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University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

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Face-to-face interactions and the use of gaze in Autism Spectrum Disorders

Study 1: A systematic review of eye-tracking during face-to-face interactions in Autism Spectrum Disorder

Study 2: The use of eye contact during a naturalistic face-to-face interaction in Autism Spectrum Disorder

Thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Clinical Psychology, University College Cork

Alasdair Iain Ross

May 2020

Supervisors: Dr Christian Ryan & Dr Jason Chan

Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism.

Submitted by: Alasdair Iain Ross

Signature of candidate:

Date: 06/05/2020

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Chapter 1 - General introduction

The focus of this thesis will centre on how eye contact is used by individuals with Autism Spectrum Disorder (ASD) during face-to-face social interactions. In the following chapters, two research projects will be presented in a journal article format (Chapters 2 and 4) and are each accompanied by their own supplementary chapter covering relevant information that could not be included for publication (Chapters 3 and 5 respectively). The first research project, in Chapter 2, will focus on a systematic review carried out of the current research-base using eye-tracking during face-to-face interactions in children, adolescents, and adults with ASD. The second research project, in Chapter 4, will focus on a study using eye-tracking during a naturalistic face-to-face interaction with two groups of adults, one with typically developed adults (often referred to as neurotypical within this research area, abbreviated to NT) and one ASD. In this chapter, a broad overview of this research area and the current landscape that my doctoral research finds itself will be provided. Firstly, before gaining an insight into the performance of a particular group of individuals, we must first gain an understanding of what happens within the general NT population. Secondly, the difficulties of individuals with ASD in relation to emotion recognition and the use of gaze will be discussed. Finally, the findings from studies of face-to-face interactions with ASD participants will be discussed in relation to the motivations behind this thesis. Inevitably, some of what is covered here will be referred to again, albeit in less detail, in the coming chapters.

Eye contact and social interactions within the general population

Directing our eyes towards others has long been considered a crucial aspect of social behaviour. Indeed a phrase that can be traced back approximately two thousand years noted: "the face is a picture of the mind as the eyes are its interpreter" (attributed to the philosopher Cicero, circa 100 BC). The first observational studies within the field of psychology began to emerge during the 1960's and into the 1970's (Argyle & Cook, 1976; Kendon, 1967; Nielsen, 1962). With new findings came a clearer understanding of how the eyes are used within the mechanics of social interaction. Gaze, the process of how we direct our eyes, came to be considered as one of the most crucial forms of non-verbal communication, along with tone of voice, physical proximity, posture and facial expressions (Argyle & Cook, 1976; Cook, 1977).

From around the age of one year old, infants can acknowledge objects that have been cued by the gaze of an adult (Thoermer & Sodian, 2001). This serves to highlight the importance of our eyes as a means of communicating, even before we have begun to develop language. Then as we become older, gaze becomes entwined with language and social context (Knoeferle & Kreysa, 2012; Liuzza et al., 2011; Macdonald & Tatler, 2013, 2015). When viewing images of real-world social scenes, participants have been shown to have a preference for fixating on the faces and eyes of the people they can observe (Birmingham et al., 2009; Zwickel & L.-H. Võ, 2010). Furthermore, when trying to follow a written story, participants were found to look towards a corresponding image of an actor and follow their gaze to an object that was part of the narrative (Castelhano et al., 2007).

Therefore, how a person uses their eyes can convey important information and cues about their current emotional state and intentions (Emery, 2000; Ristic et al., 2005; Tomasello, 1995). Indeed, directing and averting gaze from the eyes of others is considered to form several important functions during everyday face-to-face interactions. For example, managing cognitive load when thinking of a verbal response (Glenberg et al., 1998); directing gaze towards a social partner can help us understand what is being said if the information is unclear (Macdonald & Tatler, 2013); and, averting gaze can function as a social cue during conversational turn-taking (Ho et al., 2015). In terms of the latter, adult participants have been shown to direct gaze towards the eyes of an interaction partner more when they are listening to them, perhaps demonstrating active interest and attention, than when they are speaking to them (e.g. Ho et al., 2015; Kendon, 1967).

Indeed, gaze and attention are so intertwined that magicians frequently rely on it for misdirection, by diverting their own gaze they can shift an observer's attention away from their sleight-of-hand (Kuhn et al., 2008, 2009). Furthermore, there are numerous examples of how social roles and rules appear to impact on eye contact during real-world face-to-face interactions. For example, we are more likely to make eye contact with someone when we are eating at the same table, than if they are sat at a nearby table (Wu et al., 2013); and we are less likely to look towards a stranger or follow their gaze if they are present in the same room as us, than if they are presented on a screen (Gallup et al., 2012; Laidlaw et al., 2011).

Thus, how we direct gaze and use eye contact form key components of social communication during real-world interactions in the general population. Interestingly, a growing body of research has identified atypical patterns of gaze across a range of conditions that are often accompanied by social difficulties (e.g. Bögels & Mansell, 2004; Dawson et al., 2004; Hills & Lewis, 2011; Horley et al., 2003; Langdon et al., 2006; Sasson et al., 2016; Senju & Johnson, 2009; Shean & Heefner, 1995; Wieser et al., 2009). To-date, it is ASD that has received the most attention from researchers (e.g. Dawson et al., 2004; Senju & Johnson, 2009).

