiple studies still fail to find reduced engagement with social information in children (van der Geest et al., 2002) or adolescents and young adults with ASD (Fletcher-Watson et al., 2009; Freeth et al., 2010; Kuhn, Kourkoulou, & Leekam, 2016) when compared to controls. Hence, it remains unclear what the underlying mechanisms determining the presence of atypical social viewing in ASD are.

Recent reviews (Chita-Tegmark, 2016; Guillon et al., 2014) observed that, for example, social content (i.e. number of people in the scene or on the screen) of the stimulus can moderate reduced attention to social information. TD individuals seem to increase attention to social information, eyes in particular, when presented with more than one person in the scene (Birmingham, Bischof, & Kingstone, 2008). A meta-analysis conducted by Chita-Tegmark (2016) showed that the same pattern might not be occurring in individuals with ASD. Several studies have directly investigated whether increasing the social content of the scenes or presenting social stimuli in isolation may have a moderating effect on atypical attention in ASD. For example, Speer et al. (2007) showed that children with ASD differed from control participants on attention to eye and body regions when presented with dynamic stimuli encompassing multiple people. Rigby, Stoesz, and Jakobson (2016), however, contradicted these findings by showing that in scenes with multiple figures, attention to faces decreased and attention to the rest of the bodies or the background increased for adults with ASD and TD alike. Therefore, it remains unclear whether the changes in social content of the scene have an influence on atypical social attention in ASD.

One possible explanation for some studies not finding reduced attention to social information in individuals with ASD could be the nature of the competing non-social information present (Chita-Tegmark, 2016; Guillon et al., 2014). Tager-Flusberg (2010), for example, theorised that reduced social attention in ASD may be occurring not due to a lack of motivation to engage with it, but due to a preoccupation with non-social information. Indeed, some studies have reported increased looking time to non-social information of the scene in people with ASD when compared to controls (e.g. Klin et al., 2002b; Riby & Hancock, 2009b), while others have not found the same increase (Fletcher-Watson et al., 2009; Riby & Hancock, 2008; Speer et al., 2007).

Sasson and Touchstone (2014) found that for pre-schoolers with ASD, reduced attention to faces in isolation was moderated by the type of object presented as a distractor. Reduced social attention occurred only when objects perceived as belonging to circumscribed interests (e.g. trains) were present. Chita-Tegmark (2016) remarked that the evaluation of differential effects of objects in natural scenes retrospectively is near impossible due to most previous studies aggregating data across all of the non-social information present, as well as strongly varying across content and size of the areas encompassing non-social information. Thus, while it seems that certain objects may have increased relevance for individuals with ASD, it is unclear how the relevance of everyday objects in natural scenes may affect attention to social information. To this researcher’s knowledge, effects of the relevance of the non-social information within scenes on atypical attentional engagement in ASD, to date, has not been explicitly examined.

It should be noted that not only have the differential effects of non-social aspects in a scene not been fully evaluated, but the same is true for the relevance of social information. After all, a person in, for instance, the forefront of a scene should intuitively receive more attention than the passer-by in the background. We know that on the one hand, TD individuals prioritize social information, such as faces, from early infancy (e.g. Gliga & Csibra, 2007). Moreover, WCC (Frith, 1989; Frith & Happé, 1994; Happé & Frith, 2006) suggests that individuals with ASD may have a more locally oriented processing style with deficits in global information processing. In line with that, multiple anecdotal accounts further suggest that individuals with ASD find it difficult to prioritize any of the perceived information (e.g. Bogdashina, 2003). Therefore, it is possible that reduced attention to social information is occurring, not due to the social nature of that information, but as a function of a reduced ability to filter out irrelevant information.

To fully evaluate whether the atypical attention to social information in ASD occurs due to the increased relevance of objects for individuals with ASD or due to the increased relevance of social information for TD individuals, it is important to investigate within participant differences in attention across different types of information. After all, even if individuals with ASD look at social information less and at non-social information more than individuals without ASD, it cannot show if individuals with ASD prefer non-social over social information. Bird, Press, and Richardson (2011) attempted to examine similar processes by expressing gaze data as a ratio. To be precise, they focused on attention to faces in dynamic social interactions and computed a face to non-face ratio to evaluate whether adults with and without

ASD engaged with face or non-face information more. They found that the control group showed a preference for face over non-face information while adults with ASD did not show any preference. Similarly, another study has showed that the same pattern applied to children with ASD (Wilson, Brock, & Palermo, 2010). Yet, whilst computing a ratio between two areas of interest offers a valuable insight into preferential attention between two parts of the scene, it is achieved at the expense of individual differences. Regarding the length of viewing time, for example, a ratio analysis allows us to see whether individuals with ASD looked at social information more or less than non-social information, but it does not show whether they looked at it for as long as TD individuals. In other words, it makes it impossible to see whether social or non-social attentional engagement is, indeed, atypical.

Another approach to calculate proportional data that allows a comparison of both between and within participant differences has been used in previous research on typical samples (e.g. Birmingham et al., 2008). To be precise, in this approach eye-tracking data can be area-standardised by, for example, dividing the data for each information type by its area. This is particularly useful when attempting to compare attention to different areas, such as social and non-social, of a scene as it allows one to disregard attentional biases occurring due to stimulus size. No studies to date, however, have directly compared the attention to standard size social and non-social information of natural scenes in individuals with ASD and TD.

Aims

Experiment 4 described in Chapter 5 of the current thesis revealed that the current sample of adults with ASD in general engage with social information less than TD individuals, but not due to atypical attentional disengagement or capture speed. Experiment 5 described in the current chapter aimed to further investigate whether individuals with ASD differ from TD adults on attentional engagement with not only social, but also non-social, information in naturalistic scenes and, if so, what stimuli properties may be underlying this atypical attention. To expand on the previous literature, both the naturalistic scenes used and the information within them were categorised to represent different stimulus characteristics that may moderate this atypical processing in ASD. The first characteristic that the current study aimed to manipulate was social content (i.e. number of people present) of the scenes. In Chapter 5, it was found that reduced attention to social information in single person scenes occurred in the current sample of high-functioning adults with ASD. Therefore, scenes deemed as high and low in social content, respectively, have been investigated in this study. Secondly, the information within the scenes was further categorised by independent judges in order to examine how subjective relevance (i.e. perceived priority of the information within the scenes) of both social and non-social information affects attentional engagement in adults with ASD and TD. A direct comparison between different information in the scenes was made possible by the standardisation of eye-tracking data per size of AOI. Additionally, as in the previous chapters, the current study aimed to further investigate the possibility of intersensory integration difficulties and/or enhanced perceptual load in affecting gaze behaviour in ASD.

Hypotheses

In line with previous studies (e.g. Klin et al., 2002; Riby & Hancock, 2008; Speer et al., 2007), it was hypothesised that individuals with ASD will show less attentional engagement with social information than TD individuals (Hypothesis 1). Based on previous research (e.g. Klin et al., 2002; Riby & Hancock, 2009), it was also expected that individuals with ASD will look at non-social information more than TD individuals (Hypothesis 2). Previous research suggested that atypical social attention in ASD appears when a stimulus includes more than one person (e.g. Chita-Tegmark, 2016). Thus, in the current experiment a novel hypothesis was raised that reduced social viewing in ASD will be even more pronounced in scenes including a larger number of people than scenes with fewer people (Hypothesis 3). It was also predicted that when using a novel direct size standardised comparison between social and non-social information within participants, TD individuals will show a preference for engagement with social rather than non-social information of the scene, but that the same will not be the case for individuals with ASD (Hypothesis 4). Furthermore, based on the notion of impaired global perception (Bogdashina, 2003; Frith & Happé, 1994), a novel comparison based on the subjective relevance of the information within scenes was devised. It was expected that individuals with ASD will look at the areas of the picture judged as relevant less than TD individuals (Hypothesis 5). It was further hypothesised that subjective relevance of the information may also moderate reduced attention to social information in ASD (Hypothesis 6).

As suggested in the findings in Chapter 5, it was also expected that increased intelligibility of background noise will diminish attention to a social stimulus independent of diagnosis (Hypothesis 7). Even though no interactions between the presence or intelligibility of background noise and participants' diagnosis were seen when using photographs of scenes in Chapter 5, potential diagnostic effects were again posited for the current study due to increased perceptual load in high social content scenes. If such relationship was present, it was expected that participants with ASD will be less susceptible than TD participants to the interference of the high-intelligibility noise condition in comparison to the low-intelligibility noise condition. This hypothesis was raised due to the previous findings showing that individuals with

ASD have difficulties perceiving speech if presented in the background noise (e.g. Alcántara et al., 2004).

EXPERIMENT 5

Methods

Participants

All the participants (see Chapter 2) completed this experiment. However, recorded eye movement data of three participants with ASD was insufficient for meaningful analysis[4]. Therefore, the final sample consisted of 24 high-functioning adults with ASD (13 females) and 26 TD adults (13 females). The mean chronological age of the individuals with ASD was 38 years and 6 months, ranging between 18 years 3 months and 63 years 2 months. For TD participants, the mean chronological age was 37 years and 1 month with a range from 19 years 7 months to 64 years. No significant differences in gender ($\chi^2(1) = 0.09$, $p = .768$) and age, as well as full, verbal, or performance IQ as estimated by the full Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), were observed between the groups (see **Error! Reference source not found.**). Scores on the Autism Spectrum Quotient (Baron-Cohen et al., 2001) in TD sample were significantly lower than the ASD group (**Error! Reference source not found.**).

Stimuli and Apparatus

Colour stimuli were presented on a 40 x 30 cm (1024 x 768 px) CRT monitor with a white background. The data for Experiment 5 was collected as a part of the bigger study. Therefore, participants were presented with 192 photographs of natural social and non-social scenes in total, but only 24 of those photographs showing social scenes were directly relevant for the current experiment.

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[4] Excluded participants with ASD were similar to included ones on most of the background characteristics (*p*s > .062). They scored lower on the Sensation seeking subscale of the Sensory Profile, $t(25) = -2.86$, $p = .008$.

Table 6.1

Participant Comparison on Age, IQ, and AQ per Diagnosis

	ASD (*n* = 24)			TD (*n* = 26)			*t*(48)	*p*
	M	*SD*	Range	*M*	*SD*	Range		
Age	38.79	13.78	18-63	37.23	13.93	19-64	-0.40	.692
FSIQ	108.96	14.42	77-134	110.39	11.07	83-125	0.39	.695
VIQ	105.92	14.44	71-128	108.92	10.52	81-127	0.85	.402
PIQ	110.42	14.44	80-136	109.89	12.59	84-138	-0.14	.890
AQ	34.46	6.84	21-48	18.62	5.83	5-29	-8.84	<.001

Note. FSIQ = full scale IQ, VIQ = verbal IQ, PIQ = performance IQ, and AQ = Autism Spectrum Quotient.

The 192 pictures depicted either classroom, or office environments with or without people present. Educational or workplace settings were chosen as they depict relatively familiar, everyday contexts encountered by both individuals with and without ASD. Furthermore, the choice of such images allowed the relative consistency of background information and social settings across the images. It also minimized representation of emotional valence often found in other natural everyday scenes (e.g. pictures of social gatherings). All images (e.g. Figure 6.1 and Figure 6.2) presented during to the participants were retrieved from the public domain through a conventional image search engine (Google Image Search) in August 2014. The search was conducted using number of queries: “classroom”, “university classroom”, “classroom busy”, “office”, “office busy”, “classroom empty”, and “office empty”. During the search 192 photographs representing four different conditions (48 images each) of varying busyness were selected: classroom environment without any people, office environment without any people, classroom environment with people, and office environment with people. Images depicting people were carefully selected to not represent emotional expression (e.g. smiling) or direct gaze to the camera.

Experiment 5 focused on 24 social photographs depicting both people and some background objects only. Of those, 12 photographs that included a small number of people (1 to 4) were chosen to represent scenes of low social content (Figure 6.1). Another 12 photographs including a larger number of people (6-12) were used to represent scenes of high social content (Figure 6.2). The low social content scenes depicted significantly less people (M = 2.92, SD = 1.16) than the high social content scenes (M = 8.67, SD = 2.06), $t(22) = 8.42$, $p < .001$.Stimuli size varied, but all fell under the dimensions of 23.40 cm x 17.55 cm (16.67^{o} x 12.54^{o}).

Figure 6.1. Example stimulus in Experiment 5 belonging to the low social content condition. Adapted from [Untitled image], 2011. In the public domain.

Figure 6.2. Example stimulus in Experiment 5 belonging to the high social content condition. Adapted from [Untitled image], 2010. In the public domain.

Similarly to the experiments in previous chapters of the current thesis, audio stimuli were used in addition to visual stimuli. All three noise conditions: no noise, low-intelligibility noise, and high-intelligibility noise, were utilized. Same as in previous experiments, a Tobii x120 eye-tracker placed below the monitor and interfaced with the E-prime stimulus presentation package was used to record participants' eye movements (see Chapter 2).

Procedure

Overall, the task was presented in a 2x2x3 within-subject design to ensure even distribution of the stimuli. One presentation variable was the environment (classroom or office), the other was the level of socialness (non-social or social), and the last variable was noise (no noise, low-intelligibility noise, and high-intelligibility noise). The experiment encompassed 192 trials in total (16 per condition), split into three noise-based blocks. Both the order of blocks and trials within them were randomised. Each block took 18 min to complete.

Each participant received on-screen and verbal instructions to look at the photographs and describe them out loud while the pictures are on the screen. All participants were informed that there is no right or wrong way of looking at the pictures or describing them. At the beginning of each trial, a fixation cross was presented in the middle of the screen for 1000 ms. Once the fixation cross disappeared, a photograph appeared in the middle of the screen for 15000 ms. Every 16 pictures participants reached a break screen and had an opportunity to rest (e.g. close their eyes or remove headphones) for as long as they wanted.

Data Analysis

As part of a larger study, a battery of 192 photographs were presented to the participants during the data collection (see Stimuli and Apparatus). Out of the photographs included, half depicted empty classroom or office environments (48 each), whilst the other half depicted classroom or office scenes with people (48 each). Only 24 photographs out of the 96 images representing classroom or office environments were further selected to be analysed for the current experiment as they allowed a consistent distinction between the high and low social content scenes.

Previous studies attempting to distinguish between the salience of different aspects of the scenes have mostly focused on computational modelling of visual attention (e.g. Itti & Koch, 2001; Le Meur et al., 2007). These techniques are appropriate when predicting the attention deployment based on the low-level visual features. Yet, such an approach is unable to identify attention allocation guided by higher-order processing necessary for determining social or contextual relevance of the information. As exact mechanisms underlying top-down attentional allocation in scenes is not yet understood in either TD or ASD, the current experiment relied on a subjective evaluation of relevance when defining AOIs.

Prior to data analysis, four separate AOIs were devised using an evaluation of the scenes by 10 independent judges. Each judge was presented with printouts of all 24 photographs and asked to “circle areas that draw the most attention”. All the areas circled were treated as relevant information. To be precise, any area of the photograph that was circled by at least one participant was accepted as potentially containing more subjectively relevant information in comparison to the areas that were not selected by any of the judges. The social/non-social relevance of the AOIs was further defined by the researcher based on whether the area included a person (e.g. Figure 6.3).

Relevant AOIs for each photograph were defined using the ‘Draw Polygon’ function in Tobii Studio 3.3.1. When the circled area focused on a person, a high relevance social AOI was defined by the outline of the encompassed body region

(Figure 6.3). Similarly, high relevance non-social AOIs were defined by the outline of any objects included in the circled area. If the area circled by judges did not include a clearly definable object or person, but rather a part of a bigger object (e.g. a shiny part of the desk), the outline of that high relevance non-social AOI was defined at the researcher's discretion. Low relevance social AOIs were defined, when available, by outlining figures of people in the scenes that were not circled by judges as drawing attention (Figure 6.3). Low relevance non-social AOIs were determined for each scene by marking the outline of the complete picture and then subtracting the data belonging to other AOIs at the point of analysis.

Figure 6.3. Sample definition of areas of interest: high relevance social (green), high relevance non-social (orange), low relevance social (yellow), and low relevance non-social (grey).

Visit duration data per AOI for each scene was extracted in seconds using Tobii Studio 3.3.1. As trials with only partial data recorded may not be representative, trial data contaminated with blinks and poor signal is often excluded to avoid distortion (e.g. Fletcher-Watson et al., 2009). Thus, in the current study all trials that had less than 33% of viewing time recorded were treated as missing. This on average resulted in 14% (M = 3.29, SD = 5.81) of trials missing for participants with ASD and 8% (M = 2.00, SD = 3.46) of trials missing for TD participants. The difference in the average number of missing trials based on diagnosis was not significant, $t(36.91) = -0.95$, $p = .351$.

To allow a direct comparison of visit duration data across AOIs, the data was further standardised to control for AOI size differences (c.f. Birmingham et al., 2008). To achieve this, each visit duration per AOI was divided by the size of that AOI in pixels and multiplied by 67500 pixels. This way the size of each AOI was controlled to be representing an area of 300 x 225 pixels corresponding to ¼th of the maximum image size. This helped to avoid the possibility that, for example, AOIs defined as highly relevant would be gazed at for longer due to their larger size.

The Shapiro-Wilk normality test and graphical examination of residual values revealed that the visit duration data was positively skewed in both participant groups, TD: $W = .67$, $p < .001$, ASD: $W = .78$, $p < .001$. Thus, a log-transformation with the basis of 10 was applied to the data. Zero values in the current experiment were meaningful as they reflected that the overall stimulus, but not particular an AOI, was engaged with. As log-transformation of zero values is not plausible, a constant value of 10 was added to every existent measurement before the log value was computed (Field, 2013). Graphical examination of the log-transformed data confirmed that the distribution of residual values was sufficiently improved, although the Shapiro-Wilk normality test remained significant in both groups, TD: $W = .91$, $p < .001$, ASD: $W = .93$, $p < .001$.

Log-transformed visit duration data in seconds was then analysed using linear mixed-effect (multilevel) modelling with a 2x2x3x2x2 design as an alternative to ANOVA (see Chapter 2). The participant information including their diagnostic details (ASD or TD) was modelled at the fourth level of the multilevel analysis. Nested within each participant, trial information with the social content of the scene (high or low) and noise type (no noise, low-intelligibility, or high-intelligibility noise) as predictors were modelled at the third level. AOI information with AOI relevance (high or low) and AOI type (social or non-social) as predictors was modelled at the second level. Visit duration time per each AOI was modelled at the first level, nested within each trial.

Results

The mean visit durations in seconds for the AOI type and relevance, as well as social content of the scene per diagnosis are shown in Table 6.2. The model (Table 6.3) will be described by first focusing on main effects and then discussing significant interactions.

Results of the multilevel model building (Table 6.3) revealed that the main effect of diagnosis was not significant, $F(1,48) = 2.57$, $p = .116$, $\eta^2_p = .05$. In other words, participants with an ASD diagnosis ($M = 4.74$, $SD = 5.61$) did not differ on average visit duration from those without diagnosis ($M = 5.48$, $SD = 7.33$). Similarly, AOI type also did not have a significant main effect on average visit durations, $F(1,814) = 2.90$, $p = .089$, $\eta^2_p < .01$. In other words, visit durations to social ($M = 5.72$, $SD = 8.44$) and non-social ($M = 4.63$, $SD = 4.38$) AOIs were overall relatively similar.

Other main effects such as social content and AOI relevance did reach significance (Table 6.3). Indeed, visit durations were longer for scenes deemed as low ($M = 5.81$, $SD = 8.07$), rather than high ($M = 4.55$, $SD = 4.93$), in social content (Figure 6.4), $F(1,226) = 17.38$, $p < .001$, $\eta^2_p = .07$. In terms of AOI relevance, visit durations were longer when gazing at high ($M = 6.11$, $SD = 6.93$) rather than low ($M = 3.99$, $SD = 5.98$) relevance AOIs (Figure 6.4), $F(1,814) = 137.38$, $p < .001$, $\eta^2_p = .14$.

The main effect of noise type (Figure 6.5) also had a significant effect on visit durations and thus was further investigated using Tukey HSD pairwise comparisons, $F(2,226) = 7.45$, $p = .001$, $\eta^2_p = .06$. It was revealed that visit durations in the high-intelligibility noise condition ($M = 5.54$, $SD = 6.32$) were significantly different from those in the low-intelligibility noise ($M = 4.93$, $SD = 7.19$) or no noise ($M = 4.95$, $SD = 6.15$) conditions ($p < .05$). Visit durations in the low-intelligibility and no noise conditions, however, did not significantly differ from one another ($p > .05$)

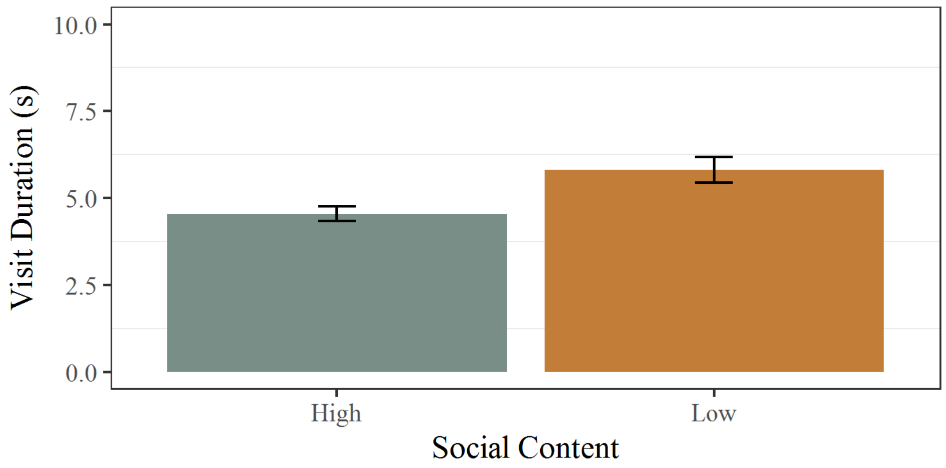

Figure 6.4. Mean visit duration per social content. Error bars represent 95% CI.

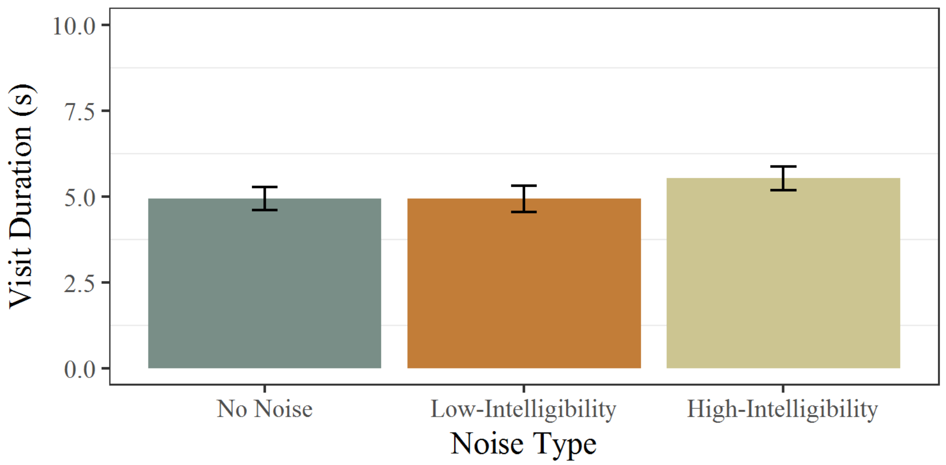

Figure 6.5. Mean visit duration per noise type. Error bars represent 95% CI.

The final model also revealed multiple two-way interactions (Table 6.3). For instance, the effect of AOI relevance was moderated by having a diagnosis (Figure 6.6), $F(1,814) = 3.99$, $p = .046$, $\eta^2_p < .01$. Both participants with ASD and TD looked at highly relevant areas of the scenes (ASD: $M = 5.55$, $SD = 6.17$; TD: $M = 6.59$, $SD = 7.50$) significantly longer than low relevance (ASD: $M = 3.79$, $SD = 4.71$; TD: $M = 4.17$, $SD = 6.91$) areas (Tukey HSD pairwise comparisons: $p < .05$). There were no significant differences between the visit durations of participants with ASD or TD towards either high or low relevance information in the scenes ($p > .05$)..

Table 6.2

Means (M) and Standard Deviations (SD) of Visit Duration (s) per Diagnosis, Noise Type, Social Content, and Relevance and Type of AOI

	ASD (*n* = 24)			TD (*n* = 26)		
	HI	LI	NN	HI	LI	NN
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
High Social Content Scenes						
High Relevance Social AOI	5.13 (4.27)	4.91 (4.25)	3.46 (2.91)	7.12 (6.51)	6.48 (5.70)	4.16 (3.36)
High Relevance Non-Social AOI	7.36 (6.89)	4.57 (6.57)	3.97 (5.51)	7.25 (7.57)	3.85 (5.38)	3.08 (3.81)
Low Relevance Social AOI	3.28 (4.40)	1.43 (1.64)	5.30 (6.92)	4.11 (5.27)	1.53 (2.72)	6.08 (7.56)
Low Relevance Non-Social AOI	4.41 (1.71)	4.09 (1.64)	4.99 (1.87)	4.28 (1.84)	4.08 (1.65)	4.43 (1.94)
Low Social Content Scenes						
High Relevance Social AOI	8.85 (8.91)	6.44 (6.80)	6.57 (7.32)	9.07 (10.02)	9.68 (8.02)	9.61 (13.43)
High Relevance Non-Social AOI	4.60 (5.44)	5.24 (5.02)	5.51 (6.14)	5.39 (4.27)	7.26 (6.03)	6.28 (5.97)
Low Relevance Social AOI	4.79 (12.11)	4.62 (11.37)	1.21 (2.22)	6.75 (13.30)	8.36 (20.84)	1.07 (2.81)
Low Relevance Non-Social AOI	3.23 (0.90)	3.67 (0.70)	3.64 (1.27)	3.03 (0.90)	3.42 (0.66)	3.61 (1.09)

Note. The average scores in seconds for each condition are presented here. For subsequent analyses, log transformed data were used. HI = High-Intelligibility noise, LI = Low-Intelligibility noise, NN = No Noise.

Table 6.3

Model Summary of the Main Effects and Interactions

	df	df_{error}	*F*	*p*	η^2_p
AOI type	1	814	2.90	.089	<.01
AOI relevance	1	814	137.38	<.001	.14
Social content	1	226	17.38	<.001	.07
Noise type	2	226	7.45	.001	.06
Diagnosis	1	48	2.57	.116	.05
AOI type * AOI relevance	1	814	50.33	<.001	.06
AOI type * Social content	1	814	15.76	<.001	.02
AOI type * Noise type	2	814	0.87	.418	<.01
AOI relevance * Social content	1	814	42.39	<.001	.05
AOI relevance * Noise type	2	814	16.25	<.001	.04
Social content * Noise type	2	226	12.58	<.001	.10
AOI type * Diagnosis	1	814	10.65	.001	.01
AOI relevance * Diagnosis	1	814	3.99	.046	<.01
Social content * Diagnosis	1	226	4.36	.038	.02
Noise type * Diagnosis	2	226	0.22	.804	<.01

	df	df_{error}	F	p	η^2_p
AOI type * AOI relevance * Social content	1	814	0.12	.727	<.01
AOI type * AOI relevance * Noise type	2	814	4.12	.017	.01
AOI type * Social content * Noise type	2	814	6.82	.001	.02
AOI relevance * Social content * Noise type	2	814	20.00	<.001	.05
AOI type * AOI relevance * Diagnosis	1	814	0.02	.882	<.01
AOI type * Social content * Diagnosis	1	814	0.62	.430	<.01
AOI type * Noise type * Diagnosis	2	814	0.14	.874	<.01
AOI relevance * Social content * Diagnosis	1	814	1.36	.244	<.01
AOI relevance * Noise type * Diagnosis	2	814	0.56	.571	<.01
Social content * Noise type * Diagnosis	2	226	1.40	.250	.01
AOI type * AOI relevance * Social content * Noise type	2	814	12.71	<.001	.03
AOI type * AOI relevance * Social content * Diagnosis	1	814	2.62	.106	<.01
AOI type * AOI relevance * Noise type * Diagnosis	2	814	0.36	.698	<.01
AOI type * Social content * Noise type * Diagnosis	2	814	0.42	.658	<.01
AOI relevance * Social content * Noise type * Diagnosis	2	814	0.59	.556	<.01
AOI type * AOI relevance * Social content * Noise type * Diagnosis	2	814	1.06	.348	<.01

Note. AOI type = social or non-social; AOI relevance = high or low; Social content = high or low; Noise type = no noise, low-intelligibility, or high-intelligibility noise; Diagnosis = ASD or TD.

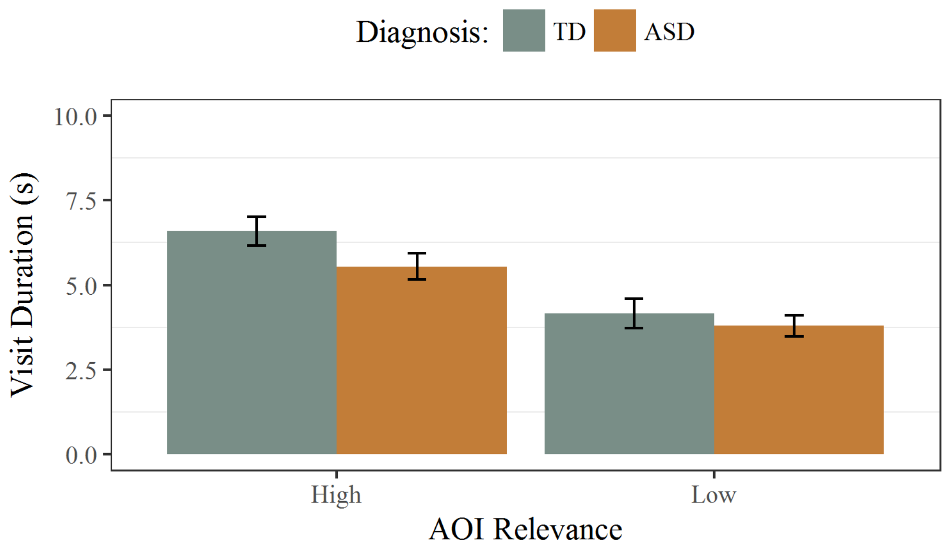

Figure 6.6. Mean visit duration per AOI relevance and diagnosis. Error bars represent 95% CI.

Although the main effect of AOI type on visit durations was not significant, the two-way interaction between the AOI type and a diagnosis was (Figure 6.7), $F(1,814) = 10.65$, $p = .001$, $\eta^2_p = .01$. Tukey HSD pairwise comparisons confirmed that TD participants ($M = 6.44$, $SD = 9.65$) looked at social information for longer than participants with ASD ($M = 4.89$, $SD = 6.73$; $p < .05$). Their visit durations towards non-social information, however, did not differ significantly based on diagnosis (TD: $M = 4.65$, $SD = 4.34$; ASD: $M = 4.60$, $SD = 4.44$; $p > .05$). Furthermore, there were no significant differences between visual durations to social and non-social AOIs in either of the participant groups ($p > .05$).

Moreover, having a diagnosis further moderated the effect of social content (Figure 6.8), $F(1,226) = 4.36$, $p = .038$, $\eta^2_p = .02$. Tukey HSD comparisons confirmed that the effect of social content occurred only in the TD group, with low social content ($M = 6.38$, $SD = 9.17$) scenes receiving longer visit durations than high social content ($M = 4.70$, $SD = 5.14$) scenes ($p < .05$). The visit durations of participants with ASD, however, did not differ either between low- ($M = 5.15$, $SD = 6.52$) and high social content (*M* = 4.39, *SD* = 4.68) scenes, or from the visit durations of TD participants ($p > .05$).

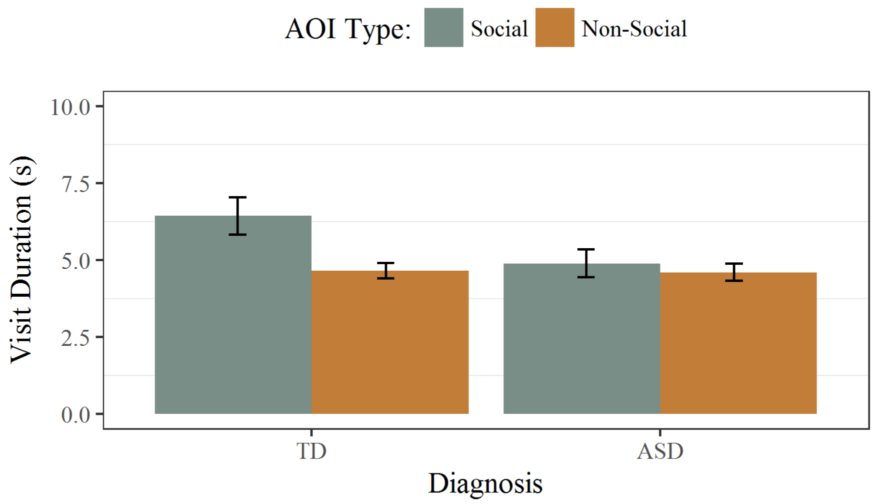

Figure 6.7. Mean visit duration per AOI type and diagnosis. Error bars represent 95% CI.

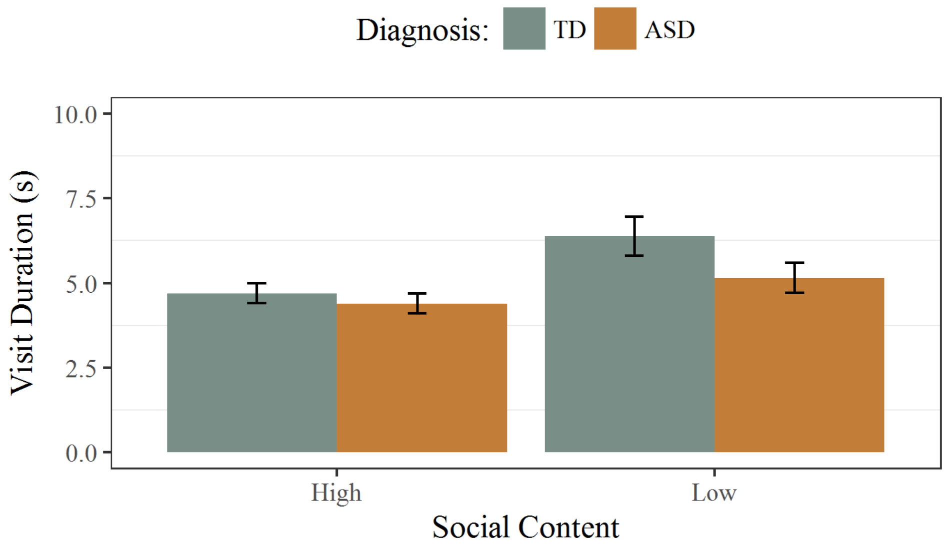

Figure 6.8. Mean visit duration per social content and diagnosis. Error bars represent 95% CI.