Differences in the use of gaze for individuals with ASD

Classically, ASD has been characterised by difficulties in social behaviour and reciprocal communication during interactions (American Psychiatric Association, 2013). In his descriptions of ASD, Kanner highlighted specific social and emotional difficulties, particularly with regard to an inattention towards the faces of others and appropriate eye contact (e.g. Kanner, 1971). Indeed, adolescents and adults with ASD have self-reported that they often experience difficulty in relation to the appropriate timing and use of gaze during face-to-face social interactions (Trevisan et al., 2017).

Studies have suggested that individuals with ASD have greater difficulty in orienting to social and emotional stimuli than NT individuals (e.g. Corden et al., 2008; Klin et al., 2002; Nakano et al., 2010; Riby & Hancock, 2009). One of the main findings is that individuals with ASD struggle with facial emotion recognition across the six basic emotions (e.g. Corden et al., 2008; Gross, 2008; Pelphrey et al., 2002; Spezio et al., 2007). This has been connected to a reduced amount of time spent fixating towards the eyes as compared to NT controls. An increased amount of time spent fixating towards the mouth or other facial regions has been suggested, and in turn this has been attributed to an increased difficulty in identifying emotions that rely more heavily on the eyes, such as fear or sadness (e.g. Pelphrey et al., 2002; Spezio et al., 2007). Therefore, a primary hypothesis has been that atypical gaze may be an underlying mechanism behind social and emotional difficulties in ASD, for instance atypical gaze in infancy has been found to be a predictor of later functioning in adulthood (W. Jones et al., 2008; Papagiannopoulou et al., 2014).

Evidence from face-to-face interactions and the motivations of this thesis

As will be explored in the coming chapters, much of the research regarding ASD described above has in fact stemmed largely from two-dimensional stimuli. Studies of both ASD and NT individuals that have tried to make inferences from two-dimensional stimuli, such as static images or videos of social scenes, have faced criticism (e.g. Chisholm et al., 2014; Kingstone et al., 2005). Conclusions made using highly standardised stimuli or scenarios do not always translate to real world behaviours (Risko et al., 2016). Thus, it has been argued that studies using more natural settings and scenarios are vital to gaining a proper understanding of the mechanisms behind social attention (Kingstone et al., 2008; Macdonald & Tatler, 2018). As noted earlier, NT participants were found to look towards the eyes of a stranger less when they were present in the same room as when they were presented on a screen (Laidlaw et al., 2011).

A slowly developing research-base investigating the use of gaze by ASD participants during face-to-face interactions has emerged. To date there have been fourteen such studies, ten investigating children and adolescents (Birmingham et al., 2017; Doherty-Sneddon et al., 2013; Doherty-Sneddon et al., 2012; Falck-Ytter et al., 2015; Falck-Ytter, 2015; Hanley et al., 2014; R. M. Jones et al., 2017; Mirenda et al., 1983; Nadig et al., 2010; Riby et al., 2012) and four investigating adults (Falkmer et al., 2011; Freeth & Bugembe, 2019; Hanley et al., 2015; Tantam et al., 1993). The purpose of the systematic review in the following chapter (Chapter 2) is to synthesise the results of these studies in the context of the broader research area. In the Major Research Project chapter (Chapter 4), the performance of adults with ASD and NT adults was compared in a naturalistic face-to-face interaction using eye tracking. The motivation behind this research was to expand upon the four previous adult studies. Employing a topic-based interaction that more closely resembled a conversation that participants could experience in their day-to-day lives.

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Chapter 2 - Systematic Review

A systematic review of eye-tracking during face-to-face interactions in Autism Spectrum Disorder

Alasdair Iain Ross[1], Christian Ryan[1], Eric Byrnes[1] & Jason Chan[1]
[1]University College Cork, Republic of Ireland

Corresponding author:
Christian Ryan, School of Applied Psychology, Cork Enterprise Centre, North Mall Campus, University College Cork, Cork, Republic of Ireland
Email: christian.ryan@ucc.ie

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Abstract

Background: Previous findings from computer-based stimuli have indicated a reduced number of fixations towards the eyes, in Autism Spectrum Disorder (ASD). This has been thought to contribute to wider social and emotional difficulties. However, it is unclear whether the reported deficits in gaze can be generalised to real-world interactions. **Method:** A systematic review was conducted on studies that explored the use of gaze during face-to-face interactions with individuals who have ASD. The search covered the EBSCO, Scopus and Web of Science databases. In total fourteen studies were included: ten contained participants who were children and adolescents, and four studies contained adult participants. **Results:** The majority of studies found little or no overall difference between ASD and comparison groups in the amount of gaze directed towards an interaction partner's face. Only one of the included studies found a significantly reduced preference for fixations towards the eyes as compared to other areas of the face. Nevertheless, neuro-typical (NT) participants were found to consistently increase fixation duration towards an interaction partner whilst listening as compared to speaking, such consistency was not found for participants with ASD. **<u>Conclusion:</u>** The results were discussed in relation to current hypotheses regarding the use of gaze in ASD (e.g. gaze aversion, a lack of automatic motivational process, low social motivation) and whether the lack of group differences was driven by individual differences. Recommendations for future studies are proposed.

Keywords

Autism; review; eye-tracking; gaze; interaction; attention

Introduction

Directing our attention towards the faces of others is seen as an innate component of social communication and interaction (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991). A person's face, in particular their eyes, can convey important information and cues about their current emotional state and intentions (Emery, 2000; Ristic et al., 2005; Tomasello, 1995). Successfully interpreting this information allows us to respond appropriately. For example, an incongruent facial expression may reveal that a social partner has told a joke. A further example is that we can use joint attention to follow another's line-of-gaze to infer what or where they are attending to. As social situations are dynamic and can change from moment-to-moment, successful participation is dependant on our ability to monitor and adapt to those around us. It is perhaps unsurprising that studies have shown that adults spend more time fixating on the eyes of others, within a social scene, than elsewhere (Birmingham, 2015; Hsiao & Cottrell, 2008).

Directing and averting gaze from the eyes of others is considered to form several important functions during everyday interactions. For example, managing the demand placed on working memory, often termed cognitive load, when thinking of a verbal response (Glenberg et al., 1998); directing gaze towards a social partner can help us understand what is being said if the information is unclear (Macdonald & Tatler, 2013); and, averting gaze can function as a social cue during conversational turn-taking (Ho et al., 2015). Indeed, gaze and attention are so intertwined that magicians frequently rely on it for misdirection, by diverting their own gaze they can shift an observer's attention away from their sleight-of-hand (Kuhn et al., 2008, 2009).

Given the importance of where and how we direct our gaze during social interactions, it has been described as providing a crucial 'window' into underlying cognitive processes (Baron-Cohen et al., 2013; Shepherd, 2010). Indeed, studies have identified atypical patterns of gaze across a range of conditions that are often accompanied by social difficulties (e.g. Bögels & Mansell, 2004; Dawson et al., 2004; Hills & Lewis, 2011; Horley et al., 2003; Langdon et al., 2006; Sasson et al., 2016; Senju & Johnson, 2009; Shean & Heefner, 1995; Wieser et al., 2009). To-date, ASD has received the most attention from researchers (e.g. Dawson et al., 2004; Senju & Johnson, 2009).

Difficulties in social processing have been viewed as a core component of ASD, characterised by deficits in behaviour and reciprocal communication during social interactions (American Psychiatric Association, 2013). Indeed, adolescents and adults with ASD have self-reported that they often experience difficulty in relation to appropriate timing and use of gaze during face-to-face social interactions (Trevisan et al., 2017). Studies have suggested that individuals with ASD have greater difficulty in orienting to social and emotional stimuli than NT individuals (e.g. Corden et al., 2008; Klin et al., 2002; Nakano et al., 2010; Riby & Hancock, 2009). One of the main findings is that individuals with ASD struggle with facial emotion recognition across the six basic emotions (e.g. Corden et al., 2008; Gross, 2008; Pelphrey et al., 2002; Spezio et al., 2007). This has been connected to a reduced amount of time spent fixating towards the eyes as compared to NT controls. An increased amount of time spent fixating towards the mouth or other facial regions has been suggested, and in turn this has been attributed to an increased difficulty in identifying emotions that rely more heavily on the eyes, such as fear or sadness (e.g. Pelphrey et al., 2002; Spezio et al., 2007). A number of hypotheses have been put forward to explain these difficulties: such as, a reflexive avoidance of the eyes due to hyper-arousal (e.g. Kliemann et al., 2012; Tanaka & Sung, 2016); a lack of reflexive motivation to make eye contact due to hypo-arousal (e.g. Dalton et al., 2005; Kylliäinen et al., 2012); simply a low social motivation (e.g. Chevallier et al., 2012); poor Theory of Mind (e.g. Baron-Cohen et al., 1985); and alexithymia (e.g. Gaigg et al., 2018), an inability to recognise your own emotions which in turn impacts your understanding of others emotions.

However, studies investigating gaze in relation to social and emotional stimuli in ASD have not always produced consistent results, with some finding no difference to NT participants (Chita-Tegmark, 2016; Fletcher-Watson et al., 2009; Frazier et al., 2017; García-Pérez et al., 2007; Norbury et al., 2009; Papagiannopoulou et al., 2014). One of the major criticisms directed broadly at the methodology, both within and beyond ASD research, is that many studies have utilised highly standardised methods that require artificial and/or two-dimensional stimuli. This has created a paradox in that the cognitive processes behind social interaction are often studied without any real-world interactions taking place. As an example, many of the studies investigating ASD have used stimuli that have consisted of isolated, static images of faces (e.g. Birmingham et al., 2008; Riby et al., 2012; Sasson et al., 2016; Wingenbach et al., 2017); pre-recorded videos of social scenes (e.g. Foulsham et al., 2010; Kuhn et al., 2008, 2009); or Skype-style computer-based conversations (e.g. Falck-Ytter, 2015).