The effect of AOI relevance was also moderated by AOI type (Figure 6.9), $F(1,814) = 50.33$, $p < .001$, $\eta^2_p = .06$. Visit durations towards higher relevance information in these scenes were longer than the information defined as less relevant regardless of AOI type. For highly relevant information, visit durations were longer for social (*M* = 6.85, *SD* = 7.74) than non-social (*M* = 5.36, *SD* = 5.92) information. This was confirmed using Tukey HSD pairwise comparisons ($p < .05$). There was also a significant difference between AOIs depicting social information of lower relevance (*M* = 4.12, *SD* = 9.12) and non-social information of lower relevance (*M* = 3.90, *SD* = 1.52; $p < .05$).

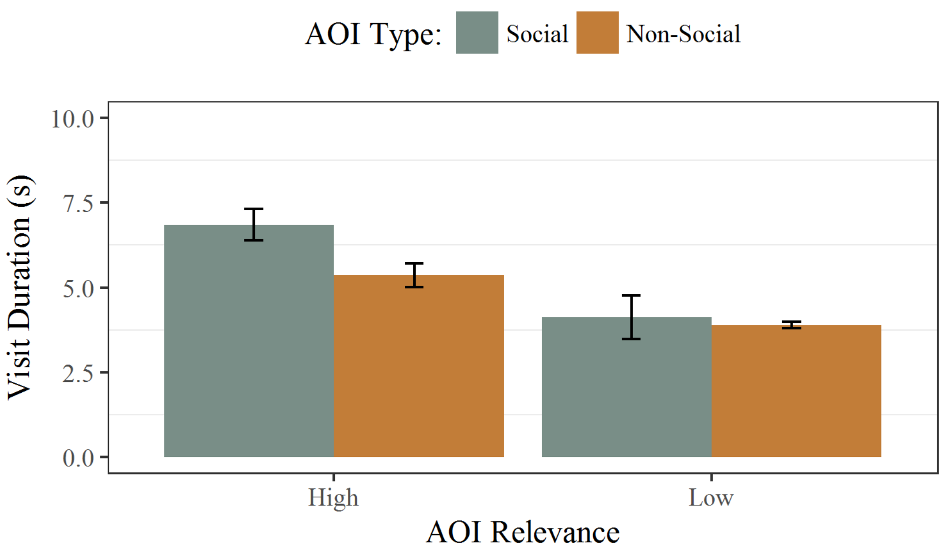

Figure 6.9. Mean visit duration per AOI type and relevance. Error bars represent 95% CI.

There was also a two-way interaction between AOI type and social content (Figure 6.10), $F(1,814) = 15.76$, $p < .001$, $\eta^2_p = .02$. Tukey HSD pairwise comparisons confirmed that the effect of AOI type on visit durations was moderated by social content of the scene. To be precise, social AOIs (*M* = 7.53, *SD* = 11.31) received longer fixation durations than non-social AOIs (*M* = 4.59, *SD* = 4.14) only when fewer people were present in the scenes ($p < .05$). The former visit durations were also statistically different from visit durations to both social (*M* = 4.44, *SD* = 5.24) and non-social (*M* = 4.67, *SD* = 4.61) information in scenes with a larger number of people ($p < .05$). They, in turn, were similar to visit durations to non-social information in low social content scenes ($p > .05$).

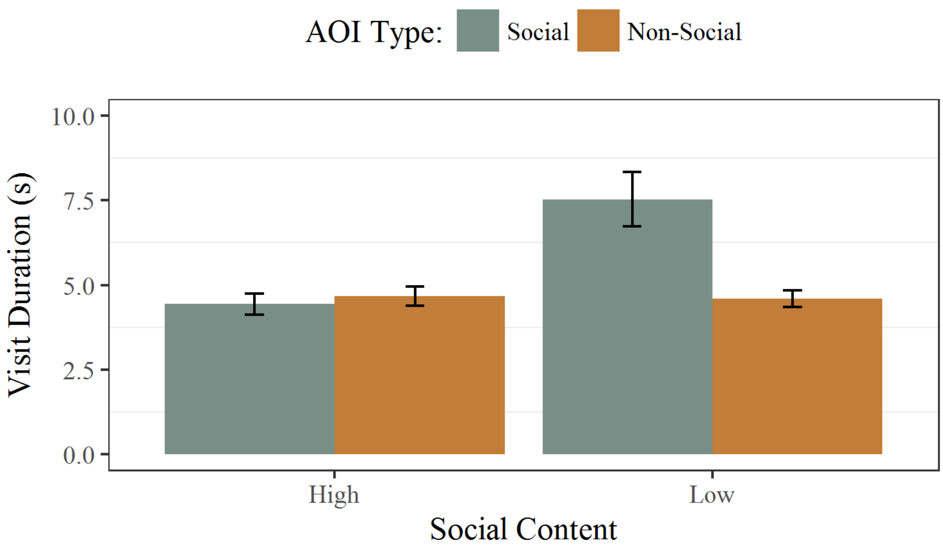

Figure 6.10. Mean visit duration per social content of the scene and AOI type. Error bars represent 95% CI.

The effect of AOI relevance also interacted with social content (Figure 6.11), $F(1,814) = 42.39$, $p < .001$, $\eta^2_p = .05$. Visit durations towards relevant information again were longer than less relevant information. Yet, visit durations on highly relevant information were longer when the scene was low ($M = 7.10$, $SD = 7.92$) rather than high ($M = 5.11$, $SD = 5.60$) in social content. This was confirmed by Tukey HSD least square mean comparison ($p < .05$). Regarding the information of low relevance, however, there was no significant difference between the visit durations to it in the high ($M = 3.99$, $SD = 4.10$) and low ($M = 3.99$, $SD = 7.93$) social content scenes ($p < .05$).

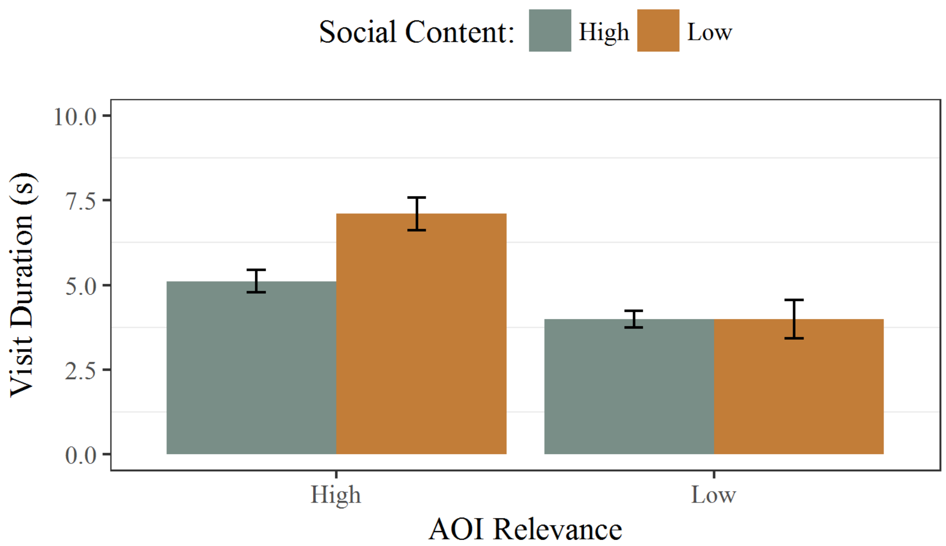

Figure 6.11. Mean visit duration per social content and AOI relevance. Error bars represent 95% CI.

Furthermore, AOI relevance moderated the effect of noise type (Figure 6.12), $F(2,814) = 16.25$, $p < .001$, $\eta^2_p = .04$. Tukey HSD pairwise comparisons revealed that in the no noise condition visit durations did not differ significantly between the high ($M = 5.39$, $SD = 7.22$) and low ($M = 4.41$, $SD = 4.45$) relevance AOIs ($p > .05$). However, visit durations were longer towards highly relevant information in both high- ($M = 6.87$, $SD = 7.17$) and low-intelligibility ($M = 6.07$, $SD = 6.29$) noise conditions than secondary information in the no noise, high- ($M = 3.88$, $SD = 4.57$), or low-intelligibility ($M = 3.73$, $SD = 7.87$) noise conditions ($p < .05$). Visit durations towards highly relevant information were also longer in the high-intelligibility condition than the no noise condition, whereas for the secondary information the significant difference occurred only between the no noise and low-intelligibility noise conditions ($p > .05$). No other comparisons in this interaction reached significance.

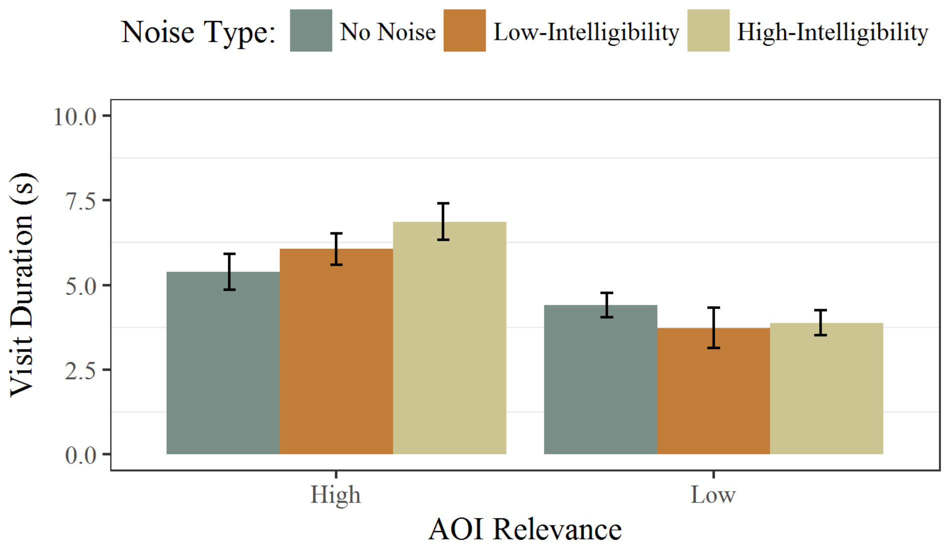

Figure 6.12. Mean visit duration per noise type and AOI relevance. Error bars represent 95% CI.

The type of noise presented during the trials also moderated the effect that social content had on visit duration (Figure 6.13), $F(2,226) = 12.58$, $p < .001$, $\eta^2_p = .10$. Tukey HSD comparisons confirmed that when low-intelligibility noise was present, average visit durations towards low social content ($M = 6.09$, $SD = 9.17$) scenes were significantly longer than those to high social content ($M = 3.87$, $SD = 4.43$) scenes ($p < .05$). In the high-intelligibility noise condition, however, there was no significant difference between the visit durations to high ($M = 5.39$, $SD = 5.45$) and low ($M = 5.72$, $SD = 7.24$) social content scenes ($p > .05$). According to the least mean square estimation, there were also no statistical differences between high- ($M = 4.43$, $SD = 4.77$) and low ($M = 5.58$, $SD = 7.47$) social content scenes in the no noise condition ($p > .05$). Visit durations to high social content scenes in the high-intelligibility condition were also significantly different from visit durations to high social content scenes in the low-intelligibility and no noise conditions ($p < .05$). Visit durations to high social content scenes in the no noise condition were also significantly shorter than those to low social content scenes in the low-intelligibility condition ($p <$ .05).

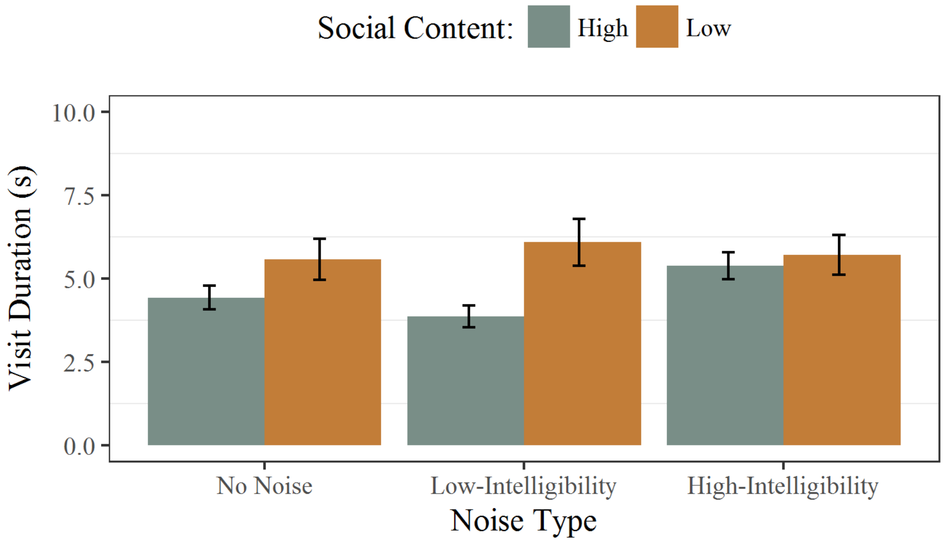

Figure 6.13. Mean visit duration per noise type and social content. Error bars represent 95% CI.

The presence and intelligibility of background noise were further involved in some three-way interactions. For instance, it moderated the effects of AOI relevance and type on visit duration (Figure 6.14), $F(2,814) = 4.12$, $p = .017$, $\eta^2_p = .01$. Tukey HSD pairwise comparisons were used to further investigate the interaction. Regarding visit durations towards highly relevant social and non-social information, respectively, they were significantly longer in the high-intelligibility noise condition (social: M = 7.59, SD = 7.93; non-social: M = 6.16, SD = 6.25) than the no noise condition (social: M = 6.06, SD = 8.55; non-social: M = 4.71, SD = 5.52; $p < .05$), neither of which differed significantly from the low-intelligibility noise condition (social: M = 6.90, SD = 6.57; non-social: M = 5.23, SD = 5.90; $p > .05$). Regarding the low relevance information there were no significant differences in visit durations towards non-social information across the different noise conditions (no noise: M = 4.15, SD = 1.67; low-intelligibility: M = 3.82, SD = 1.29; high-intelligibility: M = 3.73, SD = 1.53; $p > .05$).

They also did not significantly differ from visit durations towards low relevance social information in either the high-intelligibility (*M* = 4.14, *SD* = 7.13) or no noise (*M* = 4.81, *SD* = 6.85) conditions ($p > .05$). Yet, visit durations towards low relevance social information with low-intelligibility noise (*M* = 3.63, *SD* = 11.43) were significantly different from all other visit durations except those towards low relevance social information when high-intelligibility noise was present ($p < .05$).

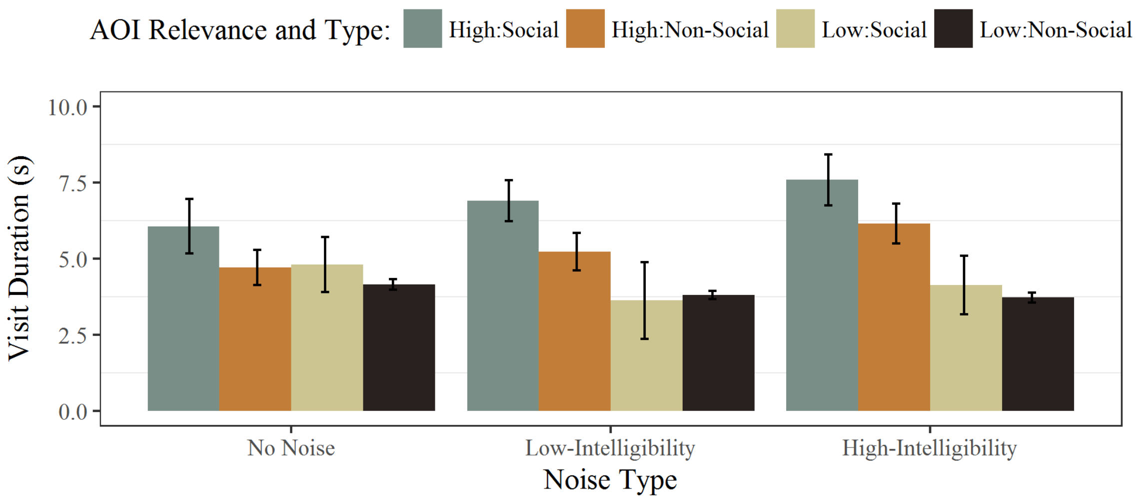

Figure 6.14. Mean visit duration per AOI relevance, AOI type, and noise type. Error bars represent 95% CI.

Background noise also moderated the effect of AOI type and social content (Figure 6.15), $F(2,814) = 6.82$, $p = .001$, $\eta^2_p = .02$. To be precise, there was a significant difference between visit durations towards social information in low (*M* = 7.43, *SD* = 12.50) and high (*M* = 3.60, *SD* = 4.47) social content scenes when low-intelligibility noise was present. When high-intelligibility noise was played there was a significant difference between visit durations towards non-social information in low (*M* = 4.08, *SD* = 3.61) or high (*M* = 5.82, *SD* = 5.47) social content scenes. Yet, there were no effects of social content on visit durations towards social information in the high-intelligibility condition (low social content: *M* = 8.36, *SD* = 10.23; high social content: *M* = 4.95, *SD* = 5.41) or towards non-social information in the low-intelligibility noise condition (low social content: *M* = 4.91, *SD* = 4.24; high social content: *M* = 4.14, *SD* = 4.38). In the no noise condition there also was no social content effect on visit durations towards either social (low social content: *M* = 6.86, *SD* = 10.52; high social content: *M* = 4.79, *SD* = 5.68) or non-social (low social content: *M* = 4.78, *SD* = 4.49; high social content: *M* = 4.08, *SD* = 3.61) information.

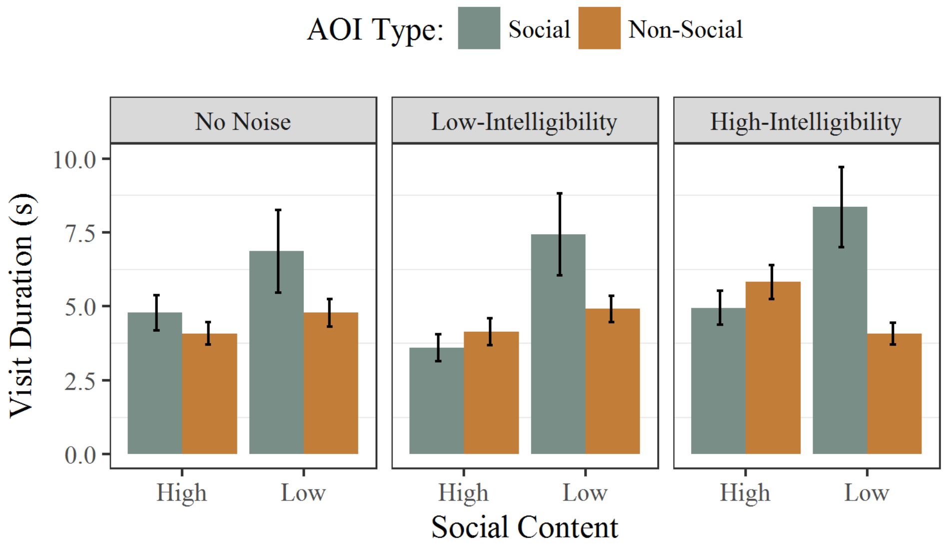

Figure 6.15. Mean visit duration per AOI type, social content, and noise type. Error bars represent 95% CI.

Another effect moderated by background noise type was the interaction between AOI relevance and social content of the scene (Figure 6.16), $F(2,814) = 20.00$, $p < .001$, $\eta^2_p = .05$. Tukey HSD comparisons were used to investigate the interaction, further. It revealed that in the high-intelligibility condition highly relevant information (high social content: *M* = 6.75, *SD* = 6.51; low social content: *M* = 7.00, *SD* = 7.78) received longer fixation durations than low relevance information (high social content: *M* = 4.03, *SD* = 3.68; low social content: *M* = 3.65, *SD* = 5.70) despite the number of people depicted within the scene (p < .05). In the low-intelligibility noise condition, however, highly relevant information received longer visit durations in low (*M* = 7.19, *SD* = 6.75) than high (*M* = 4.96, *SD* = 5.60) social content scenes (p < .05), whereas visit durations to low relevance information did not differ with social content (high: *M* = 2.78, *SD* = 2.36; low: *M* = 4.83, *SD* = 11.19; p > .05). When no background noise was present, however, in low social content scenes high relevance information (*M* = 7.11, *SD* = 9.09) received longer visit durations than secondary information (*M* = 3.13, *SD* = 1.83; $p < .05$). Yet, in high social content scenes this effect flipped and low relevance information (*M* = 5.20, *SD* = 5.34) received longer visit durations than high relevance AOIs (*M* = 3.66, *SD* = 3.99; $p < .05$).

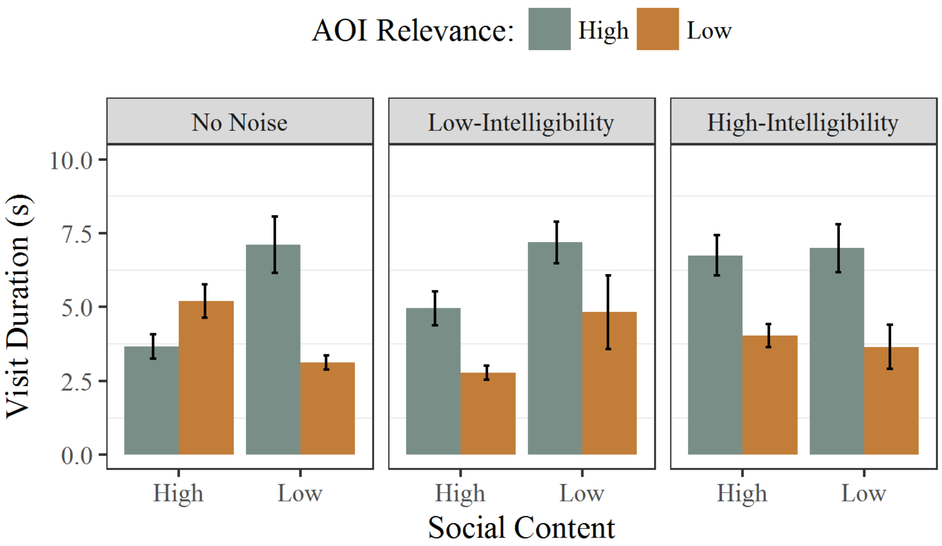

Figure 6.16. Mean visit duration per AOI relevance, social content, and noise type. Error bars represent 95% CI.

The latter effect between AOI relevance, social content, and noise type has further interacted with the AOI type (Figure 6.17), $F(2,814) = 12.71$, $p < .001$, η^2_p = .03. In the high-intelligibility condition, the difference between visit durations towards social (*M* = 8.97, *SD* = 9.49) and non-social (*M* = 5.03, *SD* = 4.84) information was only significant when looking at highly relevant information in low, but not high, social content scenes (social: *M* = 6.19, *SD* = 5.64; non-social: *M* = 7.30, *SD* = 7.24). There were also no significant differences between social and non-social information when looking at low relevance information in scenes of low (social: M = 5.84, SD = 12.65; non-social: M = 3.12, SD = 0.90) or high (social: M = 3.72, SD = 4.88; non-social: M = 4.34, SD = 1.78) social content. In the low-intelligibility condition, however, the difference between social and non-social information occurred in high social content scenes when looking at high (social: M = 5.72, SD = 5.10; non-social: M = 4.19, SD = 5.98) and low (social: M = 1.48, SD = 2.26; non-social: M = 4.08, SD = 1.64) relevance information. In low social content scenes, high relevance (social: M = 8.11, SD = 7.61; non-social: M = 6.28, SD = 5.64) information received longer visit durations than low relevance (social: M = 6.53, SD = 16.93; non-social: M = 3.54, SD = 0.69) information, despite the AOI type. Finally, in the no noise condition differences between social and non-social information occurred only when looking at low relevance information in low social content scenes (social: M = 1.13, SD = 2.54; non-social: M = 3.62, SD = 1.17). Yet, these differences were not there when looking at high relevance information in the same scenes (social: M = 8.28, SD = 11.25; non-social: M = 5.94, SD = 6.04) and either high (social: M = 3.85, SD = 3.18; non-social: M = 3.48, SD = 4.66) or low (social: M = 5.73, SD = 7.27; non-social: M = 4.68, SD = 1.92) relevance information in high social content scenes.

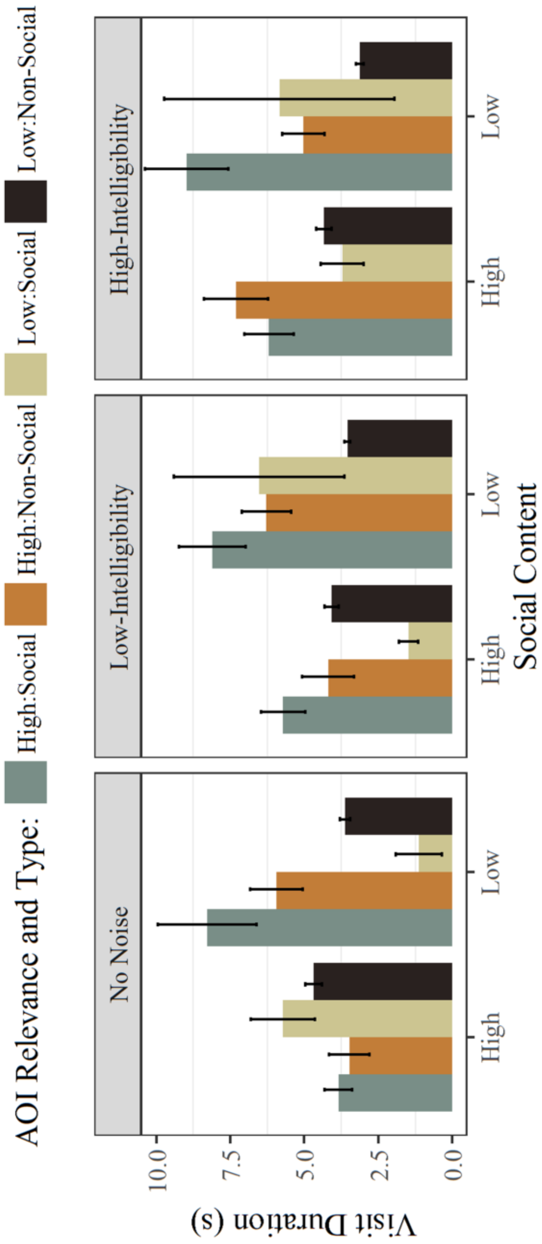

Figure 6.17. Mean visit duration per AOI relevance, type, social content, and noise type. Error bars represent 95% CI.

Discussion

The Experiment 5 is a novel study directly comparing attention to social and non-social information in naturalistic scenes within and between high-functioning adults with ASD and TD adults. Specifically, manipulation of the social content and relevance of the information allowed a further investigation into factors influencing attentional processes. Additionally, the presence and intelligibility of background noise were also investigated as potential influences.

In line with Hypothesis 1, adults with ASD exhibited reduced attention to social information when compared to TD individuals. Adults with ASD and TD, however, engaged with overall non-social information of the scenes for a similar amount of time (Hypothesis 2). It was further found that overall viewing time and attention to social information decreased with increased social content of the scene. Differently from Hypothesis 3, however, this effect was not moderated by having an ASD diagnosis, but instead it was moderated by type of background noise. There were, however, group differences in terms of preference for social and non-social information. As expected (Hypothesis 4), TD participants visited social more than non-social AOIs, yet adults with ASD did not exhibit a preference for either. The findings also revealed that whilst participants with ASD and TD engaged with the information deemed as more relevant more than that judged to be less relevant, adults with ASD did indeed look at the relevant information less than TD participants (Hypothesis 5). Again, no diagnostic differences were found with respect to the presence or the intelligibility of background noise. However, high-intelligibility background noise increased attention to high social content scenes overall and to the relevant information within the scene. The latter was especially true for the social information in low social content scenes. Therefore, the prediction that increased intelligibility of noise will reduce social attention (Hypothesis 7) was not supported.

Attentional Differences Between Adults with ASD and TD Individuals

Social and non-social biases. The main aim of the study described in this chapter was to investigate whether, and in what situations, individuals with ASD differ from TD individuals with regard to social attention to natural scenes. The natural scenes selected were divided into social (i.e. people) and non-social (i.e. objects and background) areas of interest, which were further standardised to be even in size to allow for direct comparisons both within and between participants. Our finding that adults with ASD look at social information (i.e. human figures) of a scene for less time than TD adults is in line with most of the previous studies (e.g. Klin et al., 2002; Riby & Hancock, 2008; Speer et al., 2007). This finding is also not that surprising given that the results of Chapter 5 already showed that adults with ASD looked at a single figure in naturalistic scenes proportionally less than TD adults.

Adults with ASD in the current sample, however, did not differ from TD adults in the amount of time spent exploring non-social information of a scene. This finding compliments some of the previous studies on children, adolescents and young adults with ASD (Fletcher-Watson et al., 2009; Riby & Hancock, 2008; Speer et al., 2007). Yet, it contradicts other studies on children and adolescents (Riby & Hancock, 2009b) or adults (Klin et al., 2002b) with ASD. The current study confirms that attention to social information within scenes is, indeed, reduced in high functioning adults with ASD when compared to TD adults. Moreover, it further extends our understanding of social attention in ASD by showing that this reduced attention to social information is a reflection of a stronger bias towards social information that is present in TD adults rather than a preference for the non-social information in adults with ASD.

Subjective relevance of the information. Another aim of this study was to investigate whether relevance of the information (e.g. a person in the forefront or a very bright computer screen) may moderate atypical social attention in ASD. Whilst both TD adults and those with ASD engaged with the information defined more rather than less relevant, adults with ASD engaged with the relevant information less than TD adults. It was also revealed that a social information bias occurred only in cases where there was subjectively more, but not less, relevant information. In other words, low relevant information in, for example, the background of a scene received the same amount of attention irrespective of its social nature, whereas human figures in, for example, the forefront of a scene were prioritised over other high relevance objects. Surprisingly, however, this was not moderated by having an ASD diagnosis. These findings, therefore, evidence that individuals with ASD may be poorer at prioritising perceived information as previously reported in anecdotal accounts of individuals with ASD (Bogdashina, 2003). It also suggests that high-functioning adults with ASD may, too, have a partial social bias towards highly relevant social information in a scene. In combination with previous evidence of a reduced social bias in ASD when compared to TD, however, this suggests that such a bias would also be reduced in adults with ASD.

Social content of the scene. The low social content of a scene is another factor possibly influencing the presence of reduced attention to social information in ASD (Chita-Tegmark, 2016; Guillon et al., 2014). This was investigated by examining participants' visit durations in scenes that were deemed by independent judges to be low (1 - 4 persons) or high (6 - 12 persons) in social content. First of all, it should be noted that the social content of a scene in this study did not moderate the presence of reduced attention to social information in ASD. Therefore, high-functioning adults with ASD did not exhibit a social bias, as strongly as TD adults, independent of the social content of the scene. Instead, it was revealed that visit durations in general were longer in low than high social content scenes for adults with ASD and TD, especially in terms of social information. This thus confirms some of the previous studies showing that both TD and ASD individuals display reduced attention to social information with an increase in the number of human figures present (e.g. Rigby et al., 2016), although contradicts others finding increased group differences (Chita-Tegmark, 2016; Speer et al., 2007). The inconsistency with findings of Speer et al. (2007), for example, could be explained by the fact that their finding may have been confounding the effects of stimulus content and dynamic presentation. This interpretation is further supported by Rigby et al. (2016), who in addition to not finding an effect of increased social content on group differences, showed that reduced social attention in ASD was more apparent in dynamic scenes. It should be noted, however, that information on the type of stimulus display was also included in the meta-analysis by Chita-Tegmark (2016), yet it failed to account for the effect of social content.

Nevertheless, the current findings offer a new insight into general visual processing independent of diagnosis. Previous studies (e.g. Birmingham et al., 2008) have so far shown that social attention increases as the number of people in the scene increase from one to more. By showing that social attention decreases between scenes with few and many characters, the current study suggests that reduced gaze duration may, in fact, be a curvilinear function of social content. In other words, attention paid to social information increases if there are a few people in the scene (e.g. Birmingham et al., 2008), but starts decreasing after a certain number of figures is reached. Future studies should systematically manipulate the number of people in the scene to reveal this saturation point.

It should be noted that the negative effect of social content was also moderated by relevance of the information viewed. To be precise, it was only applicable for information deemed as higher in relevance. Due to the overlap and size of the objects, it was impossible to directly control for the number of information units deemed as relevant across the scenes used. However, high social content scenes by default include more social units. Thus, this finding may indicate that there were more units, in general (i.e. figures and objects), judged as more highly relevant in high than low social content scenes. If that was so, reduced engagement with relevant information in high, as opposed to low, social content scenes could reflect time spent shifting attention between different units of information. This suggests that future studies may benefit from systematically manipulating not only the number of characters in a scene, but also the number of objects evoking attention.

Effects of Background Noise

Another aim of this thesis was to explore whether the presence or intelligibility of background noise may be affecting attentional processes in high-functioning adults with ASD differently from TD adults. Similarly, to the experiments in the previous chapters, however, the presence or intelligibility of background noise did not interact with the presence of a diagnosis in any way. Nevertheless, background noise influenced visit duration for participants with ASD and TD, alike. It also moderated the effects of AOI type, relevance, and social content. To be specific, listening to background noise with intelligible speech was associated with longer visit durations to high relevance information within a scene. High-intelligibility also increased visit durations to high social content scenes. Thus, while on average visit durations were shorter in scenes that encompassed more people, this was not the case for when background noise with intelligible speech was present. It appears that the presence of high-intelligibility noise increased attention to high relevance social and non-social information at the expense of low relevance social and non-social information, respectively. The findings of Chapter 5, however, showed that the presence of high-intelligibility noise decreased the proportional engagement with social information of the scenes. Further, investigation then revealed that the effect occurred due to reduced proportional engagement with off-centre located social information. In light of the current findings, one could speculate that off-centre information was more likely to be judged to be less relevant and thus received less attention when noise with speech was present.