It has been argued that participants' reactions to two-dimensional static stimuli cannot consistently represent how visual attention is directed during real-world social interactions (Chisholm et al., 2014; Kingstone et al., 2005). The premise that it does rests on two assumptions. Firstly, that the cognitive processes behind attention are stable across simulated social situations (e.g. static images, pre-recorded videos of social scenes) and real-world social interactions (e.g. face-to-face conversations); and that real-world social interactions are equivalent to simulated or online social interactions. Secondly, that all variability within a social situation can be reduced to one aspect (i.e. a static facial expression) in order to elicit a generalisable process/response. This is an important consideration in terms of ecological validity (Cole et al., 2016; Kingstone, 2009; Kingstone et al., 2008).

With the above in mind, a growing number of studies have begun to focus on what is attended to during face-to-face interactions (e.g. Cañigueral & Hamilton, 2019; Freeth et al., 2013; Ho et al., 2015; Macdonald & Tatler, 2013). Freeth and colleagues (2013) compared how NT participants respond to questions from a pre-recorded video of an experimenter versus questions being asked in real-time, face-to-face with the experimenter. Their results indicated that participants looked more towards the experimenter whilst answering a question face-to-face than when doing so with a pre-recorded video. One interpretation is that face-to-face interactions increase social demands, and that making eye contact with a social partner helps to maintain social attention. Thus, demonstrating a difference between real and virtual social engagement.

However, it is important to note that there is invariably more social interaction in a real-time conversation (face-to-face or virtual) compared to a pre-recorded video.

In other words, during face-to-face interactions we can subtly encode and send social cues in a fluid manner, following social norms and rules, as they are required. This is something that cannot be easily replicated in pre-recorded or static stimuli (for a discussion see Hayward et al., 2017). For example, Laidlaw, Foulsham, Kuhn and Kingstone (2011) assessed eye movements directed towards another participant (a confederate) when they were physically in the same room or when they were seen on a pre-recorded videotape. Their results demonstrated that while NT participants directed gaze towards the confederate quite freely when seen on videotape, they very rarely directed gaze towards them when they were in the same room. Both of the studies described above raise some serious questions for researchers attempting to interpret computer-based tasks in relation to 'real-world' face-to-face interactions.

The purpose of the current review

A number of reviews have already focused on eye-tracking in relation to social and emotional stimuli in ASD (Boraston & Blakemore, 2007; Cañigueral & Hamilton, 2019; Chita-Tegmark, 2016; Falck-Ytter & von Hofsten, 2011; Guillon et al., 2014; Papagiannopoulou et al., 2014). However, these reviews have predominantly focused on what has been learned from two dimensional, computer-based stimuli, including Skype-style live-streamed video. The aim of the current review will be to collate what has been learned to-date from the small pool of studies that have utilised eye-tracking during face-to-face interactions, across both childhood (from 4 years upward) and adulthood. The focus will be on studies that have used unfamiliar interaction partners. Previous studies of NT children and adults have indicated that familiarity can impact on the amount of interaction, level of perceived anxiety, and use of mutual or averted gaze (e.g. Broz et al., 2012; Feyereisen, 1994; McCornack, 1982; Vittengl & Holt, 1998). The aim will be to identify whether there are consistent, global deficits in the use of eye contact during face-to-face interactions; or, alternatively, whether the use of gaze is less consistent and more dependent on individual differences and the types of interaction used. It is also hoped that this review will be used to inform the research area and highlight gaps for future studies.

Methods

Development and implementation of the search strategy

This systematic review was conducted in accordance with the PRISMA guidelines (Moher et al., 2009). Consultation was sought from the subject librarian in University College Cork prior to commencing the review. The search strategy was developed using a thesaurus from the PsycINFO database. A scoping review was conducted of key words and their synonyms related to the three core aspects of this review: namely, autism spectrum disorder, eye-tracking and face-to-face interactions (for a detailed description see Chapter 3).

It was decided that a second search should be conducted after refining the search strategy in relation to the inclusion criteria. Twenty-six key words from the articles in the initial search were used to expand the Boolean search strategy to exclude potentially unrelated articles:

(autism OR ASD OR "autism spectrum disorder" OR Asperger*) AND ("eye-tracking" OR "eye tracking" OR "eye tracker" OR "eye movement measurement" OR "eye movement" OR gaze) AND ("social interaction" OR "social communication" OR "face-to-face" OR "face to face" OR conversation OR "social skills") NOT (infant OR mother OR friend OR caregiver OR twin OR neuroimaging OR brain* OR fmri OR mri OR eeg OR pet OR *genetic* OR biomarker OR primate OR pharma* OR medication OR modelling OR computer OR virtual OR display OR image OR static OR mimicry OR classroom OR language OR robot*)

A search was conducted on the 19th of October 2019 across all EBSCO databases (this included PsycINFO and PsycARTICLES), the Scopus database, and the Web of Science database. Articles were filtered to only include those using the English language and there was no limit placed on date of publication. This resulted in a collection of 127 articles. After duplications were removed this left a collection of 113 articles, which were put into a shared library in the referencing software Zotero in which all the authors had access.

Procedure

Title and abstract search

The first author (AR) created two subfolders within Zotero, to gather articles for potential inclusion or exclusion. Each article had a short-note attached to explain the decision-making process. Of the 113 studies, 92 were deemed to not meet the inclusion criteria for the following reasons: 13 of the studies were non-peer reviewed papers (i.e. thesis or conference abstracts), 5 studies were review articles, 15 articles did not use participants with ASD, and 59 studies did not meet our methodological criteria (e.g. therapeutic study; computer-based tasks with images, videos or symbols; or familiar environments and conversational partners). The second author (EB) served as an independent rater for this review. EB evaluated the titles, abstracts, and decisions of AR for each of the 113 studies and was in agreement with the inclusion of 18 of the 21 studies identified by AR in the next stage of the review process. The three articles that were indicated by EB as not meeting the inclusion criteria: 1 study contained a familiar interaction partner to the ASD participants and was within a familiar environment, and 2 of the studies used NT participants only.

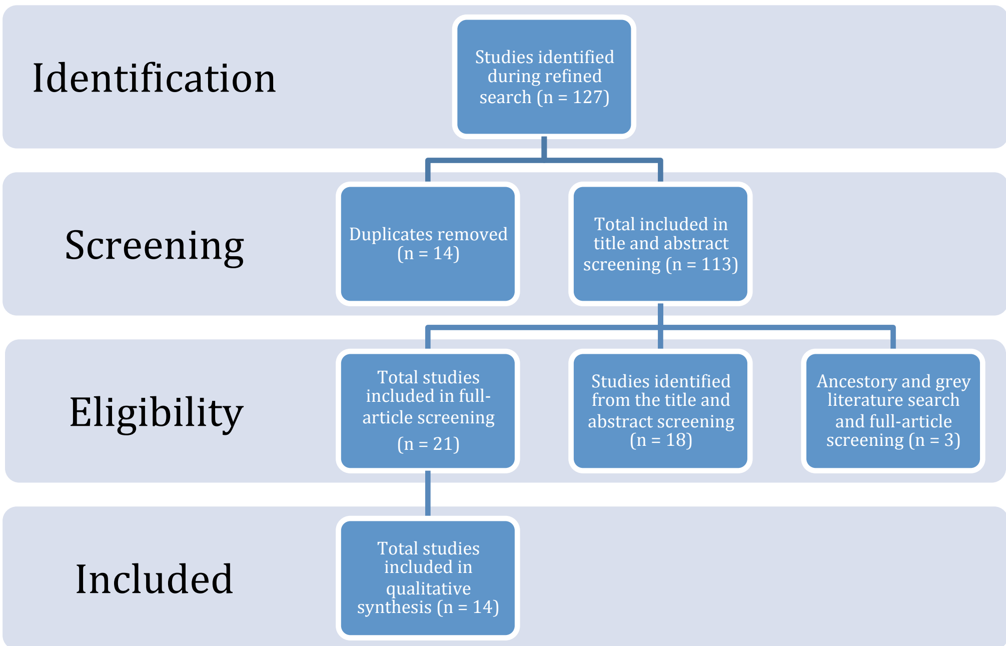
Full article search

AR and EB reviewed the full-text articles for the remaining 18 studies. Both authors were in agreement that 9 of the studies met the inclusion criteria. Furthermore, both authors were in agreement that 6 of the studies did not meet the inclusion criteria. These articles were excluded for the following reasons: 2 studies were conducted with interaction partners that were known to participants, of those 1 was also conducted in a familiar environment; 1 study was conducted with three predominantly non-verbal individuals with ASD, 1 study used a computer-based 'live' interaction; 1 study did not contain any social interactions; and 1 study only considered gaze generally, making little explanation of what constituted 'appropriate' gaze. There was uncertainty between AR and EB over the 3 remaining articles, each of them utilised aspects of psychological assessments to form the interaction. Two used an adapted Digit Span task (Falck-Ytter et al., 2015; Falck-Ytter, 2015) and the other used interactive play from the Early Social Communication Scale (Noris et al., 2012). In discussion with the fourth author (CR), it was decided that two of the studies should be included as they form types of interaction that are likely to be faced by individuals with ASD, if not in their home environment then in terms of educational or healthcare settings (Falck-Ytter et al., 2015; Falck-Ytter, 2015). The third paper, Noris et al. (2012), was excluded as the type of interaction used was designed to be utilised with non-verbal participants, in addition the reported adaptive behaviour age for both the ASD and NT groups was as low as 1 year, 3 months.

In order to identify any articles that had not been identified during the initial search, an ancestral search was conducted on the reference lists of the 11 remaining articles and an advanced Google Scholar search was also conducted. Four further articles were identified during these searches. After full-text review by AR and EB, three of the articles were deemed to meet the inclusion criteria (one used an interaction partner familiar with participants and was excluded). This brought the total number of studies for inclusion to 14. See Figure 1 below for a visualisation of the selection process.