The current findings show that intelligibility, rather than just presence, of background noise has a differential effect on attentional engagement with a stimulus. This finding is in line with open plan office research showing that increased intelligibility of background noise may interfere with, for example, memory tasks (Brocolini et al., 2016; Zaglauer et al., 2017). The load theory of selective attention (Lavie, 1995) suggests that allocation of perceptual resources to the distractor depend on the perceptual load of the target. In combination with similar findings in Chapter 5, the current study further supports the possibility that not only the perceptual load of the target, but also the distractor itself, may affect the control of perceptual resources.

Limitations and Future Directions

The experiment described in the current chapter has many strengths including, but not limited to, a stringent design and multiple explanatory variables. However, it also has space for improvement. For example, as previously mentioned, the information in the photographs used was evaluated by a group of independent judges to determine the relevance of social and non-social information. Not surprisingly, due to the smaller number of figures in the scene, some of the low social content stimuli did not encompass any social information of low relevance. Thus, viewing times on social secondary information in these trials were coded as missing for all participants. It should be noted that different scenes were presented in the different noise conditions to avoid repetition effects. Therefore, differences in attention to less relevant social information of low social content scenes across different noise conditions should be interpreted with caution.

Furthermore, only TD adults were in the group of independent judges, whose evaluations of the images were used to determine more and less relevant areas of the scenes. This has allowed the inference that attention allocation to more subjectively relevant information within the scenes was atypical in the current sample of individuals with ASD. Yet, one could argue that qualitatively different areas of the scene could be perceived as more relevant by individuals with ASD and thus not captured by the current design. It should be noted, however, that there were no differences between diagnostic groups in terms of attention to social or non-social information of lower subjective relevance. Thus, it is unlikely that adults with ASD prioritised information, which was not identified as relevant by any of judges. Having said that, the development of more objective and generalisable ways of distinguishing relevant information within the scenes would be beneficial. After all, whilst the current design can only be applied to the 24 photographs used in the current study, these findings indicate atypical prioritisation of relevant information in ASD, which should be investigated further.

Conclusion

The current chapter confirms that high-functioning adults with ASD have reduced attention to social information when compared to TD adults. It also confirms that the differences in social attention between high-functioning adults with ASD and

TD adults occur due to the presence of a stronger social bias in the TD sample rather than a non-social bias in adults with ASD. It further expands previous knowledge on visual attention in ASD, by revealing that high-functioning adults with ASD explore highly relevant information of a scene less than TD adults. The findings also suggest that increased social content of naturalistic scenes reduces attention to those scenes overall and particularly to social information in both TD and ASD adults alike.

Nevertheless, it is hard to say for sure whether the reduced gaze time to high social content scenes seen in TD adults and adults with ASD occurred due to the social or non-social nature of the content. After all, increasing the number of people, intuitively, increases the sensory load of the scene as well. Experiment 6 described in the next chapter, thus, will attempt to distinguish between those influences by manipulating the social and feature structure of patterns.

CHAPTER 7

EFFECTS OF SOCIAL AND FEATURE STRUCTURE IN ADULTS WITH ASD

Summary

Individuals with ASD are thought to process visual, social in particular, information differently from TD individuals (see Simmons et al., 2009). Yet, some social processing atypicalities could be occurring due to overall complexity of the stimuli. Thus, Experiment 6 aimed to distinguish between the interference of social structure and feature structure by using a novel paradigm. Reaction time and gaze behaviour of 26 high-functioning adults with ASD and 25 TD adults was measured. Participants were presented with 4x4 patterns of schematic faces, which belonged to one of the four conditions: high social structure, low social structure, high feature structure, or low feature structure. Manipulation of social structure was achieved by varying the number of interactions (i.e. schematic faces looking at each other) in the pattern, whilst the feature structure was kept constant. Similarly, feature structure was manipulated by varying the number of changes in gaze direction between schematic faces, whilst the number of interactions was kept constant. Results revealed that increased complexity in feature and social structure of the pattern both induced a longer time needed to correctly count the faces for adults with ASD and TD adults. In terms of visual attention, it was revealed that schematic faces that were manipulated to be looking at each other received more attention than faces that did not participate in these interactions across all conditions for TD adults. Yet, whilst otherwise similar, this effect did not occur for high-functioning adults with ASD when only one interaction was present. Therefore, it seems that while the complexity of patterns or the number of social interactions encountered may not affect overt performance of those with ASD differently from TD individuals, it seems to affect underlying attentional processes through reduced viewing of interacting faces.

Introduction

Langdell (1978) was one of the first to speculate that children and adolescents with ASD may regard social information (i.e. faces) simply as complex objects (i.e. "pure pattern"), rather than socially relevant ones ("social pattern"). Since then it has been revealed that individuals with ASD process both socially relevant and other visual information (see Simmons et al., 2009) differently from those without ASD. For instance, Experiment 5 in Chapter 6 found that changes in social content (number of people) of the scene moderated gaze behaviour in TD adults, but not adults with ASD. Yet, this effect did not differ based on whether the information engaged with at the time was social or non-social. Due to the social and sensory complexity reoccurring in naturalistic stimuli, such as used in Experiment 5, it is hard to distinguish which was responsible for the differences in the gaze behaviour observed. This is particularly important given that the previous studies using complex naturalistic stimuli often focus on attention to social information only (e.g. Hanley et al., 2013; Kuhn et al., 2010). Yet, it remains unclear whether processing of social and non-social information is related and whether atypical attention to social information in ASD occurs due to its social relevance or complexity as an object.

It has been previously shown that the complexity of visual tasks has an effect on the performance of individuals with ASD (Bertone et al., 2005). To be precise, it was found that individuals with ASD exhibit an enhanced performance when discriminating grating orientation on a simple task, but diminished performance on a more complex task. Research on complexity using social stimuli, however, is hard to evaluate in the same terms. For example, in their meta-analysis Chita-Tegmark (2016) found that the depiction of more than one person in a stimulus predicted a larger social attention impairment in individuals with ASD. The findings of Experiment 5 of the current thesis, however, showed that a social bias in general was only present in naturalistic scenes with fewer rather than more people. Moreover, having fewer people depicted increased overall visit durations on social and non-social information of the scene in TD individuals, but not adults with ASD. Yet, the overall complexity of a scene also increases with more people in the scene. Thus, it is hard to say whether the differences are occurring due to changes in complexity or an increased amount of socially relevant information.

A potential way of distinguishing between socially relevant and general complexity of information involves controlling for not only the number of people, but also their interactions. Observation of interactions between people in real life may offer important social information (e.g. emotions, relationships, etc.). Stagg et al. (2014) compared children with and without ASD on their attention to interacting and non-interacting pairs of cartoon-like figures. They found that TD children and children with ASD, but no language delay, looked at interacting figures for longer than children with ASD and a language delay, whereas attention paid to the non-interacting figures was similar across the groups. In TD adults, activity of the people in the scene has been previously shown to further increase a social bias (Birmingham et al., 2008). It is still difficult, however, to control naturalistic scenes for their structural complexity only, especially when manipulating the social aspects of it. Thus, the use of patterns may be more fitting in order to see whether social relevance affects performance or attention of individuals with and without ASD.

In general, visual perception requires perceptual organisation, which allows perception of scenes or patterns as structured wholes consisting of elements arranged in space (van der Helm, 2016). Wertheimer (1938) proposed *the law of Prägnanz* that underpins all human perception and states that ambiguous or complex information will be perceived and interpreted as the simplest form possible. Grouping principles, such as proximity, similarity, good continuation, common fate, closure, and symmetry, are used to organise a perceptual scene in a way which allows one to minimise the expenditure of energy (see Palmer & Rock, 1994). The idea of minimising the expenditure of energy is particularly relevant for the *simplicity principle* suggesting that "the less the amount of information needed to define a given organisation as compared to the other alternatives, the more likely that that interpretation will be perceived" (Hochberg & Mcalister, 1953; p.361). Consequently, it has been later suggested that complexity of a pattern can be described as a minimum amount of information needed to describe it (Aksentijevic & Gibson, 2012a; van der Helm, 2000).

A number of coding approaches, for example, including algorithmic information theory (AIT; e.g. Vitanyi & Li, 2000) and structural information theory (SIT; e.g. van der Helm, 2000), attempted to quantify structured information processing. In these models, stimuli are described as a code string, which can be compressed based on the rules representing grouping principles. Ultimately, the shortest statement that can encode the pattern represents its complexity. Notwithstanding their theoretical contributions, these measures of complexity that involve coding algorithms have been criticised for their inability to account for the processing effort and cost required (see Aksentijevic & Gibson, 2012b). In other words, devising the simplest possible code for a simple pattern may cost more computational energy than arriving at a code for a more complex pattern. This, in turn, contradicts the fact that simple patterns involve less effort and energy to process than complex patterns (e.g. Falk & Konold, 1997).

Aksentijevic and Gibson (2012a) suggest an alternative view to psychological complexity by proposing that complexity equals change. This notion is based on two assumptions. Firstly, structural information in a string or pattern is related to the transition (i.e. change) from one unit of the pattern to another rather than the unit itself (e.g. Attneave, 1954). Secondly, as per the *Minimum Principle* of Gestalt psychology (see Koffka, 1999), patterns are considered *good*, if they are compact, symmetrical, repetitive, and predictable. It is suggested that such a pattern should contain little change in order to be easy to describe and compress. In contrast, a pattern that would be perceived as complex and thus harder to process should involve more structural changes between the pattern units.

This view of binary change as the simplest representation of structural complexity (Vitz, 1968), in combination with social relevance of interactions, provides a potential avenue for distinguishing between feature and social aspects of the pattern structure. For instance, feature structure can be easily manipulated in terms of the binary array (Figure 7.1). In the example given the change is manipulated at the lowest level between the runs in each row. To be specific, the top row of the array depicts three changes between runs, whereas the bottom one depicts one change only. Creating a number of such arrays differing only in the number of changes allows a comparison in processing of structurally simpler and more complex patterns. The same pattern, however, can be expressed in any other binary element. Take for instance a pattern consisting of a number of copies of the same face that only vary in one feature (i.e. gaze direction; Figure 7.2). Both patterns depict same number of changes between the runs, yet the use of gaze direction allows for an additional level of grouping based on eye contact. Thus, manipulating that feature should allow inducing change between units (change in gaze direction) and social contact (reciprocal gaze between two units).

In other words, patterns varying in gaze direction only could be considered to reflect interference from feature, rather than social, structure. Patterns differing in the number of “interactions” would represent interference from only socially relevant structure, as the general complexity expressed as a number of changes would already be controlled for.

1	0	1	0
0	1	0	1
1	0	0	1
0	0	1	1

Figure 7.1. Patterns representing manipulation of feature structure using the concept of change between the runs of binary units.

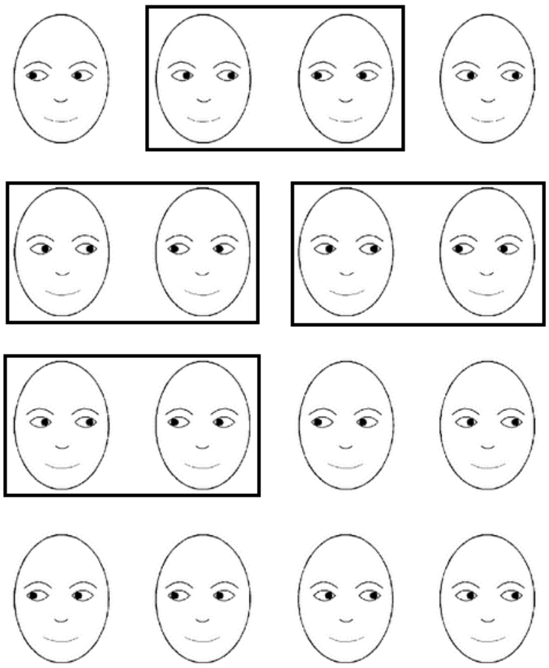

Figure 7.2. Patterns representing manipulation of feature and social structure (framed faces represent reciprocal interactions).

Individuals with ASD are known to process certain patterns just as successfully or even faster than controls (see Simmons et al., 2009). To be precise, a number of studies have shown that individuals with ASD excel at the embedded figures test (e.g. Cribb et al., 2016; Shah & Frith, 1983) and block design (e.g. Ropar & Mitchell, 2001; Shah & Frith, 1993). For the pattern to be perceived, a relationship between different units must also be processed, thus processing of a whole structure is required. Indeed, superior performance in pattern perception in individuals with ASD is often explained via differences in hierarchical perception. Such theories as Weak Central Coherence (WCC; Frith & Happé, 1994; Happé & Frith, 2006), reduced generalisation (Plaisted, 2001), and Enhanced Perceptual Functioning (EPF; Mottron et al., 2006), in particular, address hierarchical processing atypicalities in ASD. Attention to the structure based on the notion of change, as any pattern, would also involve processing at both local and global levels. That would, especially, be the case when one is guided to focus on local features (e.g. how many faces are looking to the left or right).

Aims

The main aim of the current study was to distinguish between the interference of social and feature structure on the performance and gaze behaviour of high-functioning adults with ASD. This was achieved by creating and utilizing a novel paradigm consisting of 4x4 patterns of schematic faces that varied only in gaze direction. Manipulation of the social structure was achieved by varying the number of reciprocal interactions (i.e. faces looking at each other) in the pattern, whilst the feature structure was kept constant. The feature structure was, likewise, manipulated by varying changes in gaze direction between units, whilst the social structure was kept constant (Figure 7.2). Two measures were used to obtain a comprehensive evaluation of such manipulations. Manual reaction time (RT) data was collected to see how and whether the general social or feature pattern structure interfered with performance of high-functioning adults with ASD and TD adults. Eye-tracking data was collected simultaneously in order to see whether the presence of reciprocal social interaction moderated their attentional engagement with the schematic faces in the pattern.

Evaluation of whether and how the structural changes interfered with the manual RTs was possible due to task instructions. To be precise, as participants were asked to count faces looking to the left or right, the structure of the pattern was not directly related to the task given. In turn, the potential interference of these structural relationships was aimed to be evaluated in light of the main hierarchical processing theories.

Three existent psychological theories concerning perception at the global and local level are of particular relevance for the possible processing differences between individuals with and without ASD. Firstly, the WCC (Frith & Happé, 1994; Happé & Frith, 2006) theory suggests that individuals with ASD may have a bias to process information locally and fail to extract the gist or meaning of events in everyday life as TD individuals would. Therefore, according to WCC, perception of structures in ASD would occur via a piecemeal rather than a global approach. Secondly, Plaisted's (2001) theory of reduced generalisation offers an alternative account. The theory suggests that individuals with ASD have reduced processing of the similarities, and in turn are more sensitive to the differences, between stimuli and situations. In other words, the theory suggests that individuals with ASD should not benefit from simplistic stimuli with little change between the units. Finally, the theory of EPF (Mottron et al., 2006) posits that global processing is mandatory in TD, whilst the default setting of perception in individuals with ASD is locally oriented, but flexible. In terms of hierarchical processing, it suggests that individuals with ASD can process information at both levels and thus that interference from both local and global information would be experienced. Therefore, if the interference from a feature structure in a pattern involves hierarchical processing, performance of individuals with ASD would be affected by global interference in one of these three ways (see Hypotheses section below).

The aim to investigate how the presence of reciprocal social interaction and structural changes affected social visual attention of adults with ASD was achieved via eye-tracking data. To be specific, it was explored whether the more social faces that were involved in reciprocal interactions received more of the visual attention than faces that were not. It was further explored how that was affected by the overall pattern structure.

The effects of the presence and intelligibility of background noise on participants' performance were also evaluated, as in the previous chapters. To be precise the aim again was to further investigate the possibility of intersensory integration difficulties and/or enhanced perceptual load in affecting gaze behaviour in ASD.

Hypotheses

Given the global structure of the pattern, it was expected that TD individuals will exhibit higher interference through slower RTs from a more, rather than less, complex feature structure (Hypothesis 1). Three competing predictions were raised regarding the RT performance of adults with ASD. Firstly, due to piecemeal processing, the global structure of the pattern will not interfere with RT performance. Therefore, participants with ASD will respond to patterns with low and high feature structure at a similar speed to TD individuals responding to low feature structure patterns (Hypothesis 2a: WCC hypothesis). Secondly, as individuals with ASD are posited to be less sensitive to stimuli sharing common features, it was expected that they will benefit from the simple (low feature structure) patterns less than TD participants. In other words, participants with ASD again were predicted to not differ on performance between low and high feature structure patterns, this time responding closer to TD adults' RTs on high feature structure trials (Hypothesis 2b: reduced generalisation hypothesis). Thirdly, EPF proposes that individuals with ASD process information from both local and global levels at the same time, suggesting that they are prone to both local and global interference. Yet, RTs were measured only at the local level and thus susceptible to global interference only. Thus, it was expected that adults with ASD will perform similarly to adults with TD by responding slower in the high, rather than low, feature structure trials (Hypothesis 2c: EPF hypothesis).

As TD individuals usually exhibit a social bias (Birmingham et al., 2008; Yarbus, 1967), it was expected that TD adults will experience more interference to their RTs from a higher social structure patterns than a high feature structure patterns (Hypothesis 3). It was also expected to be accompanied by an increased attention to faces looking at each other in comparison to those that were not (Hypothesis 4). In contrast, it was hypothesised that participants with ASD will not experience the same interference of increased social structure on RTs (Hypothesis 5). Stagg et al. (2014) previously found some evidence of atypical attention towards social interactions in children with ASD. Thus, it was further predicted that interacting faces sharing reciprocal gaze will attract less visual attention as represented by eye-tracking data from participants with ASD than TD (Hypothesis 6).

As in previous experiments, it was again expected that increased intelligibility of background noise will diminish social attention (i.e. interacting faces) independent of the diagnosis (Hypothesis 7). Given that in their meta-analysis Szalma and Hancock (2011) concluded that the detrimental effects of noise are stronger in psychomotor and communication tasks rather than perceptual or attention tasks, it was expected that a more pronounced interference of noise may occur for the manual RTs. In turn, it was expected that it may reveal diagnosis-based differences, yet due to the lack of previous research no a priori predictions were postulated.

EXPERIMENT 6

Methods

Participants

All the participants (see Chapter 2) completed this experiment. One participant with ASD and one participant from TD group were omitted from the sample due to testing session issues (e.g. inability to follow instructions). Therefore, the final sample consisted of 26 high-functioning adults with ASD (13 females) and 25 TD adults (13 females)[5]. The mean chronological age of the individuals with ASD was 38 years and 9 months, ranging between 18 years 5 months and 63 years 3 months. For TD participants, the mean chronological age was 36 years and 7 months with a range from 19 years 11 months to 64 years. No significant differences in gender ($\chi^2(1) = 0.20$, $p = .886$) and age, as well as full, verbal, or performance IQ as estimated by the full Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), were observed between the groups (see Table 7.1). Scores on the Autism Spectrum Quotient (Baron-Cohen et al., 2001) in TD sample were significantly lower than the ASD group (Table 7.1).

[5] The excluded participant with ASD differed from the main sample on several measures. This included scoring lower on full ($t(25) = -2.60$, $p = .015$), verbal ($t(25) = -2.21$, $p = .037$), and performance IQ ($t(25) = -2.46$, $p = .021$). They also scored lower on the Sensation Seeking subscale of the Sensory Profile ($t(25) = -2.33$, $p = .028$), Identifying Feelings subscale of Toronto Alexithymia Scale ($t(25) = -2.39$, $p = .025$), and Social Skills subscale of Autism Quotient ($t(25) = -3.15$, $p = .004$). They did not differ on any other background characteristics (*p*s > .052). The excluded TD participant did not differ from included ones on any of the background information (*p*s > .090).

Table 7.1

Participant Comparison on Age, IQ, and AQ per Diagnosis

	ASD (*n* = 26)			TD (*n* = 25)			$t(49)$	p
	M	*SD*	Range	*M*	*SD*	Range		
Age	38.79	13.82	18-63	36.61	13.84	19-64	-0.56	.577
FSIQ	111.62	13.06	78-134	110.68	11.19	83-125	-0.27	.785
VIQ	108.73	13.65	71-129	109.04	10.72	81-127	0.09	.929
PIQ	112.19	12.86	81-136	110.32	12.65	84-138	-0.52	.603
AQ	35.38	6.41	21-48	18.64	5.95	5-29	-9.66	<.001

Note. FSIQ = full scale IQ, VIQ = verbal IQ, PIQ = performance IQ, and AQ = Autism Spectrum Quotient.

Stimuli and Apparatus

Monochrome stimuli were presented on a 40 x 30 cm (1024 x 768 px) CRT monitor with a white background. Custom-made stimuli with varying feature or social structure manipulated were utilized in this task. Each stimulus composed of a 4x4 matrix of faces differentiating in gaze direction (Figure 7.3). This task was based on the notion that complexity can be defined by change between the elements (Aksentijevic & Gibson, 2012a). Thus, in the current paradigm, the simplest structural manipulation of change between runs within rows was utilized. Horizontal changes in gaze direction represent feature structure, whilst faces looking at each other represent reciprocal social interactions.

A number of different matrices of faces were created in order to find the best combination to represent conditions of low and high feature structure and low and high social structure, as well as provide sufficient variability of possible answers for the task set to participants (number of faces looking to the left or the right). It was found that for the feature structure manipulation, keeping the social structure at four reciprocal interactions whilst controlling the structure to represent four (low feature structure condition) or nine (high feature structure condition) changes produced the largest array of choices. For the social structure conditions, a combination of six structural changes and either one (low social structure condition) or five (high social structure condition) reciprocal interactions produced the best result. Therefore, 64 unique stimuli (see Appendix E for the full set of stimuli) were created to correspond to the four complexity conditions. Each condition included 16 matrices. They further represented four possible combinations of faces (four matrices each): 5 faces looking one direction (i.e. left or right) and 11 looking at the opposite direction; 6 faces looking one direction and 10 looking the other way; 7 faces one way and 9 faces the other; or 8 faces looking to the left and 8 faces looking to the right. These were split in half to have two matrices each depicting the smaller number of faces looking to the left and two matrices with the same number of faces looking to the right. Matrices spanned across 12.62^{o} x 15.74^{o} (17.67 x 22.07 cm) and each face was presented at 2.35^{o} x 3.16^{o} (3.28 x 4.41 cm) size.

Similarly to the previously described experiments, audio stimuli were used in addition to visual stimuli. All three noise conditions: control (no noise), low-intelligibility noise, and high-intelligibility noise, were utilized. The interface of the E-prime stimulus presentation package (Psychology Software Tools Inc., 2012) and a Tobii x120 eye-tracker (Tobii Technology AB, 2010) was again used to present the stimuli and record the data (see Chapter 2).

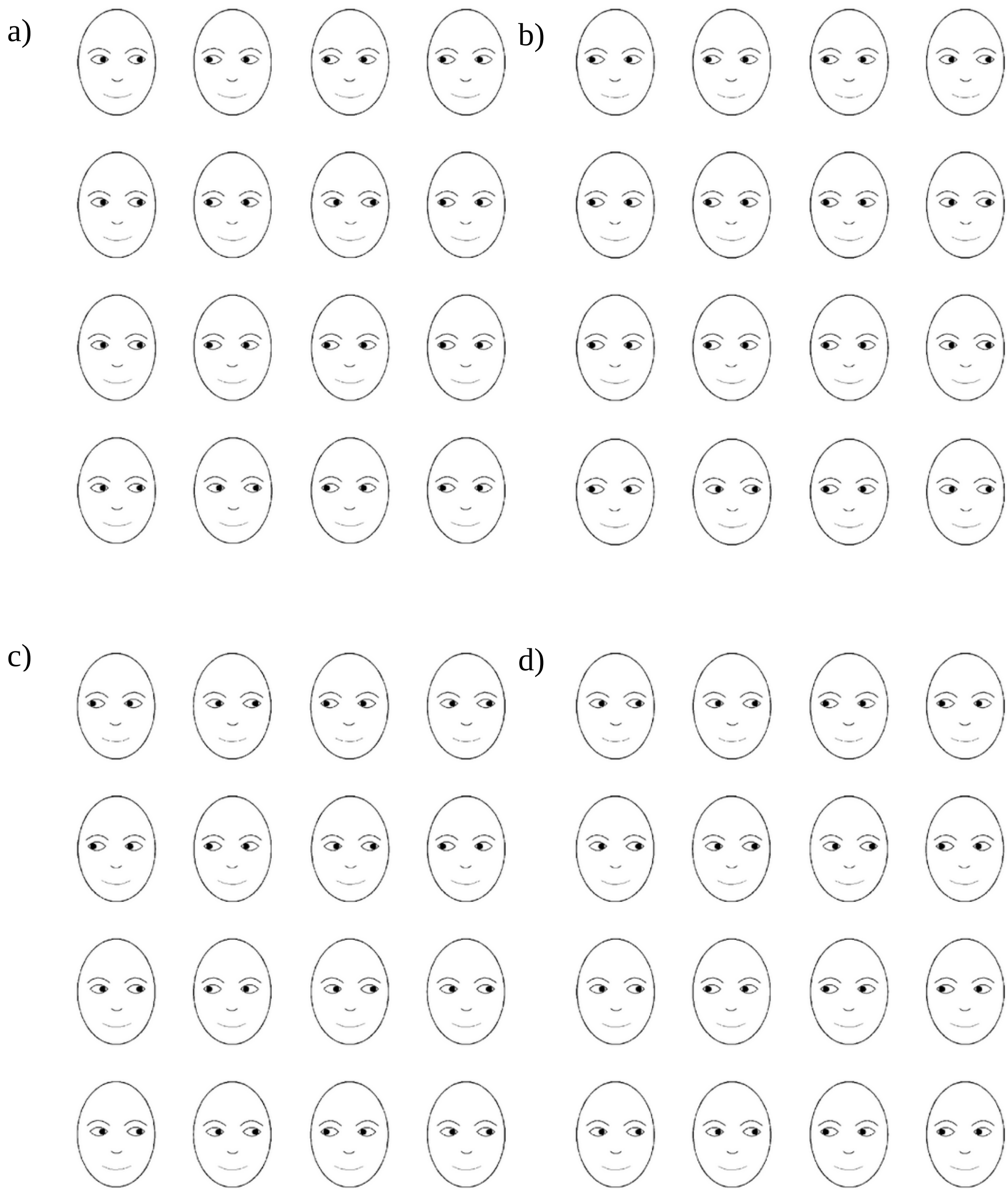

Figure 7.3. Sample stimuli used in the structure manipulation task. Stimuli were grouped into four conditions, where either social, or feature structure was manipulated whilst the other one was kept constant: a) high social structure condition with five social interactions and six feature changes; b) low social structure condition with one social interaction and six feature changes; c) high feature structure condition with four social interactions and nine feature changes; d) low feature structure condition with four social interactions and four feature changes.

Procedure

The task was presented in a 2x2x3 within-subject design, where one variable was the level of structure manipulated (low or high), the other was the type of structure manipulated (feature or social), and the third one was noise (no noise, low-intelligibility noise, and high-intelligibility noise). The experiment encompassed 192 trials in total (16 per condition), split into three noise-based blocks. Both the order of blocks and trials within them were fully randomised. Each block took around 10 minutes to complete.

Each participant received on-screen and verbal instructions regarding the procedure of the task. Participants were instructed to look at the matrices of faces appearing on the screen, count the number of faces looking either to the right or to the left, and input their response using the stimulus response keyboard (5, 6, 7, 8, or 9). At the beginning of each trial, a prompt indicating the task was presented (1500 ms), for example, “How many faces are looking to the RIGHT?”. Once the prompt disappeared, a matrix was presented in the middle of the screen. Additionally, above the matrix, an arrow of 3.55º x 0.98º (4.96 x 1.37 cm) pointing towards the left or the right (depending on the prompt) was displayed as a reminder of the task. Both the stimulus and the arrow were displayed until the participant responded.

Data Analysis

Participants with ASD were missing RT data on 0.16% (M = 0.31, SD = 0.79) of trials, whilst TD participants were missing RT data on 0.15% (M = 0.28, SD = 0.84) trials. Thus, the amount responses missing did not significantly differ between groups, $t(49) = 1.21$, $p = .904$. The amount of incorrect responses also did not differ between the participant groups. Indeed, participants with ASD made errors in 15% (M = 28.35, SD = 19.43) of trials on average and TD individuals in this study made errors on 11%

(M = 21.08, SD = 12.10) of trials, $t(49) = 1.60$, $p = .117$. Thus, incorrect trials were also excluded from the analyses as they were often contaminated by interruptions or technical problems.

Reaction time data. Manual reaction time (RT) data was analysed in order to see whether different stimuli conditions affected participants' performance. The Shapiro-Wilk normality test and graphical examination of residual values revealed that the RT data was positively skewed in both participant groups, TD: $W = .70$, $p < .001$, ASD: $W = .68$, $p < .001$. Thus, a log-transformation with the base 10 was applied to the data. The graphical examination of the log-transformed data confirmed that the distribution of residual values was sufficiently improved, although the Shapiro-Wilk normality test remained significant in both groups, TD: $W = .91$, $p < .001$, ASD: $W = .89$, $p < .001$.

The RT data was then analysed using linear mixed-effect (multilevel) modelling with a 2x2x2x3 design as an alternative to ANOVA (see Chapter 2). Participant information including their diagnostic details (ASD or TD) was modelled at the third level of the multilevel analysis. Nested within each participant, trial information with the level (high or low) and type (social or feature) of structure manipulated and noise type (no noise, low-intelligibility, or high-intelligibility noise) as predictors were modelled at the second level. RTs for each trial were modelled at the first level, nested within each trial.

Eye-tracking data. The sum of all fixation durations per AOI was used as an eye-tracking measure in this study. Each matrix of faces was divided into 16 equal AOIs, thus each AOI represented one face. Fixation durations per face rather than a pair of faces was chosen as a measure, because the faces that did not participate in reciprocal interactions were not always presented consecutively. The face AOIs were subsequently divided into those representing interacting (faces from pairs looking at each other) and non-interacting faces (faces from pairs without returned gaze). The sum of fixation durations in a particular stimulus was then averaged for all the interacting and non-interacting faces, respectively. Therefore, the final data represented mean fixation duration per single face, which either was or was not a part of interacting pair, in each trial.

Due to the technical constraints of the Shapiro-Wilks normality test (i.e. not possible for a sample size over 5000), Anderson-Darling normality tests were applied for the eye-tracking data, instead. In combination with the graphical examination of residual values, it showed that the fixation duration data was positively skewed in both participant groups, TD: $A = 218.42$, $p < .001$, ASD: $A = 265.75$, $p < .001$. Thus, a log-transformation with the basis of 10 was applied to the data. Zero values in the current experiment were meaningful as they reflected that the overall stimulus, but not particular AOI, was engaged with. As a log-transformation of zero values is not plausible, one measurement unit was added to every existent value before the log value was computed (Field, 2013). The graphical examination of the log-transformed data confirmed that the distribution of residual values was sufficiently improved, although normality test remained significant in both groups, TD: $A = 105.36$, $p < .001$, ASD: $A = 129.57$, $p < .001$.

The log-transformed fixation duration data in seconds was then analysed using linear mixed-effect (multilevel) modelling with a 2x2x2x3x2 design. Participant information including their diagnostic details (ASD or TD) was modelled at the fourth level of the multilevel analysis. Nested within each participant, trial information with the level (high or low) and type (social or feature) of structure manipulated, and noise type (no noise, low-intelligibility, or high-intelligibility) as predictors were modelled at the third level. AOI information with the presence of reciprocal interaction (interacting or non-interacting) was modelled within each trial type at the second level. The first level included visit duration times per each AOI.

Results

Reaction time Data

The mean RTs in seconds for both diagnostic groups per level and type of structure manipulated, and noise type are shown in Table 7.2. Results of the multilevel model building (Table 7.3) revealed that the main effect of diagnosis was not significant, $F(1,49) = 2.12$, $p = .152$, $\eta^2_p = .04$. In other words, participants with an ASD diagnosis (*M* = 11.14, *SD* = 4.77) did not differ on average RT from those with TD (*M* = 10.22, *SD* = 3.65).

Table 7.2

Means (M) and Standard Deviations (SD) of Reaction time (s) per Diagnosis, Noise Type, and Level and Type of Structure Manipulated

	ASD (*n* = 26)		TD (*n* = 25)	
	M	*SD*	*M*	*SD*
High-Intelligibility Noise				
High Social Structure	11.10	6.00	10.58	3.44
Low Social Structure	11.07	4.71	10.27	3.30
High Feature Structure	11.66	5.08	10.47	3.06
Low Feature Structure	11.43	5.41	10.48	3.37
Low-Intelligibility Noise				
High Social Structure	11.00	4.73	9.94	3.29
Low Social Structure	11.01	3.86	9.95	3.64
High Feature Structure	11.66	4.44	10.00	3.03
Low Feature Structure	11.17	4.65	10.06	3.78
No Noise				
High Social Structure	10.88	4.38	10.34	3.64
Low Social Structure	10.54	4.17	9.84	3.00
High Feature Structure	10.97	4.32	10.48	4.04
Low Feature Structure	11.25	5.11	10.27	5.38

Note. The average scores for each condition are presented here. For subsequent analyses, log-transformed data were used.

Table 7.3

Reaction time Model Summary of the Main Effects and Interactions

	df	df_{error}	*F*	*p*	η^2_p
Noise type	2	8186	12.69	<.001	<.01
Level of manipulation	1	253	7.94	.005	.03
Type manipulated	1	8186	17.51	<.001	<.01
Diagnosis	1	49	2.12	.152	.04
Noise type * Diagnosis	2	8186	10.07	<.001	<.01
Level of manipulation * Diagnosis	1	253	0.54	.465	<.01
Type manipulated * Diagnosis	1	8186	2.46	.117	<.01
Noise type * Level of manipulation	2	8186	0.25	.778	<.01
Noise type * Type manipulated	2	8186	0.28	.758	<.01
Level and Type manipulated	1	8186	0.03	.859	<.01
Noise type * Level of manipulation * Diagnosis	2	8186	1.43	.240	<.01
Noise type * Type manipulated * Diagnosis	2	8186	0.22	.806	<.01
Level and Type manipulated * Diagnosis	1	8186	0.66	.416	<.01
Noise type * Level and Type manipulated	2	8186	1.21	.298	<.01
Noise type * Level and Type manipulated * Diagnosis	2	8186	1.55	.213	<.01

Note. Noise type = no noise, low-intelligibility, or high-intelligibility noise; Level of manipulation = low or high; Type manipulated = social or feature; Diagnosis = ASD or TD.

Nevertheless, the analysis showed (Table 7.3) that the main effect of noise was significant, $F(2,8186) = 12.69$, $p = .032$, $\eta^2_p < .01$. Tukey HSD pairwise comparisons (Figure 7.4) confirmed that the significant difference occurred between average RT during the high-intelligibility noise ($M = 10.88$, $SD = 4.44$) and no noise conditions ($M = 10.57$, $SD = 4.33$). Similarly, there was a significant difference between the high- and low-intelligibility noise ($M = 10.59$, $SD = 4.01$) conditions.