Figure 1

A flow diagram of the literature selection process



Assessment and rating of included studies

The Crowe Critical Appraisal Tool (CCAT)(Crowe & Sheppard, 2011a) was selected to assess the methodological quality of the remaining studies (an example form can be viewed in Appendix B). The tool was selected for the two following reasons. Firstly, to the best of the authors' knowledge, only one previous review assessing the use of gaze in ASD made specific reference to an appraisal tool, which was created for studies of intellectual disability (Drysdale et al., 2018). Secondly, the CCAT was designed for clinical populations with consideration of the PRISMA guidelines, and has been evaluated in terms of its construct validity and reliability (Crowe & Sheppard, 2011b). In line with the tools scoring guidelines, each domain was rated on a scale from 0-5 (0 the lowest score and 5 the highest) with a final, overall percentage score generated. In line with previous reviews that have used the CCAT, a percentage score of 50% or below was used to determine poor methodological quality (e.g. Ismail et al., 2019; Sznitman & Taubman, 2016). Only one of the included studies was deemed to have poor methodological quality (50%; Mirenda et al., 1983), primarily due to a limited amount of information being provided in the article. The remaining studies had percentage scores that ranged from 55-80%. Three articles were pseudo-randomly selected by AR and given to EB and CR separately in order to assess reliability of the ratings. CR and ER's percentage scores were within 5% of AR's for the three articles (percentage scores, including those of CR and ER, are included for each study in Table 1, below).

Table 1

Data extraction table for the included studies

Study	Groups	*N* (*N female*)	Age Range (year:month)	Matching	Type of Interaction	Method of eye-tracking, Rater, AOI & Other measures	Main results	Interpretation
Children and adolescents								
Birmingham, Johnston, & Iarocci, 2017 **CCAT Score:** 75%	ASD NT	20 (3) 17 (4)	8-16 years across both groups	Stanford-Binet, Abbreviated	1 x card game & 1 x board game with researcher. Each lasted 1 hour. Researcher made 5 deliberate, 10 second, gaze aversions in each game (2 x towards social target [confederate], 2 x toward non-social objects).	**Eye tracking:** ASL mobile eye-tracker (poor data so was not used for analysis) & 2 x Logitech webcams **Rater:** Two of the researchers were involved in coding the video data. **AOI & Other measures:** <u>AOI</u> The researcher's face. <u>Gaze towards researcher:</u> Frequency, latency to first look (toward the experimenter), mean duration <u>Overall gaze following:</u> Proportion of trials, latency to end of turn, latency from first look, latency from last look, duration Exploratory analysis of vocalisations in response to gaze aversion	<u>Gaze towards researcher:</u> No group differences in terms of frequency, latency to first look, or mean duration. However, ASD group gazed towards the researcher sig. longer than NT group when gaze averted to non-social objects. <u>Overall gaze following:</u> No group differences in terms of proportion of trials or duration. ASD group were slower to follow researchers gaze overall, particularly towards non-social objects, as compared to NT group. <u>Vocalisations:</u> A sig. higher proportion of ASD participants made vocalisations or overt behaviours to gain attention of researcher when their gaze was averted towards non-social objects.	Subtle differences between ASD and NT groups. Suggested that ASD group gazed longer at researcher when they averted gaze toward non-social objects a) as it took them longer to identify the object or b) because it was an unexpected or ambiguous behaviour during the game. Higher proportion of vocalisations or overt behaviours to gain the researcher's attention in the ASD group potentially connected to a lack of social inhibition or lower patience as compared to NT group.
Doherty-Sneddon, Riby, & Whittle, 2012 **CCAT Score:** 75% **<u>Experiment 1 only (experiment 2 non-ASD sample)</u>**	ASD NT	20 (1) 20 (11)	11:06-17:07 5:08-13:03	BPVS-II	Participants answered 27 mental arithmetic questions (9 easy difficulty, 9 medium, 9 hard).	**Eye tracking:** Video recording set up behind researcher to assess gaze. **Rater:** Two raters coded the video data. It was unclear whether they were external to the study. **AOI & Other measures:** The researcher's face was the primary AOI. The amount of time that	Overall, the accuracy of both groups declined as question difficulty increased (no sig. difference between groups). No sig. difference for total amount of gaze aversion between both groups overall. However, ASD group used more gaze aversion while listening to questions than the NT group. There was an effect of task difficulty on gaze aversion across the three phases for both groups.	Results taken to suggest that ASD group failed to recognise the significance of social cues while listening to questions rather than actively avoid them (children in ASD group still looked towards the experimenter 63% of the time in the listening phase). This could speak against the hyper-arousal/gaze aversion hypothesis (e.g. Kliemann et al., 2012).

						Three phases considered in analysis: listening phase (while researcher spoke), thinking phase (period after researcher spoke but before answer), and speaking phase (period during which the participant answered).		
Doherty-Sneddon, Whittle, & Riby, 2013 **CCAT Score:** 77% **<u>Experiment 1 only (experiment 2 non-ASD sample)</u>**	ASD NT	11 (2) 11 (6)	12:4-15:9 7:3-15:10	BPVS II	Participants answered questions about two, one minute, animations. The interaction partner was an unfamiliar person for one video (i.e. the researcher) and a familiar person for the other video (e.g. parent, teacher or sibling). The order was counterbalanced.	**Eye tracking:** Video recording set up behind questioner to assess gaze. **Rater:** Two raters were involved in the coding of video data. One rater was involved with the study the other was naïve to hypotheses. **AOI & Other measures:** The interaction partner's face was the primary AOI. The amount of time that participants spent averting gaze was of interest. Furthermore, whether there were differences between familiar and unfamiliar questioners. Three phases considered in analysis: listening phase (while questioner spoke), thinking phase (period after questioner spoke but before answer), and speaking phase (period during which the participant answered).	No sig. differences between amounts of gaze aversion between groups overall or for familiarity. NT participants used more gaze aversion when interacting with an unfamiliar interaction partner during the thinking phase only. Both groups spent longer averting gaze during the thinking phase (period after interaction partner spoke but before answer given) as compared to the other two phases. Although no sig. difference, ASD group's mean time spent averting gaze was almost twice as high during the listening phase as compared to the NT group.	As compared to Doherty-Sneddon et al. (2012) above, there was less gaze aversion overall for both groups in the listening and thinking phases. This likely reflects differences due to task demands. No sig. differences between groups overall is reflective of considerable individual differences. However, some difference between NT and ASD groups in terms of interaction with unfamiliar interaction partner was in line with predictions.
Falck-Ytter, 2015 **CCAT Score:** (AR) 77%; (CR) 77%; (EB) 75%	ASD NT	13 (1) 27 (8)	4.9-10:4 5.1-10:2	WISC-IV/WPPSI-III	Two tasks: Storytelling - participants were read a short story (10 sentences long) by the researcher. Cognitive testing - an adapted version of the Digit Span task was used. On half of the trials the researcher gazed at the child and on half looked down at the protocol as they spoke.	**Eye tracking:** Tobii Tx300, 60Hz, eye-tracker used to record data. **Rater:** No mention of who coded the video data. An independent rater assessed the researcher's behaviour towards participants in each group (no difference found between groups). **AOI & Other measures:** AOI defined as an ellipse covering the researchers face, with the nose as the centre point. Vertical coordinates used to differentiate between eyes and mouth fixations. Two object AOI (pictures) behind the researcher also defined. Time spent looking towards face AOI as compared to non-AOI areas was calculated.	<u>Storytelling:</u> Total time for the researcher to tell the story was sig. shorter for the NT group than ASD group. Total amount of time spent looking ahead (at face or objects AOI) in the ASD group was sig. shorter. Total time spent fixating on face AOI was shorter for the ASD group than NT. Time spent looking towards the pictures or anywhere else other than the face AOI was higher in the ASD group than NT. <u>Cognitive testing:</u> No sig. difference in performance between groups. Only the ASD group increased their fixations towards the face AOI during the cognitive testing as compared to the story telling. No difference for the NT group or between groups in this task. <u>Overall:</u> No group differences in terms of where participants	While listening to a brief story, children with ASD were observed to look towards the face less than NT children. This type of task requires receptive language and is similar to a school-type situation. It was suggested that such a performance could indicate that ASD children could miss important non-verbal information during interactions. No difference in gaze between the two groups for the cognitive testing would suggest that visual attention in social contexts is not globally disrupted in ASD, but rather context dependent. Furthermore, the authors suggest it could be linked to motivation (i.e. cognitive testing places more demands on a participant).