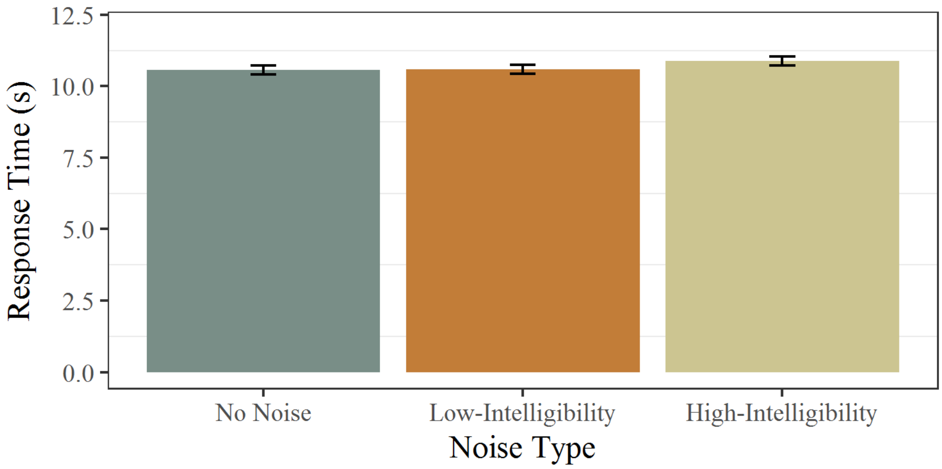

Figure 7.4. Mean reaction time per type of noise. Error bars represent 95% CI.

The main effects of the level and the type of structure manipulated on participants' RTs were also revealed to be significant (Table 7.3). On average participants responded faster in low social and feature structure trials (M = 10.61, SD = 4.30) than high social and feature structure trials (M = 10.75, SD = 4.23; Figure 7.5), $F(1,253) = 7.94$, $p = .005$, $\eta^2_p = .03$. Participants also responded, on average, faster in the trials where social (M = 10.54, SD = 4.10), rather than feature (M = 10.82, SD = 4.43), structure was manipulated, $F(1,8186) = 17.51$, $p < .001$, $\eta^2_p < .01$ (Figure 7.6).

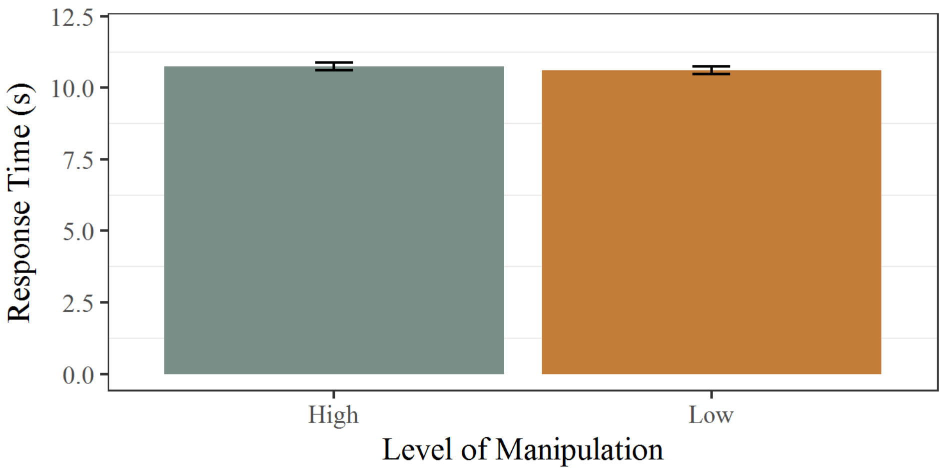

Figure 7.5. Mean reaction time per level of structure manipulated. Error bars represent 95% CI.

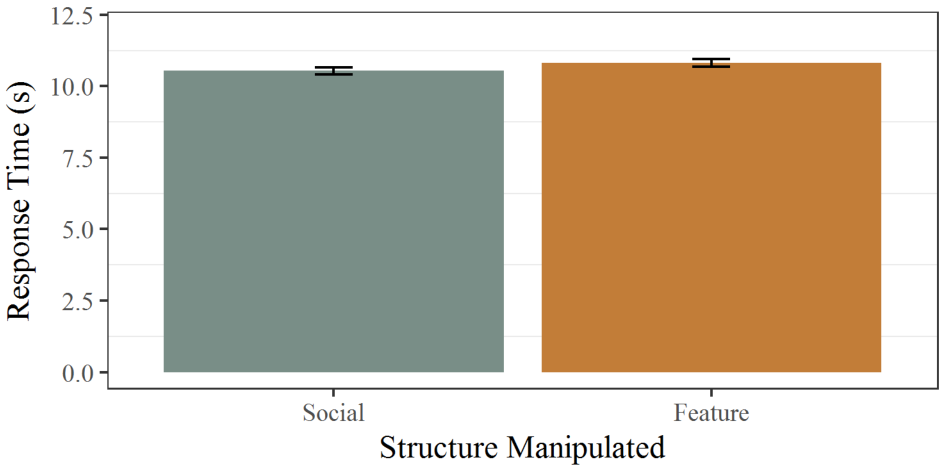

Figure 7.6. Mean reaction time per type of structure manipulated. Error bars represent 95% CI.

Only one of the interaction terms included in the final model reached significance (Table 7.3). Having a diagnosis moderated the effect of noise on participants' RTs (Figure 7.7), $F(2,8186) = 12.69$, $p < .001$, $\eta^2_p < .01$. To be precise, TD participants reacted to the high-intelligibility condition ($M = 10.45$, $SD = 3.30$) slower than both the low-intelligibility ($M = 9.99$, $SD = 3.45$) and no noise ($M = 10.23$, $SD = 4.12$) conditions. Participants with ASD, however, reacted to the no noise condition ($M = 10.91$, $SD = 4.52$) slower than both the high- ($M = 11.31$, $SD = 5.32$) and low-intelligibility ($M = 11.20$, $SD = 4.43$) conditions. These were confirmed using Tukey HSD pairwise comparisons. None of the other main or interaction effects in the model yielded significance (Table 7.3).

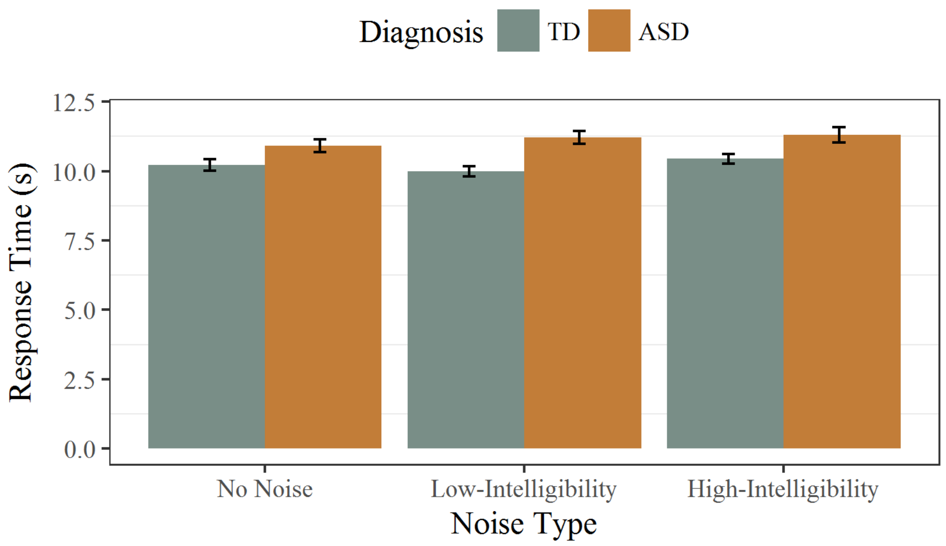

Figure 7.7. Mean reaction time per type of noise and diagnosis. Error bars represent 95% CI.

Eye-tracking Data

In comparison to the reaction time analysis, an additional variable has been added to the model to allow examination of attentional bias. To be precise, an interaction variable indicating whether a schematic face was or was not part of reciprocal interaction was included. The mean fixation durations in seconds for both groups of diagnosis per interaction, level and type of structure manipulated, and noise type are shown in Table 7.4. All the main effect and interaction terms included in the model can be seen in Table 7.5.

Multilevel model building revealed that the main effect of diagnosis was not significant, $F(1,49) = 0.60$, $p = .444$, $\eta^2_p = .01$. Hence, participants with an ASD diagnosis ($M = 0.40$, $SD = 0.28$) did not differ on average fixation duration from those with TD ($M = 0.41$, $SD = 0.21$). The effect of level of pattern structure manipulated was also non-significant. Participants' fixation duration lasted on average the same whether the trials were presented in high social or feature structure ($M = 0.40$, $SD = 0.23$) or low ones ($M = 0.41$, $SD = 0.26$), $F(1,529) = 0.76$, $p = .384$, $\eta^2_p < .01$.

Table 7.4

Means (M) and Standard Deviations (SD) of Fixation Duration per Diagnosis, Interaction, Noise Type, and Manipulation

	ASD (n = 26)				TD (n = 25)			
	Interacting Face		Non-Interacting Face		Interacting Face		Non-Interacting Face	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
High-Intelligibility Noise								
High Social Structure	0.41	0.27	0.36	0.25	0.45	0.22	0.39	0.21
Low Social Structure	0.43	0.40	0.40	0.28	0.48	0.29	0.40	0.18
High Feature Structure	0.44	0.31	0.38	0.23	0.47	0.23	0.38	0.17
Low Feature Structure	0.45	0.41	0.38	0.29	0.46	0.23	0.39	0.20
Low-Intelligibility Noise								
High Social Structure	0.45	0.25	0.39	0.24	0.40	0.19	0.34	0.16
Low Social Structure	0.40	0.31	0.39	0.23	0.43	0.28	0.36	0.16
High Feature Structure	0.49	0.32	0.42	0.26	0.41	0.20	0.35	0.16
Low Feature Structure	0.48	0.33	0.40	0.25	0.42	0.24	0.36	0.17
No Noise								
High Social Structure	0.38	0.22	0.33	0.20	0.43	0.20	0.36	0.16
Low Social Structure	0.38	0.27	0.35	0.18	0.45	0.25	0.38	0.16
High Feature Structure	0.40	0.28	0.34	0.21	0.44	0.23	0.38	0.18
Low Feature Structure	0.42	0.26	0.35	0.23	0.43	0.20	0.37	0.16

Note. The average scores for each condition are presented here. For subsequent analyses, log transformed data were used.

Table 7.5

Fixation Time Model Summary of the Main Effects and Interactions

	df	df_{error}	F	p	η^2_p
Noise type	2	529	3.89	.021	.01
Interaction	1	578	463.66	<.001	.45
Level of manipulation	1	529	0.76	.384	<.01
Type manipulated	1	529	4.66	.031	.01
Diagnosis	1	49	0.60	.444	.01
Noise type * Diagnosis	2	529	4.14	.016	.02
Interaction * Diagnosis	1	578	9.81	.002	.02
Level of manipulation * Diagnosis	1	529	0.76	.385	<.01
Type manipulated * Diagnosis	1	529	3.56	.060	.01
Noise type * Interaction	2	578	0.45	.640	<.01
Noise type * Level of manipulation	2	529	0.28	.753	<.01
Noise type * Type manipulated	2	529	0.31	.735	<.01
Interaction * Level of manipulation	1	578	4.52	.034	.01
Level and Type manipulated	1	529	1.22	.270	<.01
Interaction * Type manipulated	1	578	8.45	.004	.01
Noise type * Interaction * Diagnosis	2	578	0.79	.453	<.01

	df	df_{error}	*F*	*p*	η^2_p
Noise type * Level of manipulation * Diagnosis	2	529	1.07	.343	<.01
Noise type * Type manipulated * Diagnosis	2	529	0.14	.870	<.01
Interaction * Level of manipulation * Diagnosis	1	578	4.30	.039	.01
Interaction * Type manipulated * Diagnosis	1	578	10.11	.002	.02
Level and Type manipulated * Diagnosis	1	529	0.28	.596	<.01
Noise type * Interaction * Level of manipulation	2	578	0.00	.996	<.01
Noise type * Interaction * Type manipulated	2	578	0.23	.792	<.01
Noise type * Level and Type manipulated	2	529	0.07	.934	<.01
Interaction * Level and Type manipulated	1	578	7.18	.008	.01
Noise type * Interaction * Level of manipulation * Diagnosis	2	578	0.37	.692	<.01
Noise type * Interaction * Type manipulated * Diagnosis	2	578	0.67	.513	<.01
Noise type * Level and Type manipulated * Diagnosis	2	529	0.16	.854	<.01
Interaction * Level and Type manipulated * Diagnosis	1	578	6.45	.011	.01
Noise type * Interaction * Level and Type manipulated	2	578	0.10	.904	<.01
Noise type * Interaction * Level and Type manipulated * Diagnosis	2	578	0.40	.671	<.01

Note. Noise type = no noise, low-intelligibility, or high-intelligibility noise; Interaction = interacting or non-interacting; Level of manipulation = low or high; Type manipulated = social or feature; Diagnosis = ASD or TD.

The analysis showed (Table 7.5) that fixation duration, however, depended on the type of structure manipulated (Figure 7.8), background noise played (Figure 7.9), and presence of interaction (Figure 7.10). Fixation durations were shorter for pictures where social (M = 0.40, SD = 0.24) rather than feature (M = 0.41, SD = 0.25) structure was manipulated, $F(1,529) = 4.66$, $p = .031$, $\eta^2_p = .01$. The fixation durations also differed across background noise conditions, $F(2,529) = 3.89$, $p = .021$, $\eta^2_p = .01$. Tukey HSD pairwise comparisons revealed that fixation durations differed significantly between the high-intelligibility (M = 0.42, SD = 0.27) and no noise (M = 0.39, SD = 0.22) conditions ($p < .05$). Mean fixation durations in the low-intelligibility condition (M = 0.41, SD = 0.24), however, did not significantly differ from the other two conditions ($p > .05$). In terms of the presence of reciprocal interaction, faces that were a part of the interaction received longer fixations (M = 0.43, SD = 0.27) than faces that were not interacting (M = 0.37, SD = 0.21), $F(1,578) = 463.66$, $p < .001$, $\eta^2_p = .45$.

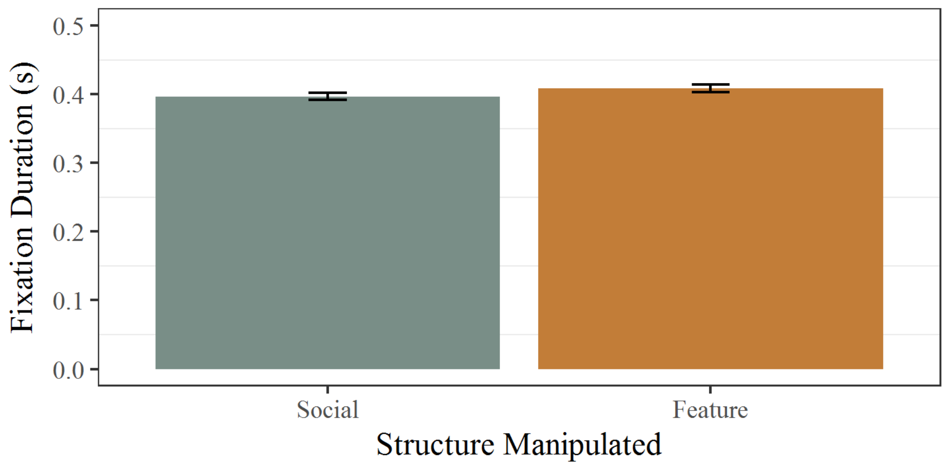

Figure 7.8. Mean fixation duration per type of structure manipulated. Error bars represent 95% CI.

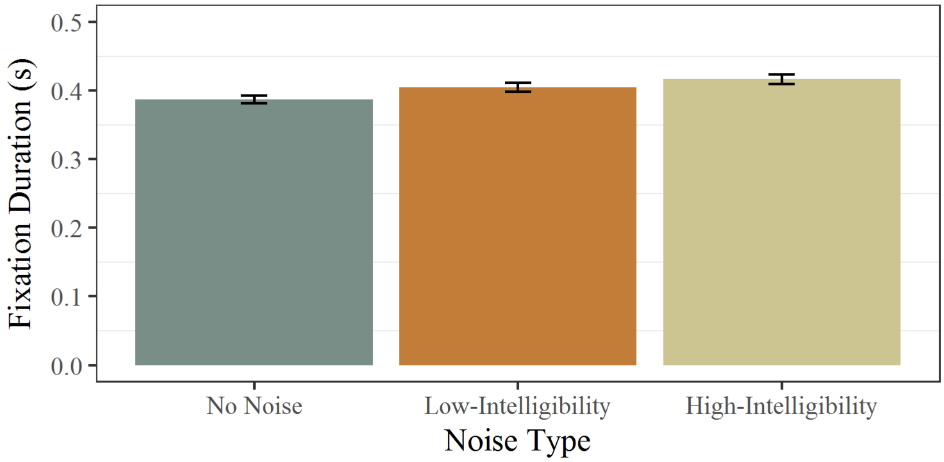

Figure 7.9. Mean fixation duration per type of noise. Error bars represent 95% CI.

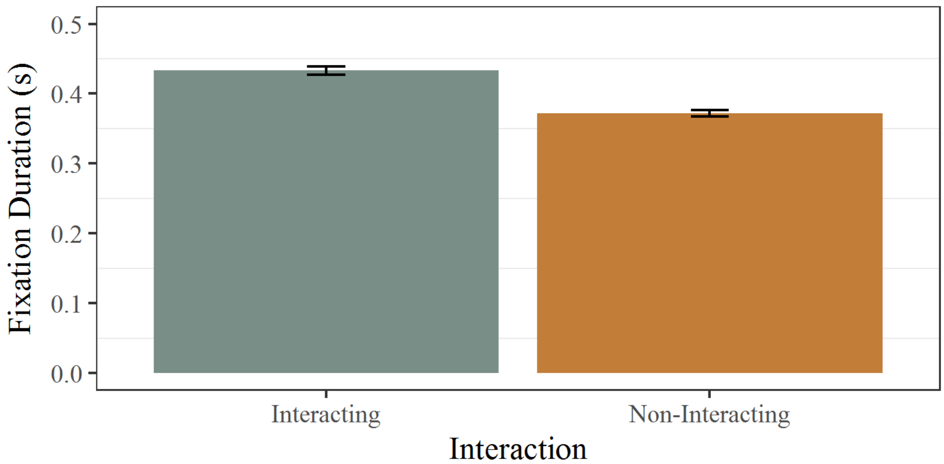

Figure 7.10. Mean fixation duration per presence of interaction. Error bars represent 95% CI.

The effects of the presence of reciprocal interaction and type of background noise were each further moderated by participants' diagnosis (Table 7.5). Participants with ASD and TD both looked at faces involved in reciprocal interactions (ASD: M = 0.43, SD = 0.31; TD: M = 0.44, SD = 0.23) more than ones that were not (ASD: M = 0.37, SD = 0.24; TD: M = 0.37, SD = 0.17; Figure 7.11), $F(1,578) = 9.81$, $p = .002$, $\eta^2_p = .02$. These differences were confirmed by Tukey HSD comparisons ($p < .05$). Visual examination of Figure 7.11 suggests that the significance may be occurring due to group differences in attention to interacting faces. However, potentially due to the presence of higher order interactions in the model, Tukey HSD comparison between attention to interacting faces in participants with ASD and TD participants did not reach significance ($p > .05$).

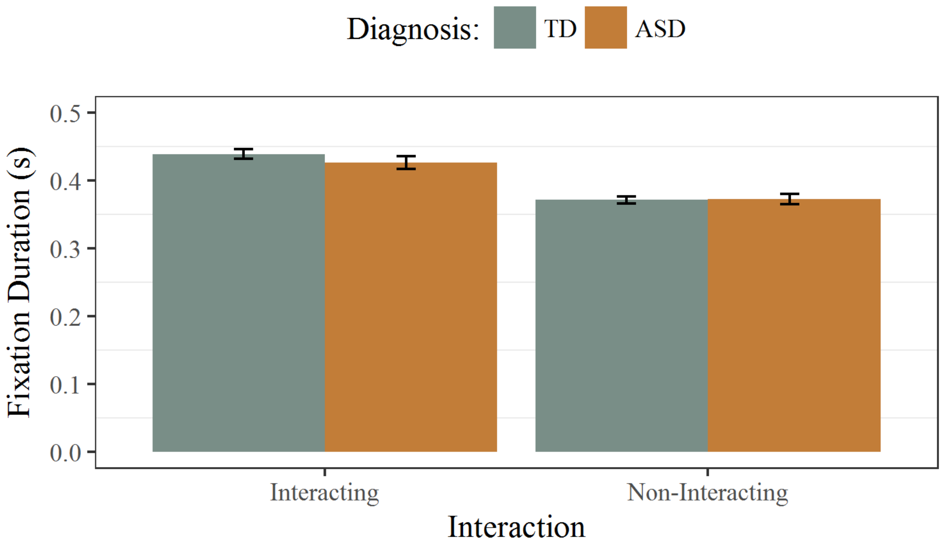

Figure 7.11. Mean fixation duration per presence of interaction and diagnosis. Error bars represent 95% CI.

The significant interaction between diagnosis and background noise (Figure 7.12) was also investigated further using Tukey HSD planned comparisons, $F(2,529) = 4.14$, $p = .016$, $\eta^2_p = .02$. It was shown that the moderating effect of noise type occurred only in TD participants. To be precise, TD individuals spent a longer time looking at faces in the high- ($M = 0.43$, $SD = 0.22$) than low-intelligibility ($M = 0.38$, $SD = 0.20$) condition ($p < .05$). Their fixation durations in the no noise condition ($M = 0.41$, $SD = 0.20$), however, did not differ from those in the conditions with noise ($p > .05$). Fixation durations of TD participants also did not differ significantly from those of participants with ASD in either of the noise conditions (high-intelligibility: $M = 0.41$, $SD = 0.31$; low-intelligibility: $M = 0.43$, $SD = 0.28$; no noise: 0.37, $SD = 0.24$), none of which significantly differed from each other ($p > .05$).

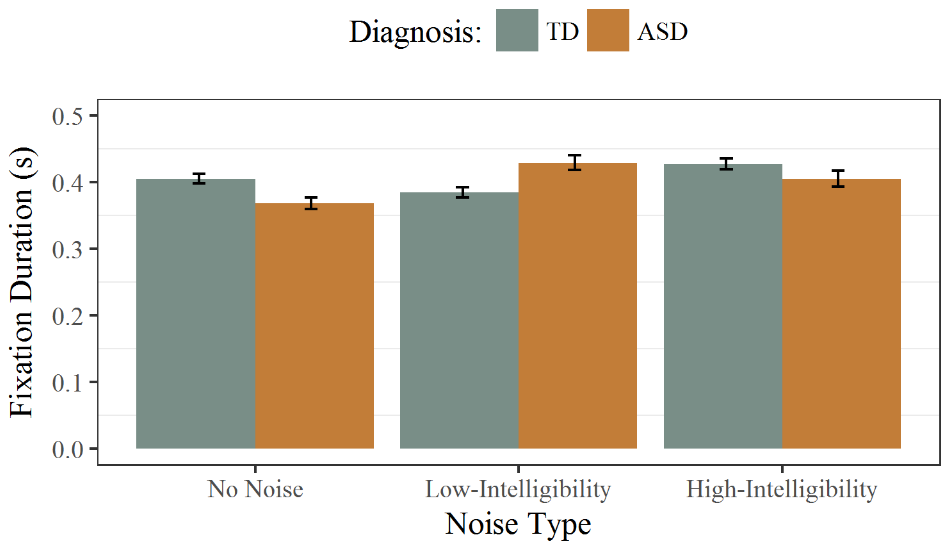

Figure 7.12. Mean fixation duration per type of noise and diagnosis. Error bars represent 95% CI.

The effect of reciprocal interaction within the pattern was further moderated by the level of structure manipulated (Figure 7.13), $F(1,578) = 4.52$, $p = .034$, $\eta^2_p = .01$. Tukey HSD comparisons ($p < .05$) further showed that for both high and low-level structure manipulated, fixation durations were longer for faces that were involved in reciprocal interactions (high: $M = 0.43$, $SD = 0.25$; low: $M = 0.44$, $SD = 0.29$) than faces that were not (high: $M = 0.37$, $SD = 0.21$; low: $M = 0.38$, $SD = 0.21$). There was also a significant interaction between reciprocal interaction within a pattern and the type of structure manipulated (Figure 7.14), $F(1,578) = 8.45$, $p = .004$, $\eta^2_p = .01$. Fixation durations towards interacting faces were longest in trials of high or low feature manipulation ($M = 0.44$, $SD = 0.27$), which differed significantly from trials of high or low social manipulation ($M = 0.42$, $SD = 0.27$). Fixation durations towards interacting faces in both types of trials also differed significantly from fixation durations to non-interacting faces when feature ($M = 0.37$, $SD = 0.21$) or social ($M = 0.37$, $SD = 0.20$) structure was manipulated ($p < .05$).

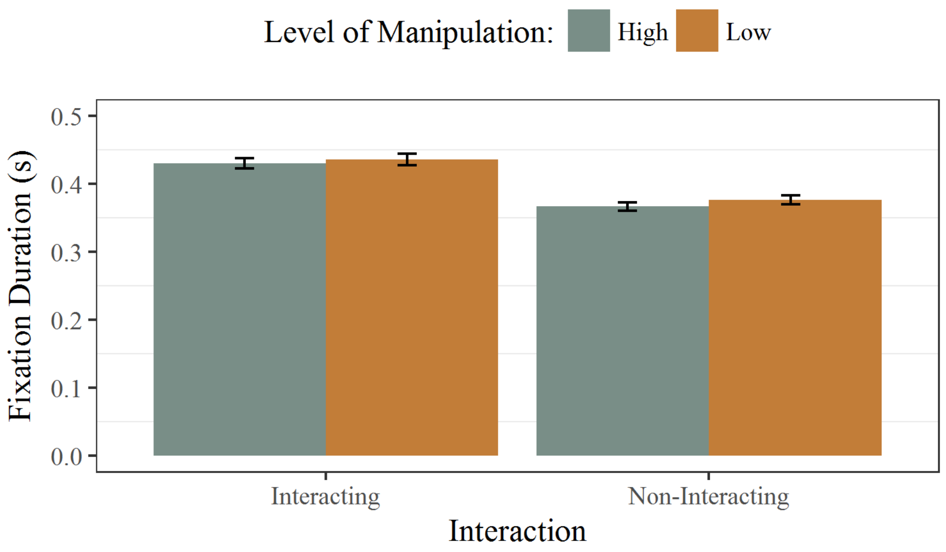

Figure 7.13. Mean fixation duration per presence of interaction and level of structure manipulated. Error bars represent 95% CI.

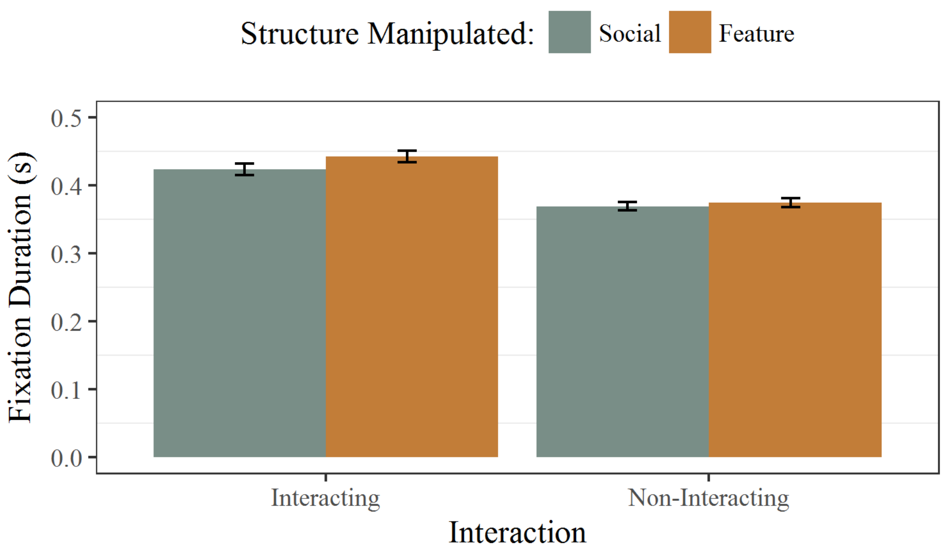

Figure 7.14. Mean fixation duration per presence of interaction and type of structure manipulated. Error bars represent 95% CI.

The combined effect of the presence of reciprocal interaction within the pattern and the level of structure manipulated was further moderated by diagnosis (Figure 7.15), $F(1,578) = 4.30$, $p = .039$, $\eta^2_p = .01$. Tukey HSD pairwise comparisons confirmed that for both diagnostic groups fixation durations were still longer for interacting (ASD high: *M* = 0.43, *SD* = 0.28; ASD low: *M* = 0.43, *SD* = 0.33; TD high: *M* = 0.43, *SD* = 0.21; TD low: *M* = 0.45, *SD* = 0.25) than non-interacting faces (ASD high: *M* = 0.37, *SD* = 0.23; ASD low: *M* = 0.38, *SD* = 0.25; TD high: *M* = 0.37, *SD* = 0.18; TD low: *M* = 0.38, *SD* = 0.17), respectively, despite the level of structure manipulated ($p < .05$). None of the rest of pairwise comparisons reached significance, however ($p > .05$).

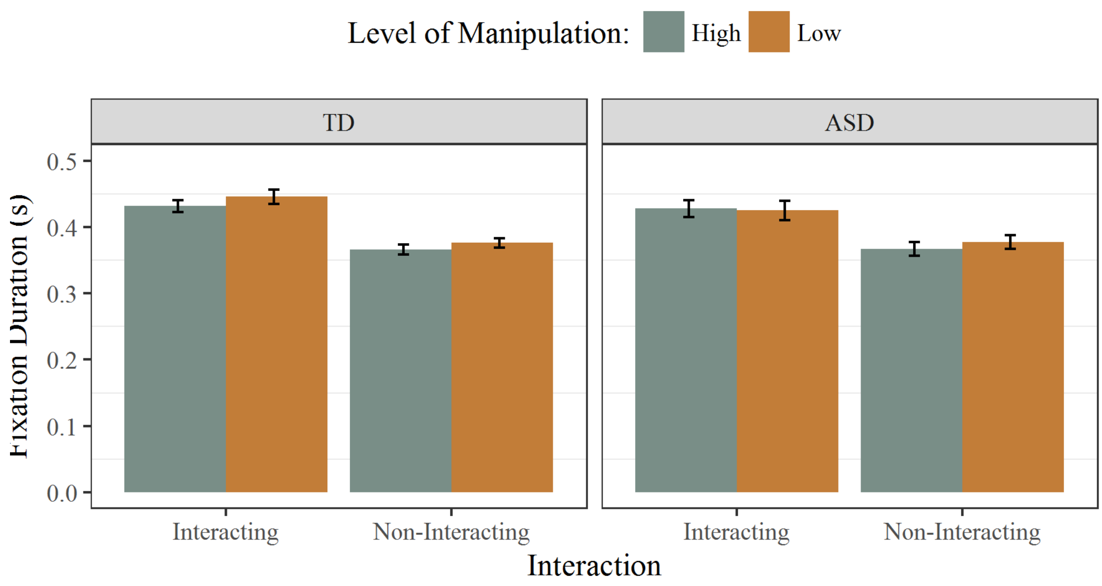

Figure 7.15. Mean fixation duration per presence of interaction, type of structure manipulated, and diagnosis. Error bars represent 95% CI.

The relationship between reciprocal interaction between the faces and type of structure manipulated was also moderated by diagnosis (Figure 7.16), $F(1,578) = 10.11$, $p = .002$, $\eta^2_p = .02$. Further analysis using Tukey HSD comparisons showed that for TD participants average fixation durations towards interacting faces (TD social: *M* = 0.44, *SD* = 0.24; TD feature: *M* = 0.44, *SD* = 0.22) significantly differed from the fixations durations to non-interacting faces (TD social: *M* = 0.37, *SD* = 0.18; TD feature: *M* = 0.37, *SD* = 0.17) irrespective of the structure type manipulated ($p < .05$). Participants with ASD, however, on average exhibited significantly longer fixation durations to interacting faces in trials where feature (*M* = 0.45, *SD* = 0.32) rather than social (*M* = 0.41, *SD* = 0.29) structure was manipulated ($p < .05$). ASD fixation durations towards interacting faces in feature manipulation trials were also on average significantly higher than to non-interacting faces in either feature (*M* = 0.38, *SD* = 0.25), or social (*M* = 0.37, *SD* = 0.23) manipulation trials ($p < .05$). Tukey HSD comparisons, however, also revealed that their average fixation durations towards interacting faces in socially manipulated trials only differed significantly ($p < .05$) from fixation durations towards non-interacting faces in socially manipulated, but not feature manipulation trials ($p > .05$). None of the other paired comparisons in this interaction reached significance ($p > .05$).

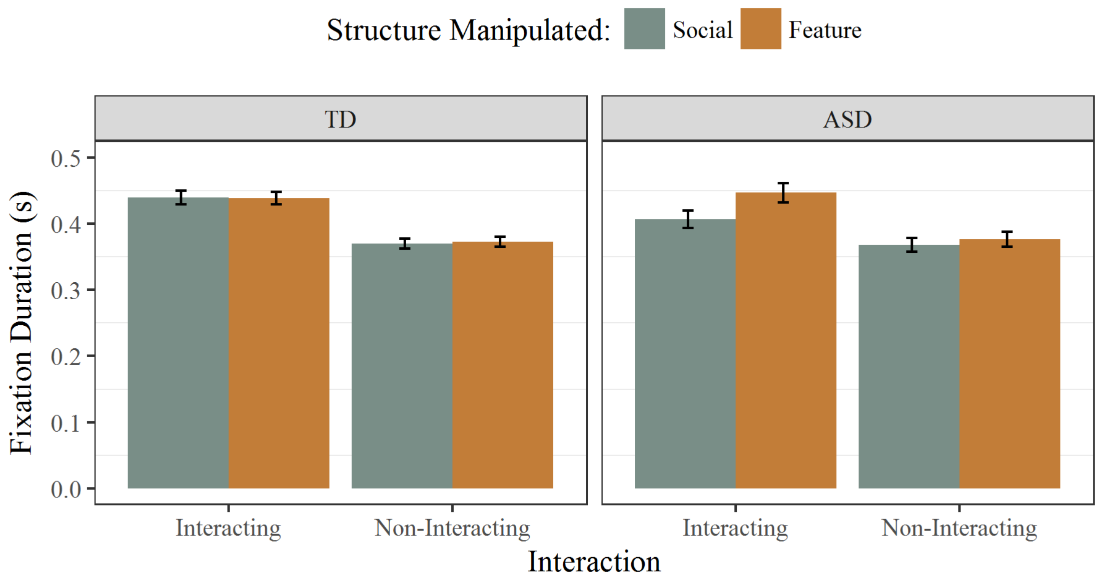

Figure 7.16. Mean fixation duration per presence of interaction, level of structure manipulated, and diagnosis. Error bars represent 95% CI.

There was also a three-way relationship between reciprocal facial interaction and the level and type of structure manipulated (Figure 7.17), $F(1,578) = 7.18$, $p = .008$, $\eta^2_p = .01$. Yet, according to Tukey HSD pairwise comparisons, interacting faces (high social: *M* = 0.42, *SD* = 0.23; high feature: *M* = 0.44, *SD* = 0.26; low social: *M* =

0.43, *SD* = 0.30; low feature: *M* = 0.44, *SD* = 0.28) again received longer fixations than non-interacting faces (high social: *M* = 0.36, *SD* = 0.21; high feature: *M* = 0.38, *SD* = 0.20; low social: *M* = 0.38, *SD* = 0.20; low feature: *M* = 0.37, *SD* = 0.22) across level and type of structure manipulated ($p < .05$). Thus, potentially due to the presence of a higher order interaction in the model, the comparisons did not reveal where the significant effect between these factors was occurring by failing to yield any other significant comparisons ($p > .05$).

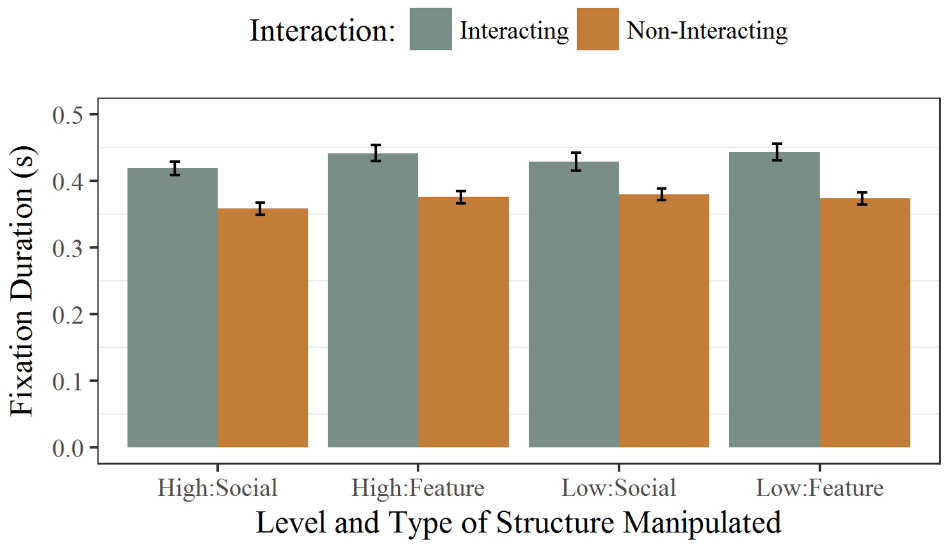

Figure 7.17. Mean fixation duration presence of interaction, and level and type of structure manipulated. Error bars represent 95% CI.

The relationship between the presence of reciprocal interaction and level and type of structure manipulated was further moderated by participants' diagnosis (Figure 7.18), $F(1,578) = 6.45$, $p = .011$, $\eta^2_p = .01$. This effect was again further investigated using Tukey HSD pairwise comparisons. For the most of it, TD participants fixated on interacting faces (high feature: *M* = 0.44, *SD* = 0.22; low social: *M* = 0.45, *SD* = 0.27; low feature: *M* = 0.44, *SD* = 0.22) for longer than non-interacting faces (high social: *M* = 0.36, *SD* = 0.18; high feature: *M* = 0.37, *SD* = 0.17; low feature: *M* = 0.37, *SD* = 0.18) independently from level and type of structure manipulated ($p < .05$). Yet, their fixation durations towards interacting faces in trials manipulated to be high in social structure (M = 0.43, SD = 0.21) were not significantly different from their fixation durations towards non-interacting faces in low social structure trials ($p < .05$). For participants with ASD, that was the case only for fixation durations towards interacting faces in trials where feature structure was manipulated to be high (M = 0.44, SD = 0.30) or low (M = 0.45, SD = 0.34) as they differed from fixation durations towards non-interacting faces in all trials (high social: M = 0.36, SD = 0.23; low social: M = 0.38, SD = 0.23; high feature: M = 0.38, SD = 0.24; low feature: M = 0.37, SD = 0.26) independently from the level and type of structure manipulated ($p < .05$). Their fixation durations towards interacting faces in high social structure trials on average (M = 0.41, SD = 0.25) differed significantly only from fixation durations towards non-interacting faces in same condition ($p < .05$). Finally, their fixation durations towards interacting faces in low social structure trials (M = 0.40, SD = 0.33) differed significantly from fixation durations towards interacting faces in trials where feature structure was manipulated to be high or low ($p < .05$), but not from fixation durations towards non-interacting faces across the level and type of structure manipulated ($p > .05$). None of the other main or interaction effects in the model yielded significance (Table 7.5).

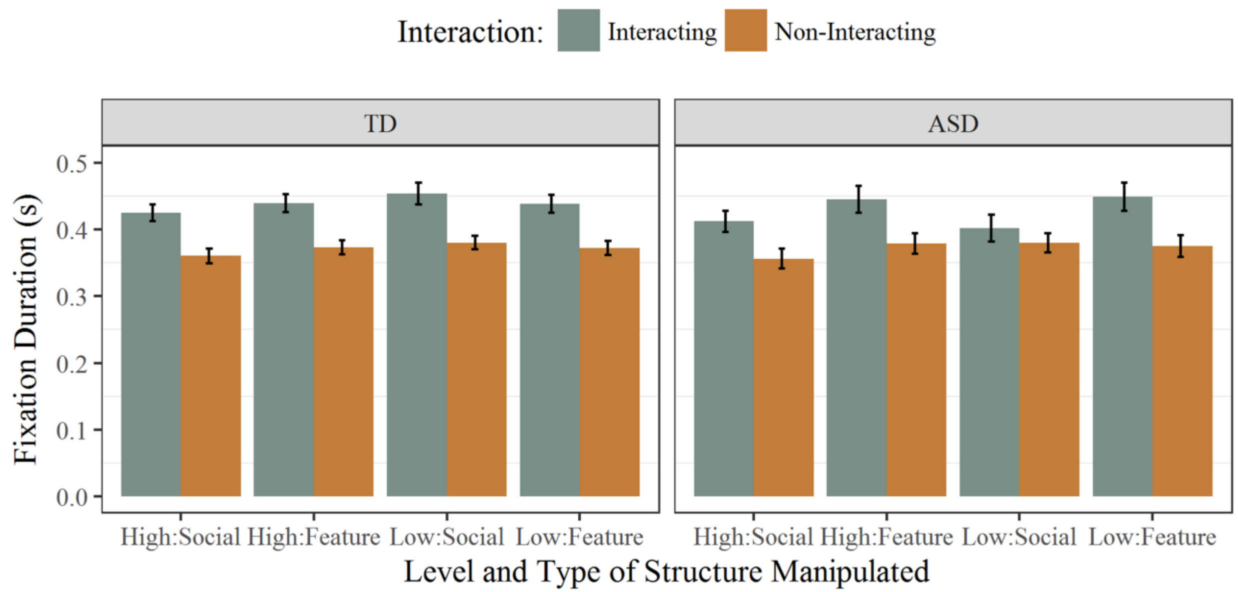

Figure 7.18. Mean fixation duration per presence of interaction, level and type of structure manipulated, and diagnosis. Error bars represent 95% CI.

Discussion

This is the first study using a manipulation of pattern structure to distinguish between the interference of social and feature structure in high-functioning adults with ASD. This was achieved by presenting participants with matrices of schematic faces that were manipulated to be either: high and low in social structure (number of faces looking at each other), whilst the feature structure was kept constant; or high and low in feature structure (changes in gaze direction), whilst the social structure was kept constant. Reaction time data was analysed in order to evaluate interference with participants' performance speed. Gaze fixation duration data was also analysed to evaluate whether pattern structure and presence of reciprocal social interaction between the stimuli moderated participants attention. In general, the pattern of findings regarding the interference effects was consistent between the two measures used.

TD participants experienced interference to RTs in higher feature structure conditions as expected (Hypothesis 1), which shows that the change-based manipulation was successful. Participants with ASD also responded slower to the high than the low feature structure trials. This is in line with the EPF hypothesis suggesting that participants with ASD also exhibit interference from the global perceptual level (Hypothesis 2c). Differently from the expectations that TD participants will experience a higher interference from an increased number of reciprocal interactions (Hypothesis 3) and that participants with ASD will not (Hypothesis 5), all participants exhibited slower responses to increased complexity irrespective of structure manipulated. In line with Hypothesis 4, however, a social bias in TD participants did occur in terms of increased attention to faces looking at each other. Whilst this bias was also present in participants with ASD, it was not as pronounced as posited in

Hypothesis 6. Furthermore, a social bias towards interacting faces in ASD was not present at all when the number of such faces was low. Contrary to the prediction of Hypothesis 7, it was also found that increased intelligibility of background noise increased overall fixation durations and did not differ per type of face. As expected, diagnosis moderated the effect of noise on participants' RTs. To be precise, only the performance of TD participants, but not participants with ASD, revealed interference from the increased intelligibility of noise (Hypothesis 8).

Interference of Social and Feature Structure

Performance speed. The main aim of the study was to investigate, in a controlled manner, the distinction between interference of social and feature structure on RT and gaze behaviour of high-functioning adults with ASD. In terms of the manipulation, increased complexity of the pattern did induce a longer time needed to count the faces. That was applicable to the same extent for the patterns that varied in social or feature structure. Given that only one type of structure was manipulated at the time, whilst the other one was kept constant, it indicates that the paradigm was successful and that two types of structure can be manipulated independently. Furthermore, because the interacting faces in the paradigm only differed from the rest of the non-interacting faces due to the presence of reciprocal gaze in the pairs, it suggests that the social relevance of this manipulation was also successfully induced.

Interestingly, the interfering effect of increased feature and social structure occurred for both TD participants and those with ASD alike. Slower answers to patterns that were high rather than low in feature structure makes sense in the light of EPF theory, which posits that individuals with ASD process information at the global level in the same way as TD individuals (Mottron et al., 2006). Yet, one of the core principles of EPF suggests a local processing bias in ASD, which reflects superior processing at that level (Mottron et al., 2006). However, only global interference could be evaluated using the current paradigm by investigating whether a task independent relationship between elements interfered with task completion. Thus, whilst EPF theory seems to fit the findings best, it was only partially supported, as the evidence for superior local processing could not be evaluated using the current paradigm. Yet, if a superior local bias was present in the current sample of participants with ASD, albeit not the focus of the current study, one could have expected participants with ASD to outperform TD individuals on tasks involving attention to features of a pattern as required in the current experiment. Similarly, high-functioning adults with ASD performed similarly to TD adults in terms of interference from more socially relevant information. This suggests that a social bias interference to the task was independent of diagnosis.

Social attention. Even though a RT analysis did not reveal any moderating effects of diagnosis on interference from social and feature structure, looking at social attention did. Eye-tracking data revealed that whilst both TD adults and those with ASD exhibited a social bias towards interacting faces that was not the case for patterns that included only one pair of interacting faces. This result is partially in line with findings of Stagg et al. (2014), who previously showed that part of their sample of children with ASD exhibited a reduced bias towards interacting pairs of figures. Yet, they examined attention to stimuli depicting two pairs of figures: an interacting (i.e. face-to-face) and non-interacting (i.e. back-to-back) pair presented on the screen simultaneously. Considering current research, it is thus possible that if more than one interacting pair were presented on the screen, the reduced bias may also have disappeared.

Nevertheless, that somewhat contradicts previous research (e.g. Chita-Tegmark, 2016) indicating that reduced social attention in ASD is more pronounced with increased social content. This is also not in line with other results, however, showing that both TD adults and adults with ASD demonstrated reduce attention to faces with an increase in the number of people in a scene (Rigby et al., 2016). It is important to note, however, that these studies evaluated the social complexity as a function of the number of people in the scene, whereas the number of people (i.e. schematic faces) in the current experiment was kept constant across the stimuli and only the feature structure was manipulated.

These findings are somewhat in line with one study that manipulated not only the number of people in the scenes, but also their interactive status (Birmingham et al., 2008). They found that TD adults increased attention to social aspects of the scene even more when people in the scene were active and interacting. Therefore, the processes observed here are more relevant for attention to reciprocal interactions rather than the number of socially relevant stimuli. It does, however, suggest that the presence of reciprocal social interactions have an additive effect of social relevance for both adults with ASD and TD and thus should be controlled for in future studies examining effects of social content on attention to social information in ASD.

It is important to note that when five pairs of faces looking at each other were present in a pattern, both adults with ASD and with TD looked at such faces for longer than faces that were not interacting. Yet, when the number of interacting faces was reduced, this bias towards interacting faces remained present only in TD, and not ASD, adults. These findings are partially in line with those of Chapter 4 showing that individuals with ASD, differently from TD adults, benefit from exogenous disengaging of attention in social orienting. In combination, these findings could suggest that if reciprocal social interactions are exogenously brought to one's attention by, for example, increasing their number, similar attention is paid to them by both high-functioning adults with ASD and TD adults. Yet, if one's attention is engaged with another task (e.g. counting faces) and the social interactions are not readily observable (e.g. seen in periphery), high-functioning adults with ASD may be less predisposed to notice them than TD individuals. In practical terms, a similar behaviour could be expected to occur in groups when one's attention is not exogenously guided to a relevant source of social information.

Effects of Background Noise

Another aim of this thesis was to explore whether the presence or intelligibility of background noise may be affecting attentional processes in high-functioning adults with ASD differently from TD adults. The faces in the patterns were fixated on for longer when background noise was overlaid with intelligible speech in comparison to when it was not. That was the same for participants with both ASD and TD. Group differences occurred, however, when investigating effects of the presence or intelligibility of background noise on participants' RTs. To be precise, increased intelligibility of background noise interfered with participants' speed in completing the task. However, that effect was present in TD participants only and not individuals with ASD. This finding is partially in line with that of Chapter 4 showing that diagnosis moderates the effect of background noise on attentional shifting from and to social and non-social information. In combination, these findings indicate that increased intelligibility of background noise requires more attentional resources for suppression and thus may exhaust those resources available similarly as perceptual load of the target is posited to do in Lavie's (2005) load theory of selective attention.

The current findings also support previous research showing that adults with ASD required higher levels of perceptual load than their TD counterparts for their available resources to be exhausted (Remington et al., 2009). Thus, in combination with the results of Chapter 4, these findings support the notion of enhanced perceptual capacity in ASD (Lavie, 2010). The current findings also expand on it by suggesting that this enhanced perceptual capacity exists not only within but across modalities.

Limitations and Future Directions

The novelty of the paradigm utilized in the current chapter is a double-edged sword as it is the greatest asset and weakness at the same time. In terms of strengths it suggests a new way of manipulating the complexity of patterns and reveals the possibility of investigating unique interference of socially relevant information. Indeed, differentiating between the feature and social structure, only via reciprocity of gaze, allowed for observing unique effects of reciprocal social interactions on performance and visual attention. Yet, it did not allow the same in regard to the feature structure. Only patterns consisting of schematic faces were used as stimuli in this experiment. Whilst that was appropriate given the main aim of the current study, future research should utilize patterns consisting of non-social (e.g. arrows; Nielsen, Slade, Levy, & Holmes, 2015) units to remove the potential social relevance of gaze change (Vlamings, Stauder, Son, & Mottron, 2005). Furthermore, due to its exploratory nature, the current study focused on participants' performance in terms of speed and visual attention in correct trials only. However, analysis of the response accuracy could offer an additional insight into underlying processed and may be worth including in the future studies.

Furthermore, the current paradigm was purposefully designed to observe behavioural and attentional differences in relation to the manipulation of the structure of the stimulus, not the task given. Therefore, all participants exhibited a near ceiling performance when counting faces looking to the left or right of the screen. There were also no differences in terms of the error rates between groups (see Data Analysis). However, if complexity of the given task increases when examining these processes in the future studies, response-accuracy trade-offs may become more likely and thus would be worth including in the analysis.

Conclusion

The current experiment is the first of its kind suggesting a new potential way of experimentally distinguishing between feature and social structure in patterns. Unique interference of the manipulation of these structures on performance in high-functioning adults with ASD and TD adults was investigated. Both groups of participants completed a simple counting task slower when either feature or social complexity was increased, which, to some extent, supports the theory of enhanced perceptual processing (Mottron et al., 2006). In terms of visual attention, it was revealed that schematic faces that were manipulated to be looking at each other received more attention than faces that did not participate in these reciprocal interactions across all conditions for TD adults. Yet, whilst otherwise similar, this effect did not occur for high-functioning adults with ASD when only one pair of interacting faces was present. Therefore, it seems that while the number of changes or reciprocal social interactions encountered in the pattern may not affect overt performance of those with ASD differently from TD individuals, it seems to affect underlying attentional processes. In conclusion, the findings of the current chapter offer an answer to Langdell’s (1978) question by suggesting that overall, similarly to TD individuals, those with ASD may process socially relevant information as an additive effect of “pure” and “social pattern”. Yet, that the social bias, whilst also present in ASD, may be less pronounced than in TD.

The findings of Experiment 6 described in the current chapter are partially supportive of the idea that the presence of social interaction rather than simply the socialness of a stimulus may be responsible for reduced social attention in ASD. Nevertheless, the findings from Experiment 4 described in Chapter 5 revealed a reduced social bias even if only one person was present in the scene. Whilst single person scenes should remove the effect of social interactions, it is possible that participants’ attention was distracted by the novel background of the scenes. Hence, Experiment 7 described in the next chapter will aim to reconcile these inconsistent findings by examining participants’ attention to stimuli depicting one person in a uniform environment.

CHAPTER 8

DISENTAGLING THE CONTEXT: VIEWING OF SCENES WITH DYNAMIC FIGURES IN HIGH-FUNCTIONING ADULTS WITH ASD

Summary

Ecological validity including increased social content, dynamic presentation, and the presence of social interactions have all been proposed as paramount for atypical social bias in ASD to occur. Yet, neither of these characteristics alone have been able to sufficiently account for the inconsistent findings of reduced social attention in ASD. Therefore, Experiment 7 aimed to disentangle these influences by examining attention to stimuli low in social context (i.e. social content and social interactions), but still ecologically valid in terms of general context (i.e. social information not presented in isolation). Participants' attention was purposefully guided towards the social information using domain general stimulus characteristics such as motion, position, and background uniformity across the stimuli. Doing so has allowed us to determine whether the social relevance of the human figure alone is sufficient to induce atypical social attention in ASD. Gaze data from 14 high-functioning adults with ASD and 15 TD adults was collected for this study. Fixation durations (i.e. time spent fixating on an AOI) on face, body, and background information whilst viewing videos representing a person walking down the corridor were extracted. Results revealed that both participants with ASD and TD individuals exhibited a bias towards social information, yet it was less pronounced in adults with ASD. Unexpectedly, the bias in both groups occurred towards the body of the person in the scene rather than the facial information. In general, the findings of present study expand on previous knowledge by showing that the presence of social interaction is not necessary for a reduced social bias in ASD to occur.

Introduction

It is generally agreed that individuals with ASD exhibit less attention to socially relevant information than TD individuals. The current debate mostly focuses on the extent and nature of these social deficits (e.g. Bird et al., 2011; Falck-Ytter & von Hofsten, 2011; Riby & Hancock, 2009b). Variations in ecological validity of the stimuli including social content, motion, and social interactions have been suggested as some of the potential moderating factors (see Chita-Tegmark, 2016). As experimental stimuli replicate more realistic social situations, gaze behaviours may increase atypicality in ASD (e.g. Chevallier et al., 2015). Nevertheless, the overlap of these factors within studies and inconsistent results across them hinders one's ability to distinguish between the influences of these moderating factors.

As discussed in Chapter 6, recent reviews (Chita-Tegmark, 2016; Guillon et al., 2014) have suggested that increased social content (i.e. the number of people visible) of a stimulus may be responsible for reduced attention to socially relevant information in ASD. Speer et al. (2007) found that children with and without ASD differed on attention to eye and body regions. They found differences when the children were presented with movie excerpts encompassing multiple characters, but not with dynamic single character scenes, static single, or static multiple character scenes. Similarly, Hanley et al. (2013) showed that adolescents with Asperger's syndrome looked at eye regions in social scenes less when faces were presented in scenes with multiple characters, rather than in isolation. On the other hand, Rigby et al. (2016) contradicted these findings by showing that in multiple character scenes attention to faces decreased and attention to the rest of the bodies or off-person increased for both adults with ASD and TD individuals equally. The experiment in Chapter 6 further extended these findings by showing that, while increased social content of the scenes decreased attention to highly relevant social information of the static scenes, there was no moderating effect of diagnosis.

In addition to social content, it has also been suggested that motion of the stimulus presentation may be partially responsible for the lack of, or the decrease in, social viewing in ASD (e.g. Speer et al., 2007). Riby and Hancock (2008) further discussed that reduced ecological validity of the static presentation could account for a typical social viewing pattern found in some studies looking at attention to drawings in children with ASD (van der Geest et al., 2002). This is further supported by evidence that children with ASD lack preference for watching biological motion (Klin et al., 2009). Yet, Riby and Hancock (2009b) explicitly investigated attention of children with ASD across static and dynamic stimuli and found that atypical gaze behaviour was present across both types of stimuli. Similarly, Rigby et al. (2016) also presented their stimuli in static and dynamic forms and did not find clear increases in atypical social attention in ASD across stimuli types. Findings from Chapter 5 and Chapter 6 of the current thesis also showed that the present sample of adults with ASD experienced atypical social attention when using static images too. Hence, although dynamic presentation may increase the ecological validity of stimuli and thus reduce social attention in ASD, evidence so far suggests that the lack of dynamic presentation does not always result in typical attention in ASD, suggesting that additional factors are at play.

Recently, the presence of social interactions within scenes has emerged as another explanation for the inconsistency of findings regarding social attention in ASD. Studies that found reduced social attention in ASD to be linked with the number of characters presented (e.g. Hanley et al., 2013) and the motion of stimuli (Speer et al., 2007), also varied in the absence or presence of social interaction across conditions. Conversely, studies that found reduced social attention in ASD occurring across static and dynamic stimuli (e.g. Riby & Hancock, 2009b) and varying social content all utilized stimuli with social interactions (e.g. Rigby et al., 2016). Even the scenes involving a single person were excerpts of scenes depicting interactions with an off-screen character. Thus, it is possible that the presence of social interaction in the stimulus rather than the number of people presented in the scene or its dynamic presentation is needed for the atypical social attention in ASD to occur.

The importance of social interaction in the stimulus used is further supported by Stagg et al. (2014), who compared children with and without ASD on their attention to interacting and non-interacting pairs of cartoon-like figures. They revealed that TD children and those with ASD and normal language development looked at interacting figures more than non-interacting ones. Children with ASD and delayed language development, however, did not exhibit the same preference. A similar bias towards faces looking at each other than those that were not interacting in this way was seen in all participants in Chapter 7 of the current thesis. Individuals with ASD, nevertheless, exhibited this bias to interacting schematic faces to a lesser extent than TD adults. These findings suggest that individuals with ASD may, on average, have a less pronounced bias towards social interactions, which may be underlying reduced social attention seen in previous studies.

Another crucial difference between studies finding a variation of group differences in social attention (e.g. Hanley et al., 2013; Speer et al., 2007) and those that do not (e.g. Rigby et al., 2016) is whether the single person stimuli were presented in isolation or context. The presence of background may have an effect on one's social bias in two ways. Firstly, presenting a social stimulus in isolation does not provide alternative targets for attention. Therefore, if atypical social attention in ASD represents a lack of social bias rather than an avoidance of social stimuli, it may not occur. Secondly, the lack of context for the scene may also reduce its ecological validity. If realistic stimuli are needed to evoke a robust social response, presenting social stimuli in isolation may diminish it. This possible confound is further illustrated by Chevallier et al. (2015). In their study, children with and without ASD were presented with three types of stimuli: a static visual exploration task with an array of isolated faces and objects; a dynamic task which simultaneously presented four videos of isolated people and objects; and naturalistic videos of children playing in a room. They found that children with ASD looked at social information less than children without ASD only in the naturalistic scenes. Thus, the authors emphasized the importance of ecologically relevant stimuli in eye-tracking research of ASD. Given the presence of competing non-social information across stimuli type and inclusion of both static and dynamic presentation, Chevallier et al. (2015) clearly evidence that neither of those alone can sufficiently account for reduced social attention in ASD. In light of previous studies (e.g. Riby & Hancock, 2009b), it remains unclear whether reduced attention to naturalistic scenes occurred due to the presence of social interactions or the general context. It is this key question that current study aimed to address.

Aims

It is evident from the previous research that it is hard to distinguish exactly what aspects of naturalistic social stimuli induce reduced social attention in individuals with ASD (e.g. Chevallier et al., 2015; Riby & Hancock, 2009b; Rigby et al., 2016). Therefore, the present study aimed to further evaluate the presence of reduced social attention in high-functioning adults with ASD. To achieve this, the presence of a social bias in TD adults and adults with ASD was compared when looking at social stimuli that were low in social content and social interactions, but still ecologically valid in terms of motion and general context (i.e. not presented in isolation). To avoid the potential interference of background information, only videos uniform in background and the camera angle were used. Additionally, in line with the previous chapters, the further aim was to investigate the presence and/or intelligibility may be affecting gaze behaviour in ASD.

Hypotheses

In line with the findings from Chapter 5 and Chapter 6, it was hypothesised that both TD participants and those with ASD will experience a social bias by looking at faces and/or bodies more than off-person (i.e. background; Hypothesis 1). Two competing hypotheses were further formulated to determine if the presence of general context rather than social interactions was sufficient for reduced social attention in ASD to occur. Firstly, it was hypothesised that, if the presence of social interaction is necessary for reduced social attention in individuals with ASD, the extent of a social bias will not differ between TD adults and those with ASD (Hypothesis 2a). However, if the presence of realistic context is necessary instead, lower attention to the person in individuals with ASD than TD will take place (Hypothesis 2b). Moreover, it was predicted that this lack of social bias in ASD will be more pronounced for attention to faces (Hypothesis 3).

Regarding background noise, the findings from Chapter 5 so far suggested that the presence of high-intelligibility noise decreased the proportional engagement with social information of scenes. Yet, findings from Chapter 6 showed that it was associated with longer visit durations of primary information of social scenes. It was previously (see Chapter 6: Discussion) speculated that peripheral social information in Chapter 5, which underlies this reduced social bias, may have been perceived as secondary and thus attended to less. Given that only one social target was present in each of the videos in the Experiment 7, the noise was not expected to moderate participants' attention in the scenes irrespective of diagnosis (Hypothesis 4).

EXPERIMENT 7

Methods

Participants

All 35 participants who took part in the second testing phase (see Chapter 2) completed this experiment. Six of the participants were, however, omitted from the sample due to technical issues (e.g. non-reliable eye-tracking data)[6]. Therefore, the final sample consisted of 14 high-functioning adults with ASD (7 females) and 15 TD adults (8 females). The mean chronological age of the individuals with ASD was 39 years and 9 months, ranging between 19 years 6 months and 63 years 3 months. For TD participants, the mean chronological age was 38 years and 10 months with a range from 21 years 11 months to 64 years and 8 months. No significant differences in gender ($\chi^2(1) = 0.03$, $p = .858$) and age, as well as full, verbal, or performance IQ as estimated by the full Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), were observed between the groups (see Table 8.1). Scores on the Autism Spectrum Quotient (Baron-Cohen et al., 2001) in TD sample were significantly lower than the ASD group (Table 8.1).

[6] Four excluded participants with ASD presented with higher Attention to Detail as measured by Autism Quotient (Baron-Cohen et al., 2001) and more difficulties in Reciprocal Social Interactions as measured with ADOS-2 (Lord et al., 2012); $t(16) = 2.54$, $p = .022$ and $t(16) = 2.97$, $p = .009$, respectively. They did not differ on any other background characteristics (ps > .062). Two excluded TD participants did not differ from included ones on any of the background information (ps > .095).

Table 8.1

Participant Comparison on Age, IQ, and AQ per Diagnosis

	ASD (n=14)			TD (n=15)			*t*(27)	*p*
	M	*SD*	Range	*M*	*SD*	Range		
Age	39.80	14.14	19-63	38.91	13.54	21-64	-0.18	.863
FSIQ	110.36	12.13	78-125	113.20	7.27	83-125	0.77	.447
VIQ	107.50	13.99	71-120	110.33	9.02	81-127	0.65	.519
PIQ	111.50	12.11	92-136	113.60	10.18	84-138	0.51	.616
AQ	33.00	6.42	21-43	16.80	6.12	5-29	-6.96	<.001

Note. FSIQ = full scale IQ, VIQ = verbal IQ, PIQ = performance IQ, and AQ = Autism Spectrum Quotient.

Stimuli and Apparatus

Stimuli were presented on a 40 x 30 cm (1280 x 1024 px) CRT monitor with a grey background. Videos from the Stirling/Economic & Social Research Council (ESRC) 3-Dimensional Face Database (University of Stirling, 2013) were used as stimuli. The database contains a number of videos, recorded using a digital camera, with males walking the length of a corridor, at their own pace (e.g. Figure 8.1). All these videos were filmed in the same environment and have had their contrast reduced to soften the overhead lighting. For the purposes of this study, videos of three different people (M1006, M1035, and M1043; University of Stirling, 2013) that matched the visual angle of the scene and the duration (7 s; Figure 8.1) were chosen. Recordings were cropped in order to control the size across the stimuli, 31.74 cm x 16.70 cm (22.62^{o} x 12.04^{o}). Thus, the only difference across the videos, and the only dynamic variable, was the person.

Similarly to the previously described experiments (see Chapter 2), audio stimuli were used in addition to visual stimuli. The three noise conditions utilized were: control (no noise), low-intelligibility noise, and high-intelligibility noise. The interface of the E-prime stimulus presentation package (Psychology Software Tools

Inc., 2012) and a Tobii x120 eye-tracker (Tobii Technology AB, 2010) was again used to present the stimuli and record the data (see Chapter 2).

Procedure

The task was presented in a 3x3 within-subject design, where the first variable represented the three different people across the videos to avoid stimulus specific effects and the other variable was noise (no noise, low-intelligibility noise, and high-intelligibility noise). Thus, each participant was presented with nine trials in total, as each video was shown in all three noise conditions. Each participant received on-screen and verbal instructions to simply watch the videos. All participants were informed that there was no right or wrong way of looking at them. In each trial a video was presented in the middle of the screen for 7s. Each video was followed by a 1s pause (blank screen). The order of trials was fully randomised. The task took around 2 minutes to complete.

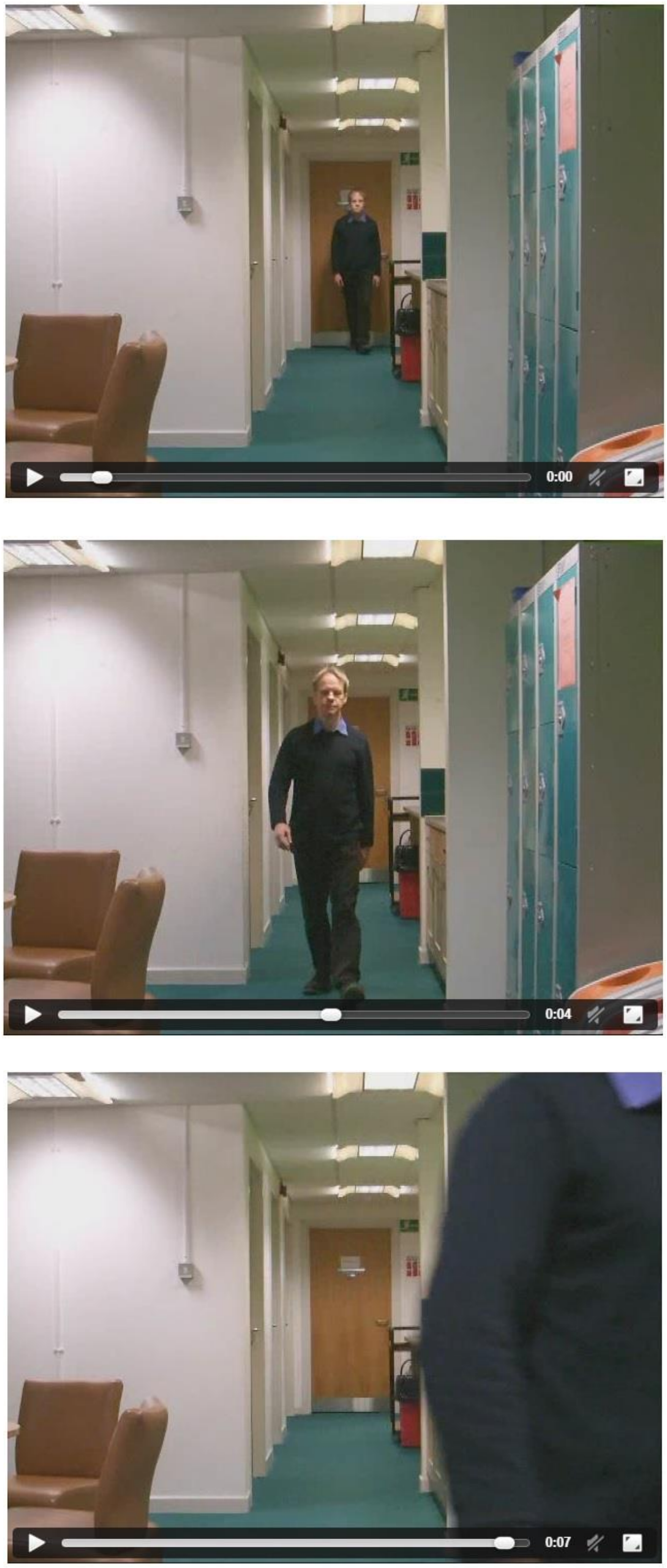

Figure 8.1. Three stills (from the top: start, middle, and end) from a sample video stimulus of a man (M1000; University of Stirling, 2013) walking down the corridor.

Data Analysis

A custom-built Matlab (The MathWorks Inc., 2013) script that allowed for frame by frame data processing was used to extract fixation durations (Appendix C). 843 frames were sampled for each video. For each video 9 to 16 (depending on the video) key frames, where the person in the scene substantially changed in size or position, were defined. For each of those key frames three rectangle AOIs, each representing a face, body, or whole scene, were manually defined using the Tobii Studio drawing function. The rest of the frames were automatically interpolated to either represent the AOI gradually expanding (body and face AOI), or to keep the AOI size constant (scene). After that, total fixation duration in seconds representing time spent fixating within each AOI was extracted. Fixation duration for the background was calculated by subtracting fixation durations on the face and body AOIs from the total fixation duration on the whole scene AOI.

Trials with fixation durations that were shorter than 16% of the stimulus presentation time (1.2 s) were deemed incomplete and thus excluded from further analysis (e.g. Fletcher-Watson et al., 2009). This resulted in participants with ASD missing data on 13% (M = 1.21, SD = 1.72) of trials and TD participants on 3% (M = 0.27, SD = 0.70) of trials on average. The amount of incorrect or missing responses did not significantly differ between groups, $t(17.01) = -1.92$, $p = .072$.

Based on the graphical evaluation of residual values, the normal distribution of residual values of the final model was deemed sufficient for both groups of participants. Yet, examination of the Shapiro-Wilk normality test suggested significant violations of normality in both groups, $Ws = .94$, $ps < .001$. Nevertheless, raw fixation duration data in seconds were analysed using linear mixed-effect (multilevel) modelling with a 2x3x3 design as an alternative to ANOVA (see Chapter

2). Participant information including their diagnostic details (ASD or TD) was modelled at the third level of the multilevel analysis. Nested within each participant, trial information with noise type (no noise, low-intelligibility noise, or high-intelligibility noise) as a predictor was modelled at the second level. Fixation duration times per each AOI were modelled at the first level, nested within each trial. The first level also included the information on AOI type (face, body, and background).

Results

The mean fixation durations in seconds for both diagnostic groups per AOI and noise type are shown in Table 8.2.

Table 8.2

Means (M) and Standard Deviations (SD) of Fixation Durations (s) per Diagnosis, Noise Type, and AOI Type

	No Noise		Low-Intelligibility		High-Intelligibility	
	ASD	*TD*	ASD	*TD*	ASD	*TD*
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Background	1.09 (1.02)	0.90 (0.60)	0.89 (0.72)	0.95 (0.70)	1.08 (0.67)	0.87 (0.73)
Body	2.73 (1.58)	3.71 (1.45)	2.88 (1.60)	3.44 (1.63)	2.89 (1.62)	3.68 (1.57)
Face	0.17 (0.44)	0.21 (0.59)	0.19 (0.41)	0.32 (0.85)	0.17 (0.46)	0.19 (0.51)

Table 8.3

Fixation Duration Model Summary of the Main Effects and Interactions

	df	df_{error}	*F*	*p*	η^2_p
Noise type	2	450	0.17	.842	<.01
AOI type	2	168	274.72	<.001	.77
Diagnosis	1	27	2.95	.097	.10
Noise type * Diagnosis	2	450	0.20	.818	<.01
AOI type * Diagnosis	2	168	5.84	.004	.06
Noise type * AOI type	4	450	0.45	.772	<.01
Noise type * AOI type * Diagnosis	4	450	1.82	.123	.02

Note. Noise type = no noise, low-intelligibility, or high-intelligibility; AOI type = background, body, or face; Diagnosis = ASD or TD.

Results of the multilevel model building (Table 8.3) revealed that the main effect of diagnosis was not significant, $F(1,27) = 2.95$, $p = .097$, $\eta^2_p = .10$. In other words, participants with an ASD diagnosis ($M = 1.34$, $SD = 1.53$) exhibited similar overall fixation durations as those with TD (M = 1.59, SD = 1.79). Similarly, an effect of noise type also did not occur, $F(2,450) = 0.17$, $p = .842$, $\eta^2_p < .01$. Therefore, the fixation durations were similar whether no noise (M = 1.48, SD = 1.68) was presented or low- (M = 1.46, SD = 1.67) and high-intelligibility (M = 1.49, SD = 1.71) background noise was present.

The analysis showed that the main effect of AOI type was significant (Figure 8.2), $F(2,168) = 274.72$, $p < .001$, $\eta^2_p = .77$. According to Tukey HSD paired comparisons, fixation durations towards each AOI type differed significantly from the other two ($p < .05$). Fixation durations towards the AOIs representing bodies were the longest (M = 3.26, SD = 1.61), followed by fixation durations towards the background of the scene (M = 0.96, SD = 0.74). Fixation durations towards AOIs representing faces of people in the videos were the shortest (M = 0.21, SD = 0.57).

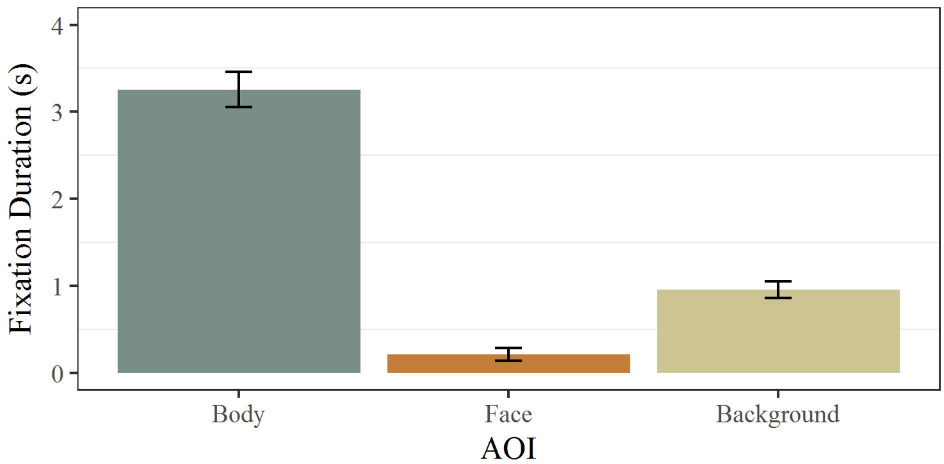

Figure 8.2. Mean fixation duration per AOI type. Error bars represent 95% CI.

There was also a significant interaction effect between AOI type and diagnosis on fixation duration (Figure 8.3), $F(2,168) = 5.84$, $p = .004$, $\eta^2_p = .06$. This interaction again was investigated using least square mean based paired comparisons. It was revealed that AOI type had a similar effect on fixation durations regardless of diagnosis, but it was more pronounced in TD individuals. To be precise, participants with ASD (*M* = 2.83, *SD* = 1.58) looked at the body AOIs less than TD participants (*M* = 3.61, *SD* = 1.54; $p < .05$). Yet, their fixation durations towards the background (ASD: *M* = 1.02, *SD* = 0.82; TD: *M* = 0.91, *SD* = 0.67) and facial information (ASD: *M* = 0.18, *SD* = 0.43; TD: *M* = 0.24, *SD* = 0.67), whilst different from one another, did not significantly differ based on diagnosis. None of the other interaction effects in the model yielded significance (Table 8.3).

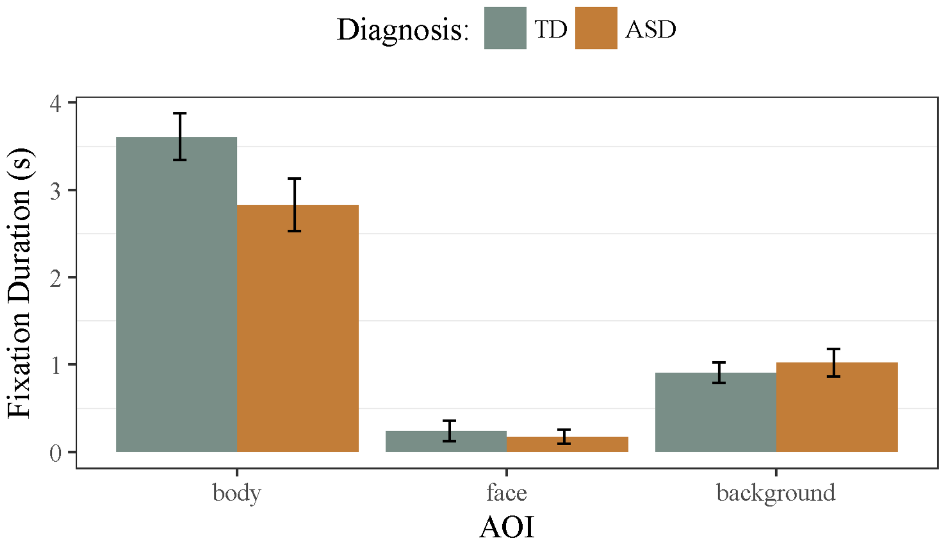

Figure 8.3. Mean fixation duration per AOI type and diagnosis. Error bars represent 95% CI.

Discussion

The current experiment investigated attention to dynamic social information within scenes in high-functioning adults with ASD and TD adults. The scenes that depicted a single person walking down the corridor were purposefully low in social context (i.e. social content and social interactions), but still ecologically valid in terms of general context (i.e. social information not presented in isolation). As expected, both participants with ASD and TD adults exhibited a social bias (Hypothesis 1). In line with Hypothesis 2b and thus in contrast to Hypothesis 2a, this social bias was weaker in adults with ASD than the TD group. Contrary to Hypothesis 3, increased attention to social information, interestingly, occurred in both groups only when looking at the social target's body, rather than the face. Finally, as posited in Hypothesis 4, and in line with findings from Chapter 5 and Chapter 6, the presence and intelligibility of background noise did not moderate the time spent looking at either social or non-social aspects of video stimuli.

Although both participants with TD and ASD exhibited a social bias in the current study, it was less pronounced in adults with ASD. This finding is in keeping with the array of previous research reporting reduced social attention in children, adolescents, and adults with ASD regardless of their level of functioning (see Chita-Tegmark, 2016). The current study expands on this by showing that a reduced social bias in adults with ASD occurs even when they are presented with social stimuli in dynamic scenes that do not involve social interactions. In other words, this indicates that the dissonance between previous research, finding that a social bias reduction in ASD is dependent (Hanley et al., 2013; Speer et al., 2007) or independent (Riby & Hancock, 2009b; Rigby et al., 2016) of the ecological validity of the stimuli used cannot be simply explained by the confounding effect of social context (i.e. absence or presence of social interactions, respectively). This is not to say, however, that social context does not have an influence on the social bias of individuals with ASD. Indeed, research by Stagg et al. (2014) and our findings from Chapter 7 indicate that the presence of social interaction has a differential effect on attention of those with ASD and TD when the social nature of the stimulus itself is controlled. Taken together these findings suggest a plausible accumulative effect of social (i.e. interaction) and non-social (i.e. background) context on reduced social attention of individuals with ASD. Future studies may benefit from systematically manipulating the presence of both of these contexts in order to reveal their unique and accumulative influences.

Furthermore, the current study expands on previous findings by showing that reduced attention to ecologically valid social stimuli in ASD occurs even when the distracting effects of non-social information are minimised. It has been previously suggested that reduced social attention in ASD may be occurring due to a preoccupation with non-social aspects of the environment, supported by findings showing increases in attention off-person (e.g. Klin et al., 2002b; Riby & Hancock, 2009b). A later study showed that preferential looking at dynamic geometrical patterns, rather than dynamic social stimuli, in toddlers was predictive of an ASD diagnosis later in life (Pierce, Conant, Hazin, Stoner, & Desmond, 2011). Yet, whilst the presence of the background was necessary to induce ecological validity in the current experiment, special care was taken to ensure uniformity of the background across stimuli in terms of the content and the camera angle. Also, the only dynamic part of the scene was the centrally located human figure, both qualities that should attract viewers' attention (Tatler, 2007). Indeed, the finding from the current study show that reduced social attention in adults with ASD was not accompanied by increases in non-social attention. Thus, it is unlikely that their attention would have been distracted by more salient non-social parts of the stimuli.

It should be noted that an unexpected difference occurred between the current findings and most of previous research finding reduced social attention in ASD (e.g. Klin et al., 2002b; Riby & Hancock, 2009b; Rigby et al., 2016; Speer et al., 2007). To be precise, previous studies show that reduced social attention in ASD mostly occurs due to the lack of a typical social bias to faces, and eye regions in particular (e.g. Klin et al., 2002b). Yet, the current study found that the social bias in both groups was expressed via increased attention to the bodies, rather than faces. That in itself is not that surprising, given that Yarbus (1967) also showed that the bias towards faces, in particular, was not present when participants were looking at images depicting full figure. However, due to this lack of bias to faces in TD individuals in the current study, reduced social attention in ASD was applicable only for the body region.

Two possible explanations pertaining to the methodological differences between the stimuli utilized in current and previous ASD research are likely. Firstly, the size of each region could partially explain such differences. The stimuli utilized in previous research often encompassed faces that were greater than 5^{o} of the participants' visual field of view and were specifically chosen to present very little of the background or body (Klin et al., 2002b; Rigby et al., 2016; Speer et al., 2007), which could account for increased attention to faces in their studies. In contrast, the size of the social target used in the present experiment, and thus the size of each region, varied across the videos starting with a full human figure at the start and finishing with only the torso of the figure being present at the end. Therefore, the lack of a social bias towards faces occurring in both groups could potentially be explained by the relatively small size of face regions in the current study. Yet, given that the face AOIs in this experiment were still easily distinguishable, this finding most likely indicates that the bias towards faces may not be occurring if the rest of the body is present.

Secondly, the position of the facial region could also account for the inconsistency between the current and previous findings. Indeed, it is conceivable that the film excerpts used in previous studies (Klin et al., 2002b; Rigby et al., 2016; Speer et al., 2007) focused on faces not only in size, but also position. However, in the current study to ensure that the full figure was included in the stimulus, the centre of the image was focused on the torso rather than the face of the person. Given previous research showing that participants tend to look at the middle of the picture (Tatler, 2007) and our findings from Chapter 5 confirming that the position of the social target moderated visual attention received, faces in our study may have received less attention by both groups due to their peripheral location in videos. If these methodological differences of the size and position of facial regions are indeed responsible for the inconsistency of findings in the current and previous studies, this may indicate that the extent of atypical social attention in ASD, being especially pronounced for faces and eyes, may have been exaggerated. Future research directly manipulating the size and position of faces and other social information would be required to evaluate this possibility.

Effects of Background Noise

Similar to experiments described in the previous chapters, the current experiment also aimed to evaluate whether background noise affected attention to social information in individuals with ASD in comparison to age and IQ matched TD individuals. Neither the presence, nor the intelligibility of the background noise in the current study, however, influenced participants' fixation durations despite their diagnosis.

The fact that the mere presence of the background noise did not have an effect is not surprising as the previous experiments also only found that background noise with intelligible speech changed one's gaze behaviour. For instance, Experiment 5 in Chapter 6 showed increased attention to subjectively more relevant, especially social, areas of the scene in presence of intelligible noise. Furthermore, Experiment 4 of Chapter 5 showed that attention to social information in the presence of highly intelligible background noise differed based on whether the person was located in the centre or off-centre in the scene. Yet, social information in the stimuli of the current experiment was always located centrally. The stimuli were also purposefully manipulated to not include other highly relevant information in the scenes (i.e. same background across videos). Thus, it is likely that the high-intelligibility background noise in the current experiment did not have an effect due to the lack of low relevance social information at the expense of which attention to high relevance social information could be increased.

The necessity of competing social information for the distractor effects of background noise to occur, indeed, fits with previous findings of this thesis. Yet, it should be acknowledged that this lack of effect from background noise may simply reflect increased differences in perceptual load of the stimulus used. To be precise, such a possibility is reflected by the second mechanism in the load theory of selective attention (Lavie, 1995). It is suggested that the relatively high perceptual load of the target stimulus may exhaust one's perceptual resources thus automatically excluding distractors from perception (Lavie, 1995). Therefore, given that the dynamic rather than static stimuli were utilized in the Experiment 7, it is possible that both TD adults and adults with ASD did not perceive the background noise due to the lack of perceptual resources available.

Limitations and Future Directions

Whilst the current study extends previous knowledge by revealing that the presence of social interactions is not necessary in dynamic scenes for a reduced social bias in ASD to occur, it did not conduct a direct comparison. A comparison condition with dynamic interactions in the same uniform environment would have arguably provided additional information. This would have been particularly relevant if a reduced social bias in ASD did not occur. It should also be noted that social information in the current study included not only the face, but also the rest of the body of the person in the scene. It could be argued, however, that only particular parts of the human body (e.g. face) present socially salient information. This can be further supported by the fact that previous studies focusing on such social areas as only face or head of the person find atypical social attention in ASD (e.g. Hanley et al., 2013). Yet, the current experiment only observed reduced social attention in ASD towards the body and not the face of the person depicted. This is in line with findings of Yarbus (1967) showing that when the whole body of the person is visible, people tend to explore the full body rather than just the face. Yet, some previous research show reduced attention to faces rather than bodies in ASD (Klin et al., 2002b; Rigby et al., 2016; Speer et al., 2007). Thus, it is likely that reduced social attention to faces would have also occurred in the current study, if only facial information was included in the stimulus.

Another potential improvement in the current design would include a condition with a subject moving across the screen rather than towards a camera. A centrally located figure suited the current experiment as it aimed to evaluate robust attention to social information. Yet, it is possible that the approaching nature of the figure may have induced a sense of intent, and thus social context. Hence, future studies may benefit from developing their own stimuli that would systematically vary in the social context and perspective.

Conclusion

The current study confirms that high-functioning adults with ASD have a social bias, which is reduced in comparison to TD adults. It also confirms that atypical social attention in ASD is not accompanied by, and thus most likely not resulting from, increased non-social attention. Further, it questions the extent to which a social bias is especially pronounced for faces and eyes, as in the current study it was only exhibited towards bodies. Finally, the present study expands on previous findings by showing that the presence of social interaction is not necessary for this reduction in social bias to occur. Yet, in combination with previous studies, it suggests a potentially unique and accumulative effect of ecological validity via the presence of social and non-social context.

CHAPTER 9

GENERAL DISCUSSION

Overview

The main aim of the current thesis was to investigate domain general attentional processes and stimulus properties that may be underlying atypical social attention in high-functioning adults with ASD. Seven experiments presented across six chapters have addressed this general aim from different perspectives. The current chapter brings together the findings made across the previously described experiments. The first section of this chapter recaps the main findings in each of the six experimental chapters. Including: typical global/ local processing (Chapter 3); subtle atypicalities in attentional capture by social information (Chapter 4); reduced engagement with social information without evidence of delayed disengagement or capture (Chapter 5); a bias towards social and subjectively relevant information, but to a lesser extent than typical (Chapter 6); atypical absence of a bias towards schematic interacting faces when only one pair of such faces was present in the pattern (Chapter 7); and a reduced social bias towards bodies, but not faces, in stimuli of low social content and high ecological validity (Chapter 8) in adults with ASD. The rest of this chapter discusses the bigger picture by drawing upon evidence across different studies of the current thesis. Evidence pertaining to the properties of the stimuli used (i.e. ecological validity, social content, presence of interactions, general context, and type of social information presented) that may be moderating the inconclusive evidence of atypical social attention in ASD seen in previous research is discussed first. It is then followed by an in-depth discussion of how the current findings align with previously proposed domain general processing difficulties (i.e. global/local processing, attentional shifting, and intersensory processing) that may be underlying atypical social attention in ASD. Theoretical and practical implications of the main findings are also addressed.

Summary of Findings

The main aim of the current thesis was to investigate domain general mechanisms and stimulus characteristics that may be underlying atypical social attention in a consistent group of high-functioning adults with ASD. This aim was further broken down into three sub-aims that were addressed across different experimental chapters. Firstly, the current research aimed to examine whether any of the three domain general mechanisms previously suggested to be underlying atypical social attention were co-occurring with reduced social attention in ASD. These attentional processes included potential global and/or local processing difficulties (e.g. Happé & Frith, 2006), attentional shifting atypicalities (e.g. van der Geest et al., 2001), and intersensory integration difficulties (e.g. Bahrick & Todd, 2012) in ASD. The second sub-aim of the current thesis was to investigate potential stimulus characteristics that may be moderating reduced social attention in ASD as suggested in previous literature (e.g Chita-Tegmark, 2016). These included such stimulus aspects as ecological validity, social content, relevance of information, presence of social interactions, and general context. Finally, the current thesis also aimed to further the understanding of ASD and its presentation in adulthood via the use of a consistent sample across experiments.

Chapter 3

Experiment 1 described in Chapter 3 aimed to investigate local and global processing in high-functioning adults with ASD. A classic divided attention task with Navon’s (1977) hierarchical figures was utilized to achieve this. Results showed that a global interference effect occurred in both TD adults and those with ASD. Thus, all participants in Experiment 1 of the current thesis took longer to respond to a locally occurring target when the stimulus was incongruent at the global level. Surprisingly, both participant groups also exhibited local interferences. Nevertheless, both high-functioning adults with ASD and TD adults experienced a global precedence effect as well. In other words, targets presented at the global level were responded to faster than targets at the local level. Therefore, these findings indicate that high-functioning adults with ASD perceived hierarchical figures similarly to TD adults. In other words, no support was found for atypical hierarchical processing in ASD as posited by either the WCC, or EPF theories. Instead, both groups of participants in the current sample exhibited interference from both local and global levels of the stimuli with a slight advantage towards global perception.

Chapter 4

The two experiments in Chapter 4 aimed to investigate potential attentional shifting atypicalities in high-functioning adults with ASD. To be precise, exogenous and endogenous attentional engagement to and from social and non-social information were evaluated. This was achieved by examining individuals' saccadic latencies to relatively simple schematic (Experiment 2) and photographic stimuli (Experiment 3) in a modified gap-overlap task. Findings of both experiments revealed that participants with ASD, just like TD individuals, experienced both gap and overlap effects. Both experiments also showed that attention shifting overall was faster towards social rather than non-social information, whereas Experiment 3 further revealed that endogenous disengagement was slower from social than non-social information.

The results of Experiment 2 also revealed that the presence of a social peripheral stimulus (i.e. drawing of a face) resulted in faster attention capture than a non-social peripheral stimulus (i.e. drawing of a rectangle) only in the overlap condition. In other words, both participants with ASD and TD individuals exhibited a social bias by shifting their attention to social stimuli faster than non-social stimuli when their attention was engaged by a different target and thus requiring endogenous disengagement. In Experiment 3, however, the type of peripheral stimulus had more influence on the presence of the gap effect. To be precise, TD individuals only benefited from exogenous disengagement of attention when shifting it towards non-social stimuli (i.e. photograph of a house), but not social ones (i.e. photograph of a face). High-functioning adults with ASD, however, exhibited the opposite behaviour shifting attention towards photographs of faces faster if attention was already disengaged. Furthermore, adults with ASD did not benefit from exogenous attentional disengagement when shifting it to photographs of houses. Thus, the findings of this chapter suggest some subtle differences in attentional processes towards social information in high-functioning adults with ASD and TD.

Additionally, potential effects of the presence and/or intelligibility of background noise were also investigated in Experiment 3. An interaction effect between noise type, combination of central and peripheral stimulus type, and diagnosis was found. However, further investigation within the analysis described in the chapter failed to independently reveal where or why such moderation occurred.

Chapter 5

Experiment 4 described in Chapter 5 followed up on similar attentional processes as those investigated in Chapter 4 by using more ecologically valid stimuli. This allowed for not only attentional shifting atypicalities to be assessed, but also an examination of whether they depend on the ecological validity of the stimuli used. Photographs of the scenes each involving either a centrally or off-centre located person were utilized to investigate general attentional engagement with, attentional capture by, and attentional disengagement from socially relevant information (Williams et al., 2013). The findings of Experiment 4 confirmed high-functioning adults with ASD spent proportionally less time engaging with socially relevant information within natural scenes than TD participants. Yet, adults with ASD oriented to social information and disengaged from it by looking at the rest of the picture just as fast as TD adults. These findings thus suggest that reduced attention to social information in ASD cannot be directly explained by slower social orienting or faster disengagement from social information.

In terms of background noise, no links between the presence and/or intelligibility of the noise and participants' diagnosis were found. High-intelligibility background noise resulted in slower attentional capture of off-centre located social information in both groups in comparison to low-intelligibility background noise or no noise. The proportional visit duration to off-centre, but not centrally, located social information was also shorter under the high-intelligibility background noise than low-intelligibility or no noise conditions.

Chapter 6

Experiment 5 in Chapter 6 aimed to directly compare attentional engagement with social and non-social information and investigate several potentially moderating stimulus properties. To be precise, it utilized complex naturalistic scenes to investigate whether stimulus characteristics such as increased social content or subjective relevance of the information presented moderated atypical attention in ASD. As expected, high-functioning adults with ASD spent less time looking at social information than TD adults. This did not, however, occur due to increased attention to non-social information as adults with ASD spent a similar amount of time looking at non-social information as TD adults. It was further found that overall viewing time and attention to socially relevant information decreased with an increase in social content, but only for TD adults. The findings of Experiment 5 also offer some new insight into attention to informative areas of scenes in ASD. It was found that, unsurprisingly, adults with ASD and TD engaged more with stimuli parts judged as more informative than those deemed to be less informative. This bias towards the more informative area, however, was more pronounced in the TD adults.

Furthermore, high-intelligibility background noise increased attention to high social content scenes in adults with ASD and TD individuals alike. It also increased attention to the more informative areas of the scenes, especially for social information in low social content scenes. This may indicate that participants paid more attention to potential sources of or explanations for the perceived speech in the background noise.

Chapter 7

Experiment 6 described in Chapter 7 aimed to distinguish between the interference of social and feature structure on the performance and gaze behaviour of high-functioning adults with ASD. Moreover, in connection to the overarching aims of the thesis, it also aimed to investigate whether the structure of social information induced the effect of global interference in TD adults and/or those with ASD. Experiment 6 utilized a new paradigm, which manipulated pattern structure, to distinguish between the interference of social and feature structure. This was achieved by presenting participants with matrices of faces that were either: high and low in social interactions (number of faces looking at each other), whilst the feature structure was kept constant; or high and low in feature structure (horizontal changes in gaze direction), whilst the number of interactions were kept constant. Findings showed that TD participants experienced interference to reaction times (RTs) in patterns with higher feature structure, which shows that the change-based manipulation was successful. Participants with ASD also responded slower to the high feature structure than the low feature structure trials. Both participants with ASD and TD individuals exhibited slower

RTs to matrices with a higher rather than lower number of interactions. Furthermore, an eye-tracking analysis showed a social bias towards faces looking at each other to be present in both TD adults and those with ASD. This effect, however, was less pronounced in the latter group. A social bias towards interacting faces in ASD was not present at all when the number of such faces was low. Therefore, it seems that while the number of structural changes or social interactions encountered may not affect overt performance of those with ASD differently from TD individuals, it seems to affect underlying attentional processes.

Differently from the experiments described in the previous chapters, the findings from Experiment 6 also revealed clear group differences in the effect of background noise. It was found that diagnosis moderated the effect of noise on participants' RTs. To be precise, only the performance of TD participants, but not the participants with ASD, was accompanied by interference from increased intelligibility of background noise, which may indicate an enhanced perceptual load capacity in ASD. Regarding visual attention, it was found that the increased intelligibility of background noise increased overall fixation durations and did not differ based on whether the faces were involved in the interaction or not. That was, however, most likely a result of a longer time taken to answer due to the increased intelligibility and thus a reflection of longer on-screen time.

Chapter 8

Experiment 7 in Chapter 8 utilized the dynamic presentation of social information in scenes to further investigate atypical attention to social information in this sample of high-functioning adults with ASD. Experiment 7 differed from the previous experiments not only due to the video format used, but also the focus on social information. Firstly, the social information was the only changing and moving part across the scenes. Secondly, it was centrally located. It was also defined separately as areas representing faces and bodies. Similarly to previous chapters, a reduced bias to social information, via fixation durations, was observed in ASD participants in comparison to TD adults. Yet, these findings revealed that these differences in social bias occurred only when looking at bodies of the approaching figures, and not faces. This surprising finding suggests potential artefacts of centrally located information and thus challenges the existence of attentional bias towards faces. The potential effects of the presence or intelligibility of background noise were also examined in this experiment but did not moderate participants' attention. This may represent the dynamic stimuli being high enough in perceptual load to deplete attentional resources that would otherwise be assigned to the audio distractor.

Characteristics of the Stimuli Presented

Ecological Validity, Motion, and Complexity

The presence of reduced social attention in ASD when compared to TD was consistently confirmed across the different experiments in the current thesis. To recap, findings of Chapter 7 showed that participants with ASD fixated less than TD adults on relatively simple schematic faces, albeit only the ones participating in interaction. When static photographs of scenes involving people where used, participants with ASD spent less time exploring (i.e. visit duration) the areas of the scenes representing human figures than TD adults (see Chapter 6). Similarly, a reduction of social attention was also seen even if the visit durations on areas representing social information were evaluated in proportion to viewing of the whole scene (see Chapter 5). Finally, Experiment 7, described in Chapter 8, showed that fixation durations on areas representing social information were shorter in adults with ASD than TD individuals, when looking at dynamic scenes. Therefore, high-functioning adults with ASD, in the current thesis, looked at social information less than TD adults irrespective of stimulus presentation form or, indeed, type of measure utilized.

These findings contradict previous findings of reduced social attention in ASD occurring when using dynamic videos, but not static photographs (Speer et al., 2007) or cartoon images (van der Geest et al., 2002). By doing so, it also indicates that these inconsistencies in previous findings are unlikely to be reflecting difficulty with processing complexity (Loddo, 2004) or motion (Klin et al., 2009). Instead, it is possible that due to small sample sizes (24 in Speer et al., 2007; 30 in van der Geest et al., 2002) these studies may have been unable to find potentially weaker group differences when using less ecologically valid stimuli. Typical processing of complexity in ASD in the current thesis is further supported by the findings of Experiment 6 in Chapter 7 showing that in general participants with ASD processed patterns with an increased feature structure at a similar speed to TD individuals.

The current findings, however, are in line with other empirical studies showing that atypical social attention in ASD occurs regardless of whether drawn or photographic stimuli are presented (Riby & Hancock, 2009b) and despite the presence of motion (e.g. Rigby et al., 2016). It also further confirms the conclusion of the meta-analysis by Chita-Tegmark (2016) that neither atypical motion processing, nor ecological validity of stimuli presentation, in terms of its realism, can fully account for reduced social bias in ASD.

Social Content

In the meta-analysis by Chita-Tegmark (2016) the only significant factor predicting reduced social attention in ASD across the studies appeared to be higher social content of the stimuli (i.e. the number of people exceeded one). Yet, in the current thesis a reduced social bias was visible not only when multiple figures or faces were presented, but also when only one person was depicted within a scene. For instance, high-functioning adults with ASD in the current sample looked at a single human figure presented in a static scene in Chapter 5 or a dynamic scene in Chapter 8 on average less than TD adults. Furthermore, the experiment described in Chapter 6 directly investigated whether the presence of low (1 – 4 people) and high (6 - 12 people) social content of the scene differentially affected social attention in adults with ASD when compared to TD. Yet, it was found that overall social information in the low social content scenes was explored for longer than that in the high social scenes. Additionally, it was revealed that lower social content was related to longer overall visit durations (i.e. time spent exploring each area of the image on average) in TD, but not adults with ASD. Therefore, in the current sample the size or the presence of an atypical social bias in ASD did not depend on the number of people presented in a stimulus.

At the first glance, the current findings contradict existing research of the relationship between social content on social attention in ASD (Chita-Tegmark, 2016; Hanley et al., 2013; Speer et al., 2007) or TD (Birmingham et al., 2008). Yet, it should be noted that the previous studies defined high social content stimuli as involving more than a single person. For example, in the study by Birmingham et al. (2008) only the scenes involving one or three people were utilized. In Experiment 5 in Chapter 6, however, independent judges were used to define the level of social content in the scenes resulting in the low social content category encompassing up to four people. It may thus be that a decrease in social attention would have also been observed within the low content category in the current research, if it was differently categorised. Yet, atypical social attention in ASD was present in Experiment 4 and Experiment 7, both of which utilized stimuli depicting a single person. Thus, it would have been unlikely that atypical social attention in ASD would have altogether disappeared, if single person scenes were included in Experiment 5. Nevertheless, the current findings extend previous research by indicating that the effect of social content on social attention in general may be following not a positive linear relationship, but potentially a curvilinear trend with social attention decreasing after a certain number of targets is exceeded.

Interactions

Another aim of the current thesis was to evaluate whether the presence of social interactions rather than simply the number of people in a scene could be explaining atypical social attention in ASD instead. Indeed, in the study by Birmingham et al. (2008) the effect of social content was moderated by whether an action was depicted in the scene. As the action involved in the multiple people scenes mostly meant an interaction between the characters, it is possible that the observed effect resulted from a presence of social interactions rather than the number of people in the scene (Chita-Tegmark, 2016). One of the aims of Chapter 7 of the current thesis was thus specifically devoted towards evaluating the potential effects of the number of social interactions involved in the stimuli. It was found that, indeed, a higher number of interacting faces in a pattern delayed task completion for both adults with ASD and TD adults. Furthermore, all participants looked at interacting faces, in general, more than the non-interacting pairs of faces. Yet, for participants with ASD this effect was not present when the number of interactions was kept low (i.e. one pair of interacting faces), albeit their attention to the non-interacting faces remained similar. It thus appears that individuals with ASD may have been less likely to notice the one pair of interacting faces in the array of other faces when compared to adults with ASD. Therefore, at least in the current sample, adults with ASD exhibited somewhat atypical attention to social interactions in comparison to TD adults.

These findings are in line with previous research investigating the effects of interactions on attention to figures and finding that children with ASD increase attention to interacting figures less than controls (Stagg et al., 2014). Indeed, it may also explain why other studies (e.g. Rigby et al., 2016; Speer et al., 2007) find the difference in attention to social information between individuals with ASD and TD increases if the stimulus involves more people. Given that the images used in Chapter 6 were mostly of an office or a classroom environment and thus rarely centred on an interaction, the lack of group differences in the effect of social content could also be partially explained by the lack of interactions in the stimuli. Nevertheless, reduced social attention in adults with ASD when compared to TD in the current research was also found in the experiments in Chapter 5 and Chapter 8 where only one person was presented within each scene in those experiments. Thus, no interaction was depicted suggesting such it is not necessary for reduced social attention in ASD to occur. In line with that, adults with ASD looked at interacting faces just as much as TD adults when four or five pairs of social interactions were present in the stimuli. The latter further confirms that it seems unlikely that the presence of social interactions on their own can account for atypical social attention in ASD. Instead, it suggests that the presence of social interactions have an additive, but distinctive, effect on social relevance for both adults with ASD and TD and thus should be controlled for in future studies examining the effects of social content on attention to social information in ASD.

Context

The research described in the current thesis also investigated the possibility that atypical social attention in ASD may be related not to the socialness of the information, but the context of the scene. For example, it has previously been suggested that atypical social attention in ASD may be occurring due to a bias towards non-social information (e.g. Tager-Flusberg, 2010). Indeed, the study in Chapter 5 of the current thesis showed that there were group differences in attention to social information in proportion to the rest of the scene. Yet, multiple explanations are possible for such a difference, including a lack of social bias, the presence of a non-social bias, or both in participants with ASD. The experiment described in Chapter 6 examined this atypical attention further by controlling the size of social and non-social AOIs. This was done to enable the investigation of whether participants with ASD, indeed, look at non-social information for longer than social information. It was found that both high-functioning adults with ASD and TD adults in the current sample experienced a social rather than a non-social bias, but that it was more pronounced in the TD group. This was further confirmed in the Experiment 7 in Chapter 8 where participants with ASD looked at background information of original size (in contrast to standardised areas of interest in Experiment 5) in the videos for as long as TD adults but differed in their attention to human bodies.

These findings are in line with most of the previous studies that do not show increased attention to the background information in individuals with ASD (e.g. Fletcher-Watson et al., 2009; Riby & Hancock, 2008; Speer et al., 2007). It is also in keeping with past research utilizing a gaze data ratio which found a preference for social (i.e. facial) information in TD individuals, but not those with ASD (Bird et al., 2011; Wilson et al., 2010). In combination, these findings suggest that an atypical attentional bias in adults with ASD occurs due to lower than typical social, rather than higher non-social, attention. In other words, individuals with ASD do not have an atypical preference for non-social information over social information, but instead prefer social over non-social information less than TD individuals.

Chapter 6 also investigated whether the nature of both social and non-social information present in the scenes could be related to atypical attention in ASD. To be precise, in addition to the socialness of the information, the stimuli were also divided into areas of relevance. The distinction of those areas was based on the ratings of independent judges. The findings revealed that, firstly, all participants exhibited an attentional bias towards the areas judged as more relevant. Yet, this bias was again more pronounced for TD adults than adults with ASD. Secondly, a social bias occurred only within the more, rather than less, relevant areas of the picture and, in that way, it was not moderated by the diagnosis. Finally, it should be noted that the bias towards informative areas of the scenes increased with background noise but was less pronounced without background noise. Therefore, it appears that individuals with ASD may experience not only atypical social attention, but also subtle differences in prioritizing relevant information, which may reflect atypical global perception. Future eye-tracking studies, thus, should consider comparing attention in ASD and TD to not only social, but also otherwise relevant information. Specifically, when investigating social biases in ASD, researchers should be careful aggregating attentional data across more and less relevant social information. Atypical gaze behaviour in those instances may reflect not a reduced bias to social information per se, but a more general failure to orient to relevant social and non-social information.

While the current findings show that increased attention to non-social information is an unlikely explanation for reduced social attention in ASD, the differences in processing subjectively relevant areas of the scenes could explain some inconsistencies in the past research. For instance, Klin et al. (2002b) showed that in their experiment individuals with ASD looked off-person for longer than controls, whereas the same was not found in the current thesis. It should be noted, however, that in the experiment in Chapter 8 background information did not vary across the videos. Yet, a study by Klin et al. (2002b) used excerpts of a film, which potentially involved relevant background information. Given that previous research also showed that individuals with ASD are more susceptible to distractor effects from certain objects (Sasson & Touchstone, 2014), it is simply possible that the stimuli utilized by Klin et al. (2002b) included background information of particular interest to individuals with ASD. Notwithstanding that, the current findings show that reduced social attention in ASD occurs without increases in attention to non-social information despite its subjective relevance (Chapter 7) and even when the distracting effects of the background information are minimized (Chapter 8).

It also should be noted that one aspect shared between all the experiments in the current thesis finding reduced social bias in individuals with ASD when compared to TD individuals was the presence of general context (i.e. when information is not presented in isolation). In the experiments in Chapter 5 and Chapter 8 using naturalistic scenes with a single person, the context was provided via the presence of the background. The scenes presented in Experiment 5 described in Chapter 6 also involved contextual information via the background. In Experiment 6 (Chapter 7) atypical social attention occurred when manipulating the number of social interactions, which could be seen as a social context. It is important to note that the stimuli used in the Chapter 7 were patterns of schematic faces and thus were not otherwise highly ecologically valid, whereas the experiments in Chapter 5 and 8 did not involve social interactions.

Findings of context inducing atypical attention in ASD are partially in line with the results of Chevallier et al. (2015), who showed that neither the presence of irrelevant competing social or non-social information, nor the dynamic presentation of stimuli were sufficient to induce atypical attention to isolated social stimuli in children with ASD. They found, however, that reduced attention occurred when looking at videos depicting two children interacting in a room and thus they emphasized the importance of ecological relevance via social interactions. Taken together these findings indicate that social interactions may be sufficient, but not necessary to induce atypical social attention in ASD. Instead, the current thesis further expands on previous findings by suggesting a unique and potentially accumulative effect of ecological validity via the presence of social and non-social context. This finding supports the notion that ecological validity is a key factor for eye-tracking studies in ASD to consider. Yet, the current finding expands it by suggesting that future studies attempting to investigate reduced social bias in ASD should avoid using stimuli in isolation rather than static presentations. This may also have more practical implications for the design of, for example, social skills training materials by showing the importance of context when atypical social attention is targeted. Yet, in teaching an opposite design with isolated materials may be more beneficial if attempting to relay the information from the social source.

Type of Social Information

Albeit not one of the original research aims of the current research, an interesting finding has been made in relation to which part of social information is receiving the most attention and thus is the most relevant for atypical social attention in ASD. In general, the consensus in past research has been that social attention in ASD is particularly impaired when looking at the eyes (e.g. Klin et al., 2002b) and face (e.g. Riby & Hancock, 2009b; Rigby et al., 2016) regions of social information, although atypical attention to bodies in addition to faces (e.g. Speer et al., 2007) or the overall figures (e.g. Stagg et al., 2014) has also been exhibited. These findings have thus resulted in other research focusing solely on facial social information as particularly impaired in ASD and not even defining the other areas of the human figures visible in the stimuli (Kuhn et al., 2010). In the research described in the current thesis social information AOIs were usually defined as all the social information available on the screen. In Chapter 3 and Chapter 7, the social information available included only faces. In Chapter 5 and Chapter 6, however, social information was defined as all visible parts of the human figures in the scenes as the face regions were too small in relation to the overall scene to be defined as separate AOIs. Therefore, both body and facial areas of the social information were only distinctive enough in the videos used in the experiment in Chapter 8. Unexpectedly, the findings in Chapter 8 revealed that a social bias occurred only towards the AOIs representing human bodies rather than faces. In turn, reduced social attention in ASD also occurred only in relation to the body AOIs.

The current findings thus indicate that faces may not be as relevant for atypical social attention in ASD as previously thought. Based on the current findings, it is possible that the bias towards faces in previous research may instead be stemming from either the disproportional size of the area representing facial information or its position. Indeed, the stimuli utilized in previous research often encompassed faces that were greater than 5^o of the participants' visual field of view and were specifically chosen to depict very little body or background (Klin et al., 2002b; Rigby et al., 2016; Speer et al., 2007). It is also likely that the excerpts of films used in previous studies (Klin et al., 2002b; Rigby et al., 2016; Speer et al., 2007) focused on faces not only in size, but also position by presenting them in the centre of the scene. In the experiment in Chapter 8, however, a full human figure was shown thus keeping the size of the face proportional to the rest of the social information. Furthermore, it resulted in the torso of the human figure rather than the face being placed at the centre of the image. In line with this, the experiment in Chapter 5 extended previous knowledge of a bias towards the centre of a stimulus (Tatler, 2007) by showing that it applied for socially relevant information as well. However, both participants with ASD and TD looked at centrally located social information more than peripherally located information. Consequently, atypical social attention in ASD is unlikely to be explained via decreased attention to centrally located information, in general. Thus, these findings question the extent to which atypical social attention in ASD is especially pronounced for facial information rather than representing a choice of stimuli used. Future research manipulating the size and position of faces and other social information is required to directly evaluate their effects.

Mechanisms Underlying Atypical Social Processing in ASD

Some domain general mechanisms have been previously proposed as potentially underlying ASD (e.g. Behrmann, Thomas, et al., 2006; van der Geest et al., 2001). Thus, one of the main aims of the current thesis was to test whether they co-occur with reduced social attention in ASD and, in turn, may be explaining it.

Global and/or Local Processing

The experiments described in Chapter 3 and Chapter 7 directly investigated the presence of atypical processing of hierarchical information in high-functioning adults with ASD when compared to TD. The findings in Chapter 3 showed that participants with ASD, just like TD, experienced interference from both global and local levels of the stimuli. Furthermore, all participants exhibited a global precedence effect by responding to targets presented at the global level faster than those at the local level. The experiment in Chapter 7 only examined the potential interference of task irrelevant global structure yet did so by manipulating both the feature structure and the social structure of the patterns. Results revealed that adults with ASD, similarly to TD, were slower at the task when the pattern was manipulated to be high, rather than low, in structural changes. It did not differ based on whether those structural changes represented social interactions or feature structure. Therefore, typical hierarchical processing has been observed in the current sample of high-functioning adults with ASD with domain general global interference occurring despite the socialness of the global structure.

These findings contradict theoretical approaches suggesting that hierarchical processing may be atypical in ASD. In particular, it stands in contrast to a WCC account that suggests individuals with ASD as having a more locally oriented processing style (Frith, 1989; Frith & Happé, 1994; Happé & Frith, 2006). Yet, they also do not support an EPF account suggesting that atypical processing in ASD comes due to difficulty integrating local and global information (Mottron & Belleville, 1993; Mottron et al., 2006). To be precise, it proposes that individuals with ASD process information at the global level typically, but exhibit superiority at the local level. Only the experiment in Chapter 3 tested for the presence of a local advantage or precedence, yet neither was found in the current sample of participants, whereas a local interference effect occurred in both adults with ASD and TD. Thus, given that atypical social attention across studies was characteristic of this sample of adults with ASD, it seems unlikely that this would be occurring due to the presence of pervasive and rudimentary hierarchical processing atypicalities.

Nevertheless, it should be noted that the research described in the current thesis has been conducted on a specific sample of high-functioning adult participants and thus these findings cannot necessarily be generalised across development. In other words, whilst the current research shows that reduced social attention in adulthood does not co-occur with hierarchical processing atypicalities, it does not contradict an existence of such deficits earlier in development. For instance, a few studies have shown that atypical hierarchical processing is characteristic of children and adolescents with ASD (e.g. Mottron et al., 1999; Plaisted et al., 1999; Rinehart et al., 2000). If development of hierarchical processing at either of the levels, or their integration indeed is delayed in

ASD, that could have lasting consequences, especially when perceiving complex structures like social information. Indeed, participants with ASD in the current thesis exhibited reduced attention not only to social information, but all information perceived as more relevant by other subjects (see Chapter 6). This visual behaviour may be indicative of difficulty when perceiving the scene as the whole and, in turn, distinguishing attention worthy areas. Therefore, the current findings do not necessarily exclude the possibility of delayed hierarchical processing in ASD overall or its effects on other behaviours later in life, but rather contradicts it being a permanent characteristic of ASD. Longitudinal studies, however, are needed to confirm an existence of these developmental pathways.

Attentional Shifting

Potential issues in attentional capture and disengagement have also been investigated as plausible mechanisms underlying atypical social attention in ASD. Chapter 4 and Chapter 5 were devoted to examining the presence of attentional shifting atypicalities in high-functioning adults with ASD compared to TD adults. In general, however, it was found that individuals with ASD, just like TD adults, exhibited slower endogenous disengagement from social than non-social information. Both adults with ASD and TD also exhibited an overall social bias in faster attentional capture by social rather than non-social information. Furthermore, participants in this study benefited from exogenous disengagement from attention and were delayed by the overlapping presentation of stimuli regardless of their diagnosis. In line with these findings, the experiment discussed in Chapter 5 also failed to reveal any group differences in attentional capture by, or disengagement from, social information in naturalistic scenes which would require endogenous disengagement. These findings are consistent with some previous research that also did not show group differences when using a non-social gap-overlap task on children (Crippa et al., 2013; Mosconi et al., 2009), adolescents (Goldberg et al., 2002), and adults (Kawakubo et al., 2004) with ASD. Furthermore, the current findings are consistent with the only previous research using a gap-overlap task to examine social orienting in children with ASD and not finding atypical attention either (J. Fischer et al., 2014).

Nevertheless, some subtle diagnostic differences were found in Experiment 2 in Chapter 4. Unexpectedly, adults with ASD benefitted from exogenous disengagement when shifting attention towards social, but not non-social information. In contrast, for TD individuals the presence of a forceful disengagement of attention led to faster attentional capture by non-social, but not social, information. If only the gap and overlap conditions were considered, both groups of participants in the current sample would have appeared to experience a gap effect when shifting attention towards social or non-social information. Therefore, including their baseline performance revealed an otherwise masked effect of difference occurring in endogenous disengagement condition. In this case, one could speculate that TD individuals already experience a social bias when shifting attention towards a social stimulus that appears at the same time as the currently engaged information disappears, thus diminishing the facilitation effect of the increased inter-stimulus interval. Given that the difference between reaction times in gap and baseline conditions is usually smaller than the difference between overlap and baseline conditions (e.g. Goldberg et al., 2002), faster attentional shifting in the baseline condition could diminish the said gap effect.

Yet, individuals with ASD seem to benefit from forcefully disengaged attention when shifting attention to social, but not non-social information. This suggests that a typical social bias may not be present in adults with ASD and thus exogenous disengagement is required to facilitate attentional capture. This necessity for attention to be forcefully disengaged for a social bias to occur partially supports the previously suggested concept of “sticky” attention in ASD (Landry & Bryson, 2004). The current findings, however, contradict the original concept of “sticky” attention by showing that it may not occur via delayed overall disengagement, but rather an obstruction of a social bias. In other words, whilst TD individuals exhibit faster attentional capture by social information even if their attention is already engaged, a similar bias fails to occur in individuals with ASD unless their attention is already disengaged and freely available for capture.

The presence of “sticky” attention in ASD, which results in a diminished bias towards social information can potentially also explain some other findings seen across the studies of the current thesis. The experiment in Chapter 7 showed that reduced social attention to interacting pairs of faces in ASD when compared to TD only occurred when only one pair of such faces was present in the pattern. It thus may be that participants with ASD are less likely to experience a social information “pop out” effect (i.e. visual perception phenomena characterised by the target's ability to stand out from surrounding distractors), if their attention is engaged elsewhere.

Therefore, the current findings indicate some subtle attentional differences depending on the socialness of information between adults with ASD and TD. Yet, they do not confirm that atypical social attention in ASD can be easily explained by pervasive domain general attentional disengagement issues (e.g. Courchesne et al., 1994; Landry & Bryson, 2004; van der Geest et al., 2001; Wainwright & Bryson, 1996) or social domain specific delays in attentional capture (Freeth et al., 2010; Riby & Hancock, 2009a). Instead, it shows that attentional capture is biased towards social information and attentional disengagement from social information is delayed in high-functioning adults with ASD just as much as in TD adults. Yet, current findings also indicate that a social bias in attentional capture may be less pronounced in individuals with ASD and may require outside prompts for it to occur.

Intersensory Processing

Another domain general mechanism that has been proposed to underlie atypical processing in ASD and investigated across the current thesis was the inability to successfully integrate information from different modalities. It has been suggested that due to inaccurate integration, noisy environments may be particularly detrimental for individuals with ASD (Bahrick & Todd, 2012). Across the studies in the current thesis, however, only background noise with intelligible speech, rather than the presence of background noise overall, resulted in interference in participants' performance. Indeed, the experiment in Chapter 7 revealed that only the TD adults were slower responding to, and thus spent more time looking at, the patterns of faces in the high-intelligibility background noise condition. High-functioning adults with ASD, instead, took the longest time to complete the task without any background noise. Experiment 2 in Chapter 4 further confirmed that background noise interfered with attentional shifting to and from social and non-social information differently in participants with ASD and TD. Therefore, diagnostic differences occurred only when participants were presented with photographs of faces in isolation (Chapter 4) or arrays of relatively simple drawn faces (Chapter 7). In naturalistic social scenes, however, background noise interfered with gaze behaviour of both high-functioning adults with ASD and TD adults similarly.

As mentioned, high-intelligibility background noise in social scenes had a similar effect on high-functioning adults with ASD or TD, alike. To be precise, high-intelligibility background noise increased visual attention to the areas of the scene judged as more informative, especially when that information was social (see Chapter 6). Yet, in Chapter 5 it was found that high-intelligibility background noise decreased social attention in proportion to the rest of the scene. It also resulted in slower attentional capture by social information. At first glance, these findings seem somewhat contradictory to those of Chapter 6. Nevertheless, it should be noted that this decrease in social attention in Chapter 5 was moderated by the position of social information. In other words, high-intelligibility background noise decreased attention to off-centre, but not centrally, located social information. This was further confirmed by the findings of the experiment in Chapter 8, as neither the presence, nor intelligibility of background noise influenced attention to centrally presented social information. It seems intuitive, thus, that peripherally occurring information may be perceived as less relevant or informative. It is also worth noting that the high-intelligibility background noise consisted of a generic noise of people entering a room with an overlay of intelligible speech. Given that, it may have prompted the participants to attempt to integrate the received multisensory information by focusing on parts of the image that could potentially provide explanatory information for the noise (e.g. a person at the centre of the image or the note on a blackboard). In other words, perceiving speech could have guided attention of both adults with ASD and TD adults to the explanatory information within scenes, in turn, increasing their attention to information of high relevance, but decreasing it to the less relevant information (e.g. a figure in periphery).

The current findings are thus partially in line with existing studies finding atypicalities in ASD when integrating visual and auditory information (de Gelder et al., 1991; Smith & Bennetto, 2007). However, researchers suggest that the performance of individuals with ASD in comparison to TD should be diminished due to the presence and poor integration of the background noise (Bahrick & Todd, 2012). Current findings, instead, indicated that atypical integration of visual information and irrelevant background noise may be more applicable to tasks using relatively simple rather than complex and naturalistic stimuli. Furthermore, in the former tasks, individuals with ASD appeared to experience less interference from the background noise than TD participants. Such performance, thus, seems unlikely to be directly related to social difficulties and sensory overload reported by individuals with ASD (see Bogdashina, 2003). Atypical processes of selective attention in ASD, however, could potentially explain these inconsistent findings.

The load theory of selective attention suggests that the relatively low perceptual load of the target stimulus requires attentional control mechanisms to supress the perception of distractor stimuli to avoid interference (Lavie, 1995). This seemed to have successfully happened in participants with ASD and TD when looking at scenes when the distractor was of relatively low (i.e. low-intelligibility), but not higher (high-intelligibility), perceptual load. From research on effects of noise in open plan offices, we know that increased intelligibility of background noise also interferes with higher cognitive load, such as memory, tasks (Brocolini et al., 2016; Zaglauer et al., 2017). These findings, therefore, compliment the load theory of selective attention (Lavie, 1995) by suggesting that not only the perceptual load of the target, but also the distractor itself, may determine how the perceptual resources will be allocated and controlled.

Interestingly, the effect of high-intelligibility noise was less pronounced in adults with ASD than TD adults in the tasks that were not using social scenes as the stimuli. This potentially indicates that those with ASD, differently from TD adults, were more successful in supressing the distractor effect of the intelligible background noise in terms of their speed of performance. Yet, their attention may still have been guided by the intelligibility of the background noise towards the more informative and social parts of the naturalistic scenes. It has before been suggested that individuals with ASD may have an enhanced perceptual capacity, in turn, requiring higher levels of perceptual load for this automatic suppression mechanism to occur (Remington et al., 2009). This refers to another selective attention mechanisms suggested by load theory stating that high perceptual load tasks may exhaust one's perceptual resources thus automatically excluding distractors from perception (Lavie, 1995). That would, however, propose an opposite pattern than the one found within our studies. To be precise, one would expect that the high perceptual load of the information perceived would automatically result in the exclusion of the distractor effect in TD individuals, but not necessarily those with ASD.

A differential diagnostic effect occurred only in the task using relatively simple drawings of faces of a lesser perceptual load than the naturalistic scenes. It thus seems more likely that the low rather than high perceptual load mechanism proposed by the load theory of selective attention (Lavie, 1995) would have been at play. To recap, if the perceptual load of the task is relatively low, the distractors are perceived but supressed by attentional control mechanisms to avoid interference (Lavie, 1995). It thus is plausible that the enhanced perceptual capacity in ASD may be proportional, thus affecting not only high perceptual load stimulation, but in general shifting the boundaries of perceptual load. In other words, for a TD individual a certain task or stimulus may require too many processing resources for it to be supressed via attentional control mechanisms, but not be high enough in perceptual load to exhaust the available resources yet. According to the load theory of selective attention, such a situation would result in the interferences of distractors as neither of the selective attention mechanisms would take place. Yet, if individuals with ASD, indeed, have enhanced perceptual capacity, the same task or stimulus of a relatively low perceptual load may then leave enough resources available for the distractor effects to be supressed. It is, therefore, possible that the current findings of the intelligible background noise interference on the manual reaction time of TD adults, but not those with ASD, may be reflecting differences in effect of perceptual load. Although the likeliest explanation for the findings relating to background noise across the current thesis; the existence of proportionally enhanced perceptual load capacity in ASD has not been directly tested. Thus, future studies directly examining the possibility of the enhanced perceptual capacity in ASD are necessary.

Limitations and Future Directions

The current research has many strengths including, but not limited to, a stringent statistical method allowing analysis of all the data, consistency of the participant groups across the tasks allowing to draw direct comparisons, carefully considered data extraction using custom built scripts, novel paradigms, and a comprehensive research design. It does, however, also have overarching limitations.

For instance, the stimuli used within the experiments of this thesis were systematically varied in ecological validity. This has allowed a comparison between social attention to simple representations of social information and those of increasing complexity and realism. Yet, all the experiments were still conducted within laboratory settings. To be exact, it is possible that even realistic representations do not induce the same social attention as would interactions with real people. Indeed, previous research examining gaze behaviour in children with ASD and TD have not found atypical social attention to their partner’s face in in-person interactions (Falck-Ytter, Carlström, & Johansson, 2015). Thus, it remains to a large extent unknown whether their findings can be generalized to real life situations. Therefore, more studies comparing performance across tasks with social representations and live stimuli (i.e. via live interaction paradigms or the use of eye-tracking glasses) are needed to gain a better understanding of how lab-based findings transfer to real life experience.

To enable a fair comparison between the participants with ASD and TD population, the groups in the current research were carefully matched on age, gender, cognitive functioning. As previously discussed (see Chapter 1), examining higher-functioning individuals with ASD, as fully formed adults, offers a unique opportunity for examining characteristics that are pervasive across development and unique to ASD. Nevertheless, the behaviour seen in high-functioning adults with ASD may not be exhibited by younger or lower-functioning individuals. This is particularly relevant for the more standard laboratory tasks tapping into hierarchical processing (Chapter 3) and attention shifting (Chapter 4). Indeed, some previous studies have found atypical hierarchical processing in children with ASD (e.g. Plaisted et al., 1999) and others have found atypical attention shifting in children and adults (Elsabbagh et al., 2009; Goldberg et al., 2002; Kikuchi et al., 2010; Landry & Bryson, 2004; Todd et al., 2009; van der Geest et al., 2001) or lower functioning individuals with ASD (Kawakubo et al., 2007).

In general, the severity of some symptoms in ASD decreases in high-functioning individuals and increases in low-functioning individuals as they grow older (see Levy & Perry, 2011). It is thus possible that high-functioning individuals with ASD have a different developmental trajectory, which allows them to deal with increasingly higher cognitive load as they mature and, subsequently, compensate for atypical processes (Mayer et al., 2014). Moreover, the lack of atypical hierarchical processing and attentional disengagement in adults with ASD also does not disprove the existence of such processing atypicalities at a younger age. Yet, it rather indicates that atypical hierarchical processing and attentional disengagement in ASD may be an expression of a developmental delay and not a pervasive deficit. Hence, the current findings show that clearly atypical hierarchical processing and attentional shifting in ASD do not persist across development and symptom severity and is thus not co-occurring with reduced social attention. Longitudinal studies, however, are needed to examine how these processes may potentially relate across development.

It is also worth noting that the current sample of participants included a wide age range (i.e. 18-64 years old). Indeed, aging can have an impact on one's attentional processing, especially in terms of the response speed. Therefore, certain effects (e.g. global advantage effect) usually observed in younger individuals could disappear when averaging performance across development. This is particularly important for research studying adults with ASD as previous research indicates potentially atypical aging effects on cognition and attention in ASD (see Happé & Charlton, 2012). Nevertheless, the statistical method applied in the current study addresses this issue by utilizing a hierarchical structure of the data. The ability to specify each data point as nesting within each individual allows for the parameters to be calculated in terms of slope (i.e. difference between conditions/measurement points) rather than intercept (i.e. mean differences between individuals). In the current research, this ensured that any reaction time or attentional disengagement delays associated with aging would not have direct impact on effects observed. This is further confirmed by the fact that addition of age as random effect did not increase the model fit in any of the analyses described in the current thesis. Having said that there is a chance that qualitatively different developmental pathways in ASD exist not only when transitioning to adulthood but persist across one's lifespan. This thus further emphasises the importance of future longitudinal studies in ASD.

The current research makes use of a relatively novel approach to analysing experimental data by using multilevel modelling as alternative method to classic ANOVA approach (e.g. Field & Wright, 2011). That, however, means that due to the methodological differences direct comparisons with previous studies should be done with caution. For instance, when simulating six different approaches for attending to the outliers, Ratcliff (1993) found that the most appropriate way depended on the shape of individual distribution and could not be generalised across different datasets. He also noted that unambiguous identification of outlier data is near impossible, thus the best we can hope for is to reduce the potential effect of outliers while losing least of the data (Ratcliff, 1993). This is particularly important for research studying heterogeneous populations, such as individuals with ASD, where a wide range of responses may be representative of the effects in actual population. Therefore, the current study only removed the impossible values indicated by previous research prior the data collection and then applied log-transformation to the data to correct for a disproportionate influence of potential outliers, is so indicated by the model evaluations (see Chapter 2: Statistical Approach). The current approach was judged to be most suitable for the current data and statistical analysis based on the steps outlined by Tabachnick and Fidell (2007). Yet, other research studies sometimes utilize different approaches, such as mean trimming (e.g. Ballantyne & Núñez, 2016; Mann & Walker, 2003; Wainwright & Bryson, 1996). Hence, it is important to keep these differences in outlier treatment in mind when making comparisons with or between previous studies as results may vary based on approach adopted (Ratcliff, 1993).

There is one drawback to the use of multilevel modelling. That is the lack of the appropriate statistical power calculations (see Chapter 2: Statistical Approach). This is particularly relevant for the current research as the sample size used in the current research stayed relatively small across the experiments, albeit varying in exact number. Therefore, some weaker effects may have not been shown due to a lack of power. Nevertheless, the use of multilevel modelling has allowed for the maximization of available statistical power by avoiding a loss of variance due to the aggregation of data and listwise deletion (Hoffman & Rovine, 2007). Furthermore, a recommended number of 20 units at the highest level of the hierarchical model (Kreft & De Leeuw, 1998) has been consistently surpassed across the studies, with the final sample size never falling below 29 participants (Chapter 8). Thus, statistical power should have been sufficient to analyse the hierarchically structured data and find main effects. Furthermore, although appearing small, the sample size across the current research has been similar or larger than that usually seen in ASD research (e.g. Klin et al., 2002b; Plaisted et al., 1999; van der Geest et al., 2001). Therefore, it is unlikely that the discrepancy between findings described in the current thesis and those of the previous studies could be assigned to power differences due to the sample size.

Practical Implications

In addition to the theoretical connotations, these findings also have wide-reaching practical implications for social interventions and suitable work and education environments for individuals with ASD. In particular, it increases understanding of strengths and weaknesses associated with adulthood in ASD. For instance, the current findings show that high-functioning adults with ASD on average are able to process globally presented information just as well as TD adults, mostly successfully disengage and shift attention, and prioritise both social and otherwise important information, albeit sometimes to the lesser degree. Awareness of strengths and weaknesses of ASD presentation is particularly relevant when developing efficient interventions to improve the quality of life for individuals with ASD.

For instance, the findings of reduced social attention in ASD, especially when viewing naturalistic scenes, have implications for potential interventions to aid social functioning of individuals with ASD. Recent research has been exploring a possibility of using eye-tracking for training successful disengagement and pre-emptive responding in children with ASD and finding some indication of feasibility (e.g. Powell, Wass, Erichsen, & Leekam, 2016). Such interventions could be extended to high-functioning adults with ASD, who do not have attentional shifting issues, but still attend to social information in context less than typical. A similar training to that of cognitive bias modification in anxiety (e.g. MacLeod & Mathews, 2012) could be applied. Yet, more complex visual displays could be utilized to enhance their ability to automatically attend more to social information in different situations.

Multiple findings across the currently described studies have indicated that individuals with ASD may have difficulty automatically identifying or noticing relevant information when competing information is present. For instance, participants with ASD exhibited a social bias when their attention was previously exogenously disengaged but did not show a bias towards interacting faces in an array when only one pair of them was present. Furthermore, individuals with ASD looked at the subjectively informative areas of scenes less than TD participants. This thus indicates that individuals with ASD may benefit from more explicit prompts or instructions in guiding their attention towards relevant social or non-social information. Indeed, it has previously been observed that, for example, susceptibility to illusions in ASD depends on the instructions given (Brosnan et al., 2004). Furthermore, previous intervention research has also shown that, for instance, participating in training for joint attention bid use resulted not only in improved joint attention, but extended to expressive language and other social characteristics in children with ASD (Jones, Carr, & Feeley, 2006). Therefore, in combination with previous research, current findings further emphasise the importance of attentional bids in interventions designed for individuals with ASD.

Whilst adults with ASD in the current study exhibited reduced bias towards social and otherwise relevant information, they did not exhibit clear atypicalities in processing of hierarchical stimuli or exogeneous disengagement. Given the previous evidence of these atypicalities being present in younger participants (e.g. Crippa et al., 2013; Rinehart et al., 2000), it is possible that these adults developed compensatory mechanisms. Further investigation of developmental patterns associated with these processes is necessary for a better understanding of these potential adjustment mechanisms. Yet, the knowledge of different atypicality in viewing patterns of social information in adults with ASD could already inform a development of more sensitive diagnostic procedures. For instance, Dawson and colleagues (2018) are currently developing smart-phone based eye-tracking methodology to apply viewing pattern information for earlier identification of ASD. Understanding these patterns in broader presentation of ASD offers to further expand the application of such techniques for diagnosis of individuals with ASD, who exhibit mostly typical attentional processes.

About half of individuals with ASD are unemployed or underemployed (67% in USA and 42% in Australia; Lerner et al., 2018). Yet, little is still known about factors affecting employment and effective interventions helping to maintain the employment in ASD. Recent research shows adapting the workplace environment to need and skills of individuals with ASD is one of the main potential factors promoting successful employment as identified by the relevant stakeholders (Bolte et al., 2018). Studies examining attentional processes in response to complex environments, like it was done in the current research, can help show what employers can do to help individuals with ASD adapt to the workspace environment.

For instance, current research suggests that individuals with ASD may be poorer at prioritising relevant information. This could certainly be applied to increase suitability of the workspace environment by minimizing the amount of stimulation and new information. For instance, for some individuals with ASD it may be beneficial to have a workspace facing the wall of the office or to utilize the dividers in order to diminish the amount of information encountered. Alternatively, it may be advisable to have optional out of hour shifts when less people and thus less stimulation is present. This is especially important for offices in open-plan space, where the constant movement and change is inevitable.

Findings in relation to background noise across the current thesis hint that susceptibility to distractors may be also different for those with and without ASD. Current findings support the existence of enhanced perceptual capacity of selective attention in ASD (Remington et al., 2009). Yet, they expand on previous knowledge by implying that enhanced perceptual capacity may affect selective attention not only when the perceptual load is high, but also low. It shows that perceptual load is dependent not only on the task, but a distractor, too. In practical terms, on the one hand, this may mean that individuals with ASD may benefit from extra stimulation (e.g. background music or stimming behaviour) when attempting to focus on a task with a high perceptual load. To be precise, the additional perceptual load may help deplete the available perceptual resources thus diminishing the distractor effects. On the other hand, at the lower end of perceptual tasks individuals with ASD may be better at supressing the distractor effects for a relatively larger range of perceptual load than TD individuals. This means that the boundary of sensitivity to distracting effects may not coincide with that of TD individuals and thus should be adjusted on more personal basis.

Having said that, it is important to remember that, whilst beneficial in some ways, enhanced perceptual capacity also has negative implications. Being able to take in more information at any one time may lead to sensory overload and be detrimental in certain everyday situations. Hindering effects of overload has been previously described by both researchers (e.g. O'Neill & Jones, 1997) and individuals with ASD (see

Bogdashina, 2003 for an overview). The risk of sensory overload may be particularly high in certain crowded or noisy environments, such as university or open-plan office settings. In turn, it may further hinder ones one's ability to successfully function in education or workspace. Whilst no negative effects of enhanced perceptual capacity were evident in the current research, it is important to note that background noise was controlled to not exceed 65 dB SPL at its peak, which is the level commonly found in many classrooms (Jamieson et al., 2004). Were louder or more intermittent and thus less expected presentation used for the background noise, adverse effects of background noise may have also been observed (Szalma & Hancock, 2011). This ability of individuals with ASD to process more information simultaneously before the perceptual capacity is saturated and extend of positive and negative effects it can have on one's quality of life should be investigated further. Nevertheless, findings to date support the need for access to quite or otherwise low-sensory stimulation safe space available to individuals with ASD in classroom and work environment. Alternatively, acceptance of noise cancelling headphones, tactile sensory sensitivity permitting, may also be beneficial in workspaces adapted for individuals with ASD.

Conclusion

Overall, the studies outlined in the current thesis confirm the presence of reduced attention to social information in high-functioning adults with ASD in comparison to TD. It expands previous knowledge, however, by evidencing that this atypical attention reflects a reduced social bias rather than increased attention to non-social information. Using stringent statistical and experimental designs, the current research also demonstrates that atypical social attention in ASD cannot be simply explained by either co-occurring domain general hierarchical processing difficulties, or obvious attentional shifting atypicalities. Nevertheless, across the studies the findings hint at subtle processing differences. In particular, it appears that adults with ASD were less prone to automatically identify or notice information perceived as relevant (e.g. social information) by TD individuals, especially in the presence of competing information. Moreover, background noise related findings also indicate that high-functioning adults with ASD attend to distractor stimuli slightly differently from TD adults. This pattern of findings is in keeping with the load theory of selective attention and suggestion of enhanced perceptual capacity in ASD. Yet, current findings add to the previous research by showing that these processes occur across modalities.

Finally, taken together the results of this thesis shed some light on the inconsistencies across the previous research on social attention in ASD. To be precise, it shows that ecological validity of social representations is not simply induced via the life-like presentation, motion, complexity, or increased social content. Instead, it provides evidence that social representations that are realistic or ecologically valid in terms of a context may be necessary to observe social bias atypicalities in ASD. Current findings reveal that the presence of either social interactions or relevant background information separately is sufficient to provide contextual effect. In sum, context of social representations, automatic attention allocation, perceptual load, and differential developmental pathways has emerged across this thesis as promising avenues for future research.

APPENDICES

Appendix A

Sample Consent Form Used for the Phase 1 Recruitment

University of Roehampton London

PARTICIPANT CONSENT FORM

Title of Research Project:

Sensory information processing in high-functioning adults with autism

Brief Description of Research Project, and What Participation Involves:

This research aims to obtain a comprehensive understanding of mechanisms underlying visual processing of social and non-social stimuli of high-functioning adults with ASD. Around 40 adults with ASD and 40 neurotypical adults will participate in this study.

The first part of this study consists of online questionnaires about emotions and general wellbeing, a link to them and an electronic consent form are provided via email. Completion of this part should not take longer than 30 minutes and can be carried out in location convenient for you.

A second part of the study will take place at the University of Roehampton and consist of four experimental blocks of tasks. During it you will be asked to either respond to stimuli as fast as you can, or describe a picture. Your descriptions and eye movements would be recorded using an eye-tracker. This is a safe, infra-red camera that tracks where you are looking when you look at a screen. For some of the tasks you will be asked to wear headphones so that we can play sounds and noises to you whilst you are completing them. The noise level will be within the normal range experienced in everyday situations. This part of the study should take about 2 hours. After the study you will be reimbursed for your overall participation of 2.5 hours (£20).

Please note: if you have a concern about any aspect of your participation or any other queries please raise this with the investigator or the Director of Studies. However, if you would like to contact an independent party please contact the Head of Department.

Investigator	**Director of Studies**	**Head of Department**
Contact Details:	**Contact Details:**	**Contact Details:**
Simona Skripkauskaite	Dr Lance Slade	Dr Diane Bray
Department of Psychology	Department of Psychology	Department of Psychology
University of Roehampton	University of Roehampton	University of Roehampton
Whitelands College	Whitelands College	Whitelands College
Holybourne Avenue	Holybourne Avenue	Holybourne Avenue
London SW15 4JD	London SW15 4JD	London SW15 4JD
Email: skripkas@roehampton.ac.uk	Email: l.slade@roehampton.ac.uk	Email: d.bray@roehampton.ac.uk
Telephone: 020 8392 3342	Tel: 020 8392 3576	Tel: 020 8392 3627

Consent Statement (tick by the point to indicate that you agree)**:**

_____ I agree to take part in this research and am aware that I am free to withdraw at any point without giving a reason, although if I do so I understand that my data might still be used in a collated form.

_____ I agree to the experimenter linking data from this study with the previous studies I have participated in.

_____ I agree to the experimenter linking data from experimental tasks with data collected online.

_____ I agree to be audio recorded during parts of the data collection.

_____ I agree to be contacted for future studies.

_____ I understand that the information I provide will be treated in confidence by the investigator and that my identity will be protected in the publication of any findings, and that data will be collected and processed in accordance with the Data Protection Act 1998 and with the University's Data Protection Policy.

Name ………………………………….

Signature ……………………………… Date………………………………

Appendix B

Sample Matlab Script for Saccadic Latencies (Experiments 2 and 3)

```
dbstop if error

clear
%clearallexceptin('base','RAW')

%set directory
cd('H:\MATLAB\GO\Phase I')

%add participant names
fnames={'participant1.xlsx','participant2.xlsx','participant3.xlsx',
'participant4.xlsx'};

for sub = 1:4 %change participant number

clearvars -EXCEPT fnames sub

[NUM,TXT,RAW] = xlsread(fnames{sub});

data = RAW;

data = missing1_d(data); %run function to interpolate missing values

                         % function [data] = missing1_d(data)
                         % missingPs = find(strcmp(data(:,8),''));
                         % for missingPs = missingPs'
                         % data(missingPs,8) = data(missingPs 1,8);
                         % end end

stimeventPs = find(strcmp(data(:,4),'SceneStarted'));
NoRows = size(data,1);

terminate = 0;
saccadenum20 = 1;

    for stimeventP = stimeventPs'
        stimcode = data{stimeventP,5};
        if ~(strcmp(stimcode(1),'B') && strcmp(stimcode(end),'3'))
&& ~(strcmp(stimcode(1),'G') && strcmp(stimcode(end),'3')) &&
~(strcmp(stimcode(1),'O') && strcmp(stimcode(end),'2')); continue;
end %find right stimulus

        saccadeRT20(saccadenum20) = 0;
        saccadedur20 = 0;
        stimeventP3 = stimeventP;
        while saccadeRT20(saccadenum20) <= 80 || saccadedur20 <= 15
|| (saccadedirection20(saccadenum20) <= 100 &&
saccadedirection20(saccadenum20) >= -100) ||
~(strcmp(stimcode(4),direction20(saccadenum20))) %satisfy conditions
            % find saccade at 20deg/s
            GazeEvent20 = '';
            lastGazeEvent20 = '';
            while (~strcmp(GazeEvent20,'Saccade') ||
strcmp(lastGazeEvent20,'Saccade')) && stimeventP3 < NoRows %evaluate
a beginning of saccade only
```

```
                stimeventP3 = stimeventP3+1;
                lastGazeEvent20 = data{stimeventP3-1,6};
                GazeEvent20 = data{stimeventP3,6};
            end
            saccadedur20 = data{stimeventP3,7};
            saccadeRT20(saccadenum20) = data{stimeventP3,3}-
data{stimeventP,3}; %calculate saccade RT
            saccstartstimeventP2 = stimeventP3-1;
        % find sacc direction
        for stimeventP4 = stimeventP3:stimeventP3+50 % change the
number of lines (arbitrary)
            if stimeventP4 < NoRows
        %       stimeventP4 = stimeventP4+1;
                lastGazeEvent20 = data{stimeventP4-1,6};
                GazeEvent20 = data{stimeventP4,6};
                if ~strcmp(GazeEvent20,'Saccade') &&
strcmp(lastGazeEvent20,'Saccade') % find if end of saccade for
saccadedirection
                    saccadedirection20(saccadenum20) =
data{stimeventP4,8}-data{saccstartstimeventP2,8}; %calculate the
lenght of the saccde: diff between the end and beginning
                    if saccadedirection20(saccadenum20) > 100
%assign direction
                        direction20(saccadenum20) = 'R';
                    elseif saccadedirection20(saccadenum20) < -100
                        direction20(saccadenum20) = 'L';
                    end
                end
            else
                terminate = 1; %if no answer to last stimulus, the
analysis terminates (the last value printed may be bogus)
                break
            end
        end
        if terminate; break; end
        end

        stimcodes20{saccadenum20} = stimcode;

        if saccadeRT20 <= 699; saccadenum20 = saccadenum20+1; end
    end

xlswrite('H:\MATLAB\GO\Phase
I\RT',cat(1,stimcodes20,num2cell(saccadeRT20),num2cell(saccadedirect
ion20))',fnames{sub}(1:12));

end
```

Appendix C

Sample Matlab Script for Fixation Durations (Experiments 7)

Step 1: Automatically interpolating AOI size (done separately for each video)

```
dbstop if error

clear
%clearallexceptin('base','RAW')

[NUM,TXT,RAW] = xlsread('H:\MATLAB\video\video06.xlsx');

data = RAW;

missingBodyPs = find(~([data{:,13}]>0));

missingBodyP = missingBodyPs';

for i=1:length(missingBodyP);

    rowBodyP = missingBodyP(i);
    rowbodyLast = missingBodyP(i)-1;

    data(rowBodyP,13) = num2cell([data{rowbodyLast,13}]-0.14);
%addition or subtraction number adjusted per AOI change
    data(rowBodyP,14) = num2cell([data{rowbodyLast,14}]+ 0.21);
    data(rowBodyP,15) = num2cell([data{rowbodyLast,15}]- 0.22);
    data(rowBodyP,16) = num2cell([data{rowbodyLast,16}]+ 0.14);

end

missingFacePs = find(~([data{:,17}]>0));
missingFaceP = missingFacePs';

for j=1:length(missingFaceP);

    rowFaceP = missingFaceP(j);
    rowFaceLast = missingFaceP(j)-1;

    data(rowFaceP,17) = num2cell([data{rowFaceLast,17}]- 0.10);
    data(rowFaceP,18) = num2cell([data{rowFaceLast,18}]- 0.02);
    data(rowFaceP,19) = num2cell([data{rowFaceLast,19}]- 0.26);
    data(rowFaceP,20) = num2cell([data{rowFaceLast,20}]- 0.16);

end

  xlswrite('H:\MATLAB\video\video06.xlsx',data);
```

Step 2: Adding AOI coordinates to participant files

```
dbstop if error

clear

 %set directory
cd('H:\MATLAB\video')

%add participant names
fnames={'participant1.xlsx','participant2.xlsx','participant3.xlsx',
'participant4.xlsx'};

for sub = 1:4 %change participant number

    clearvars -EXCEPT fnames sub

[NUM,TXT,RAW] = xlsread(fnames{sub});

data = RAW;

disp(sprintf('Processing data from participant %.0f. %.0f Percent
complete...', sub, (sub-1)/36*100))

stimeventPs = find(strcmp(data(:,4),'SceneStarted'));
% NoRows = size(data,1);

AOI35 = xlsread('H:\MATLAB\Video\Video35.xlsx');
AOI43 = xlsread('H:\MATLAB\Video\Video43.xlsx');
AOI06 = xlsread('H:\MATLAB\Video\Video06.xlsx');

for stimeventP = stimeventPs'
         stimcode = data{stimeventP,5};
         stimeventP2 = stimeventP;

        for a = 1:843
                for b = 9:20

                  if strcmp(stimcode,'Video35');
                      data(stimeventP2+a,b)= num2cell(AOI35(a+1,b));
                  elseif strcmp(stimcode,'Video43');
                      data(stimeventP2+a,b)= num2cell(AOI43(a+1,b));
                  elseif strcmp(stimcode,'Video06');
                      data(stimeventP2+a,b)= num2cell(AOI06(a+1,b));
                  end
                end
        end
end

xlswrite(fnames{sub},data);
end
```

Step 3: Coding AOI hits

```
dbstop if error

clear

 %set directory
cd('H:\MATLAB\video ')

%add participant names
fnames={'participant1.xlsx','participant2.xlsx','participant3.xlsx',
'participant4.xlsx'};

for sub = 1:4 %change participant number

    clearvars -EXCEPT fnames sub

[NUM,TXT,RAW] = xlsread(fnames{sub});

data = RAW;

disp(sprintf('Processing data from participant %.0f. %.0f percent
complete...', sub, (sub-1)/36*100))

stimeventPs = find(strcmp(data(:,4),'SceneStarted'));
NoRows = size(data,1);

    for stimeventP = stimeventPs'

            stimeventP2 = stimeventP;

            for i = 1:843

                if strcmp(data(stimeventP2+i,6),'Fixation') ...
                    && ([data{stimeventP2+i,7}] >
[data{stimeventP2+i,9}]) && ([data{stimeventP2+i,7}] <
[data{stimeventP2+i,10}]) ...
                    && ([data{stimeventP2+i,8}] >
[data{stimeventP2+i,11}]) && ([data{stimeventP2+i,8}] <
[data{stimeventP2+i,12}]); %check if hits overall AOI;
                 data(stimeventP2+i,21) = num2cell(1);
                else data(stimeventP2+i,21) = num2cell(0);
                end

                if strcmp(data(stimeventP2+i,6),'Fixation') ...
                    && ([data{stimeventP2+i,7}] >
[data{stimeventP2+i,13}]) && ([data{stimeventP2+i,7}] <
[data{stimeventP2+i,14}]) ...
                    && ([data{stimeventP2+i,8}] >
[data{stimeventP2+i,15}]) && ([data{stimeventP2+i,8}] <
[data{stimeventP2+i,16}]); %check if hits body AOI;
               data(stimeventP2+i,22) = num2cell(1);
               else data(stimeventP2+i,22) = num2cell(0);
                end

                if strcmp(data(stimeventP2+i,6),'Fixation') ...
```

```
                    && ([data{stimeventP2+i,7}] >
[data{stimeventP2+i,17}]) && ([data{stimeventP2+i,7}] <
[data{stimeventP2+i,18}]) ...
                    && ([data{stimeventP2+i,8}] >
[data{stimeventP2+i,19}]) && ([data{stimeventP2+i,8}] <
[data{stimeventP2+i,20}]); %check if hits face AOI;
               data(stimeventP2+i,23) = num2cell(1);
               else data(stimeventP2+i,23) = num2cell(0);
                end

             end
     end

   xlswrite(fnames{sub},data);

end
```

Step 4: Calculating fixation durations

```
dbstop if error

clear

 %set directory
cd('H:\MATLAB\video')

%add participant names
fnames={'participant1.xlsx','participant2.xlsx','participant3.xlsx',
'participant4.xlsx'};

for sub = 1:4 %change participant number

    clearvars -EXCEPT fnames sub

[NUM,TXT,RAW] = xlsread(fnames{sub});

data = RAW;

disp(sprintf('Processing data from participant %.0f. %.0f percent
complete...', sub, (sub-1)/36*100))

stimeventPs = find(strcmp(data(:,4),'SceneStarted'));

duration = cell(9,3);

    for i=1:length(stimeventPs);
    lineP = stimeventPs(i);
         stimcode = data{lineP,5};

      duration(i,1) = num2cell(i);
    duration{i,2} = stimcode;

allDuration = 0;
bodyDuration = 0;
faceDuration = 0;

         for j = 1:843
```

```
            if [data{lineP+j,21}]== 1;
            allDuration = allDuration + 1;
            else allDuration = allDuration;
            end

             if [data{lineP+j,23}]== 1;
            faceDuration = faceDuration + 1;
            else faceDuration = faceDuration;
             end

            if [data{lineP+j,22}]== 1;
            bodyDuration = bodyDuration + 1;
            else bodyDuration = bodyDuration;
            end

         end

duration(i,3) = num2cell(allDuration*0.008);
duration(i,4) = num2cell(bodyDuration*0.008);
duration(i,5) = num2cell(faceDuration*0.008);

    end

 xlswrite('H:\MATLAB\Video\duration',duration,fnames{sub}(1:12));

end
```

Appendix D

Navon's Hierarchical Figures Used

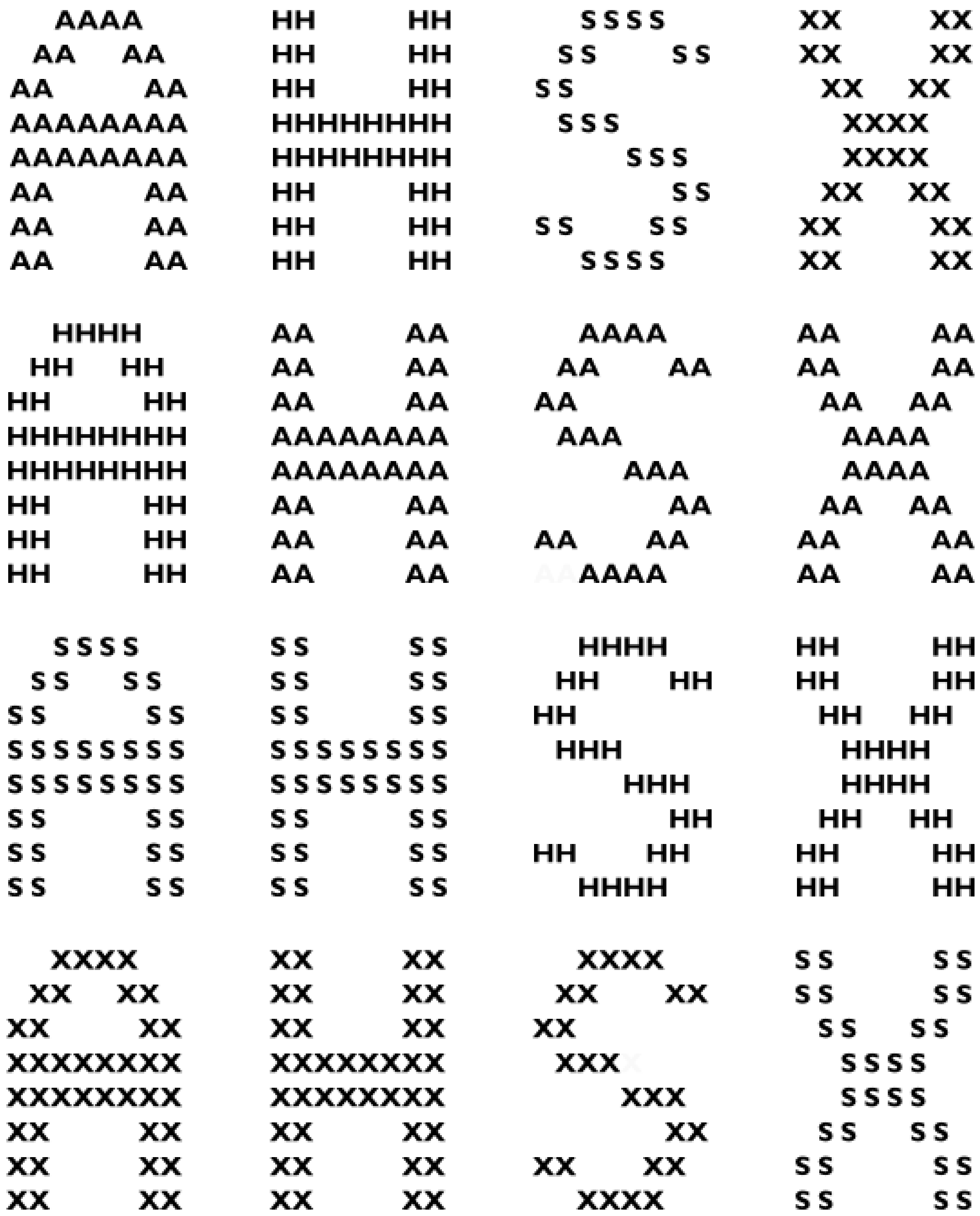

Figure D1. Hierarchical figures used in the study. The first row depicts congruent figures, whereas the rest represents incongruent figures.

Appendix E

Full set of stimuli used in the structure manipulation task.

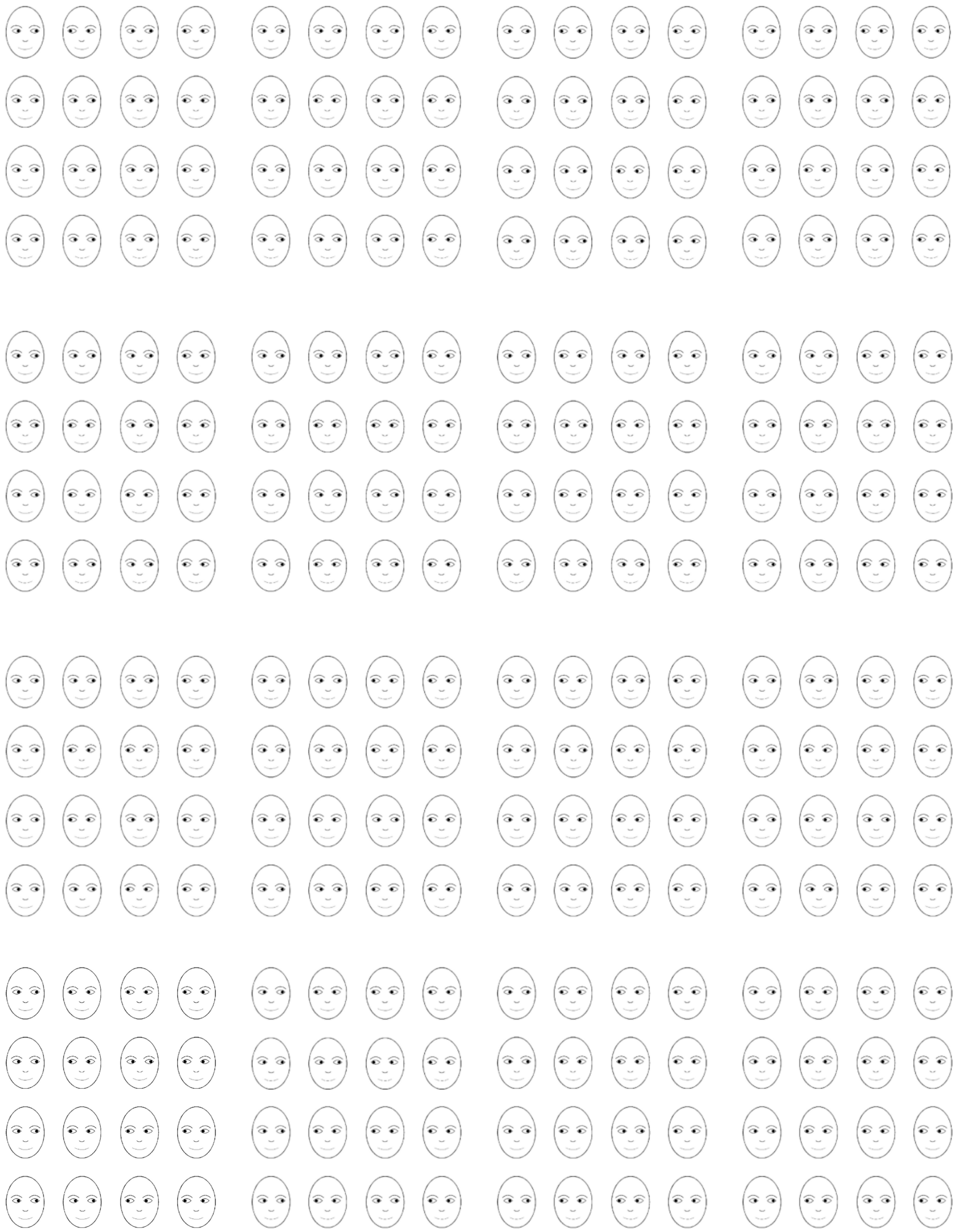

Figure E1. Stimuli representing high social structure condition with five social interactions (i.e. pairs of faces looking at each other) and six feature changes (i.e. horizontal change in gaze direction).

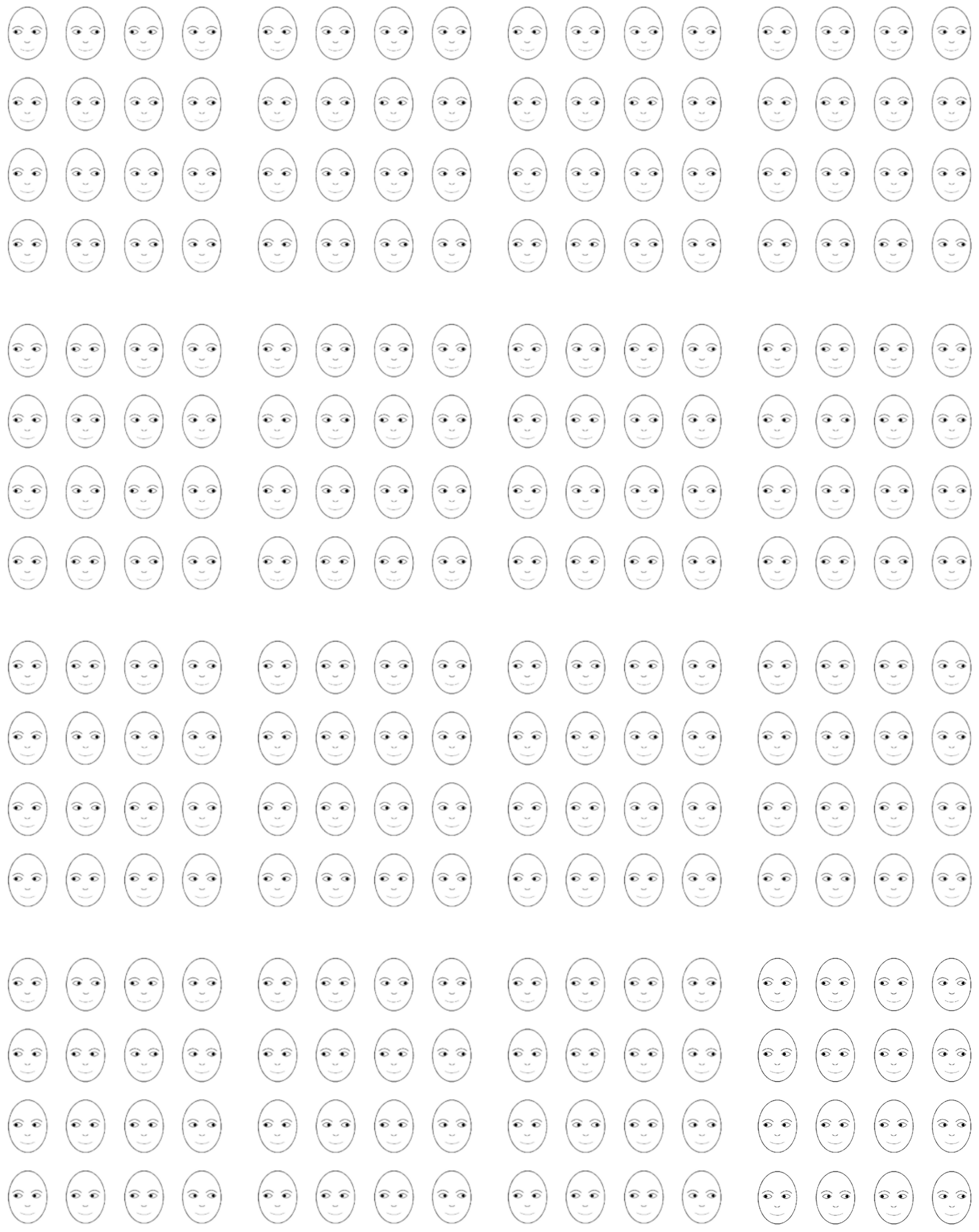

Figure E2. Stimuli representing low social structure condition with one social interaction (i.e. pairs of faces looking at each other) and six feature changes (i.e. horizontal change in gaze direction).

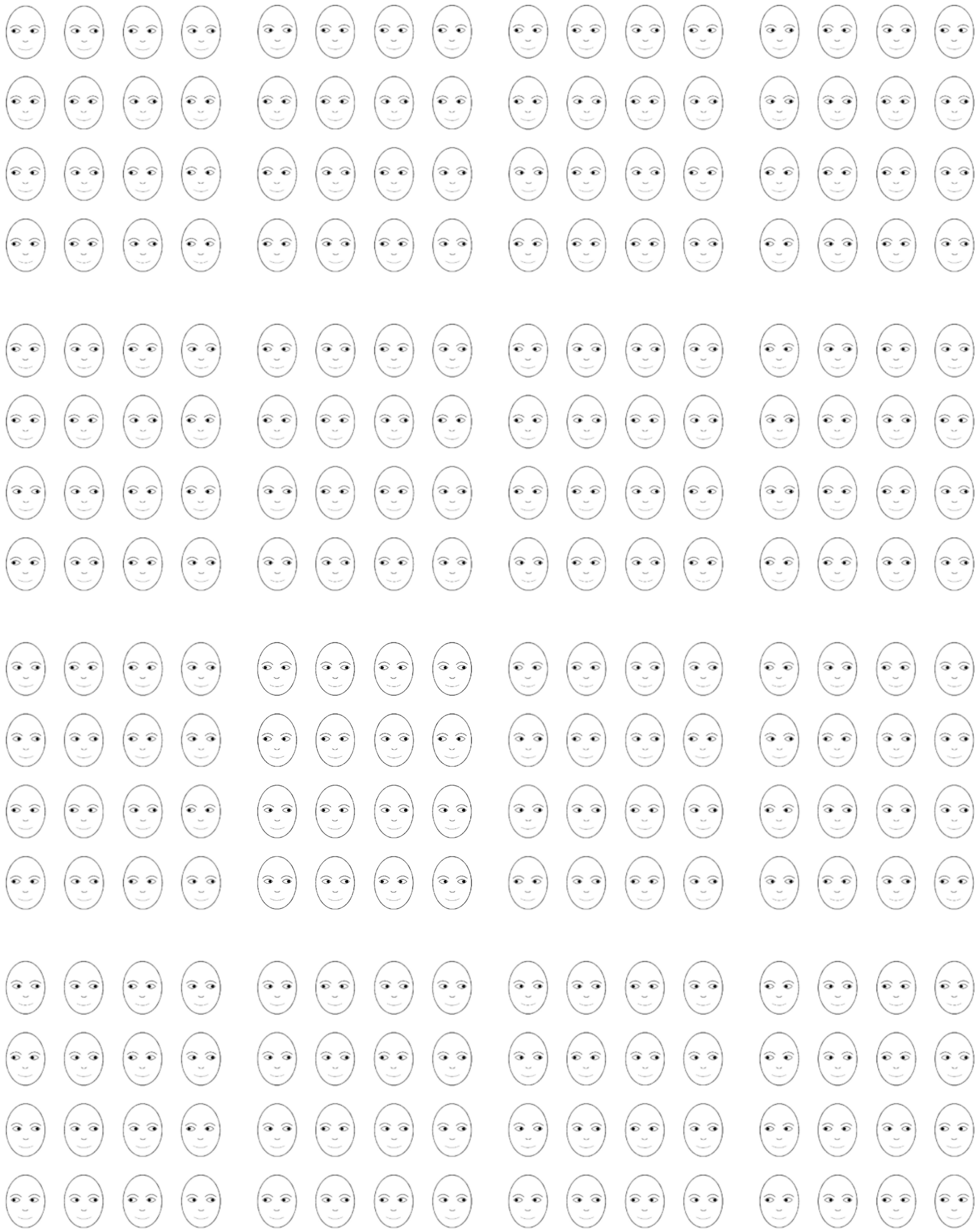

Figure E3. Stimuli representing high feature structure condition with four social interactions (i.e. pairs of faces looking at each other) and nine feature changes (i.e. horizontal change in gaze direction).

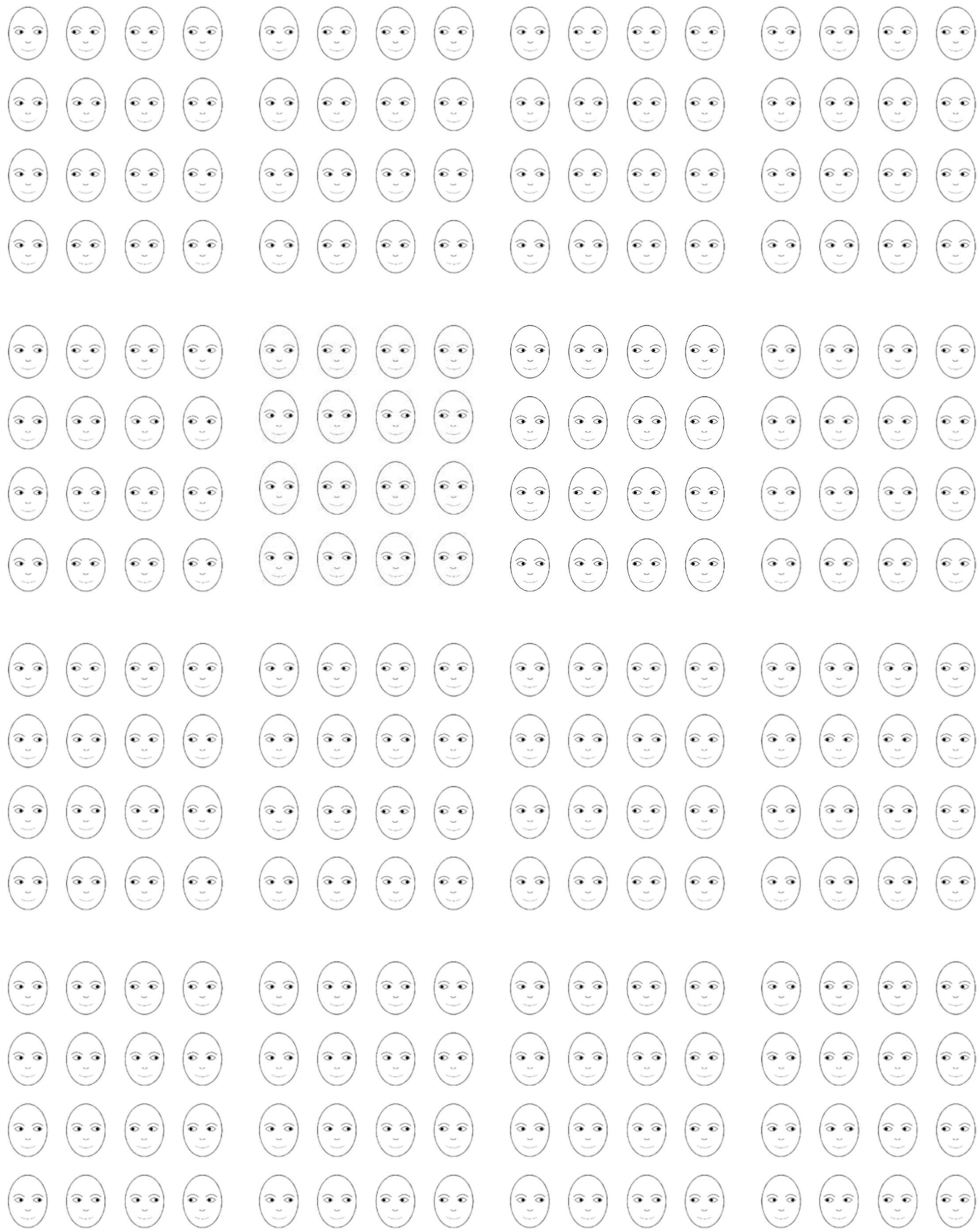

Figure E4. Stimuli representing low feature structure condition with four social interactions (i.e. pairs of faces looking at each other) and four feature changes (i.e. horizontal change in gaze direction).

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