							looked within the face AOI. Both groups spent longer looking toward the mouth than eyes.	
Falck-Ytter, Carlström, & Johansson, 2015 **CCAT Score:** (AR) 80%; (CR) 80%; (EB) 75%	ASD NT	10 (1) 25 (8)	4:9-10:4 5:1-10:2	Groups did not differ in terms of age, WPPSI/WISC, SES, SRS	The interaction was a modified version of the Digit Span test, commonly found in cognitive assessments. Digit Span trials were separated into blocks that were easy or challenging in difficulty. 6-12 blocks in total depending on engagement. Only the difficult trials were used in the analysis, with the easy trials functioning as a break. In half of trials the researcher averted gaze away from the child and in the other half directed gaze toward them.	**Eye tracking:** Tobii Tx300, 60Hz, eye-tracker used to record data. **Rater:** It was alluded to that the researchers rated the video data, but this was not made explicit. **AOI & Other measures:** AOI defined as an ellipse covering the researchers face, with the nose as the centre point. Vertical coordinates used to differentiate between upper face and lower face. Time spent looking towards face AOI areas was calculated. Encoding phase (researcher read our the digits) and answering phase (where the participant responded) were used in the analysis.	Cognitive Performance: The main sig. difference between groups was that the performance of NT group in Digit Span dropped when the researcher averted their gaze. There was no difference in performance for the ASD group whether the researcher's gaze was direct or averted. Correlation was found for NT groups SRS score and performance when researcher's gaze was averted. The better the score the poorer the performance. Eye Movement: Overall, children looked toward the researcher's face less in the answering phase than in the encoding phase of the interaction. Perhaps unsurprisingly, overall, the children also looked less towards the researcher when their gaze was averted than when gaze was directed towards the children. In consideration of the vertical position of gaze, overall, children in both groups looked more to the upper face when in the answering phase than encoding phase.	The findings suggest that children with the least ASD traits in the NT group were more sensitive to the researcher's gaze. Namely, the NT group performed better overall when the researcher directed their gaze towards them. This is an important consideration for cognitive assessment. The finding that there were no differences in gaze towards an interaction partners face during a non-social task would support the notion that eye contact difficulties in ASD is context specific.
Hanley et al., 2014 **CCAT Score:** 80%	ASD SLI NT	17 (6) 14 (2) 16 (10)	7:11-12:11 8:1-11:1 9:1-11:9	All groups matched in terms of mean age. SLI group matched with ASD group on BPVS NT group matched with ASD group on Wechsler Non-Verbal Ability Scale	Researcher posed as a 'magician in training'. Children asked to be a cameraperson and record the researcher practicing tricks. No tricks were included as part of analysed interaction. Instead the first part of the interaction where the researcher introduced themselves and asked a few questions (e.g. who are you? where are you from?) was used. This lasted on average 35 seconds. The second part of the interaction used for analysis was when the researcher introduced a hand puppet and recited a poem about magic. Towards the end of the	**Eye tracking:** SMI head-mounted eye-tracker was used. **Rater:** One rater coded all the video data. A second rater coded a percentage of each video to ensure reliability. It was unclear whether they were external to the study but they were naïve to a participant's group. **AOI & Other measures:** AOI defined around the eyes and mouth of the researcher. External face regions (forehead, ears etc.), body, hair, hands and hat were all defined as AOI. The puppet, wall behind researcher were defined as AOI. Off screen and 'other' were used as AOI to define poor or lost data.	Introduction conversation: Overall, the face and non-body regions were looked at longer than body regions. The ASD group looked towards the face for a smaller percentage of time than either of the two comparison groups. This was partly driven by data to 'off screen' areas that could not be tracked. However, the ASD group did spend a higher percentage of time viewing the wall behind the researcher than the other two groups. Overall, the eyes were viewed for longer than the nose and external face regions. The mouth was viewed longer than the external face regions. Groups differed in terms of percentage of time spent fixating towards the eyes and the nose, but not the mouth or external face regions. The ASD groups spent a sig. smaller percentage of time viewing the eyes than either comparison group. The NT group spent a higher percentage of time viewing the nose than the ASD group. Puppet and poem: Similar to the introduction the ASD group spent a	ASD children showed specific differences in social attention that separated them from SLI and NT groups. Both the SLI and NT groups used a more 'social' gaze, making more fixations towards the interaction partner's face. The NT group on the other hand, made a larger proportion of fixations on the researcher's body or non-body areas. In contrast to Nadig et al. (2010) the study demonstrated reduced face gaze in a face-to-face interaction. It also showed that the greatest differences were in the eye area. This would appear to provide support for the generalisation from static computer-based tasks. A key finding of this study is that it is the first that shows reduced face gaze when participants are required to predominantly listen rather than talk. This could indicate a risk that ASD individuals could miss non-verbal facial cues during interaction.

					poem a second researcher snuck in as a distractor and pulled the puppet from the first experimenter's hand and dropped it on the floor. The first experimenter did not react (as to explore how participants react when a social norm is not met).		smaller percentage of time looking towards the face than either comparison group and more time towards the body and non-partner areas. Overall, the face was viewed for a longer percentage of time than both the body and non-partner regions, and the non-partner region for a higher percentage than the body. Overall, the eyes were looked at longer than other face regions. However, the ASD group viewed the eyes for sig. smaller percentage of time than either comparison groups. When the puppet was present the ASD group spent a smaller percentage of time looking at either the researcher's face or the puppet as compared to either comparison group. However, overall, participants looked toward the puppet for a greater percentage of time than the researcher's face once it was presented. When the puppet was pulled off the hand, the ASD group were equally likely to look towards the researcher's face or the hand. The two comparison groups spent a greater percentage of time looking towards the researcher's face. After interruption and puppet removed, ASD group sig. slower to shift gaze back towards the researcher's face than either comparison group. Approx. 6 percent of the ASD group made their first fixation to the eyes of the researcher, compared to 36 percent of SLI and 38% of NT.	The ASD group generally had more looking time to non-partner areas than towards the interaction partner, and always more than towards the face area. This was taken by the authors as evidence of gaze avoidance. Two possible explanations are distraction or over arousal. There were no differences between groups for the introduction of the puppet, all three groups looked towards the puppet when it was introduced. This could indicate the potential value of using inanimate objects in classroom settings to capture the attention of children with ASD. SLI and NT children were much faster to check if the researcher had noticed that the puppet was removed from her hand, which is a sign of social monitoring. Real world check of mentalising ability. This could highlight the importance of looking beyond timing of gaze but also it's time-course.
Jones et al., 2017 **CCAT Score:** 80%	ASD (sample 1) ASD (sample 2) NT	20 (4) 15 (8) 20 (6)	4-13 5-13 4-13	Age, Gender; DAS, WAIS-IV or WPPSI-III	All participants took part in a conversation based on the Brief Observation of Social Communication Change, approx. 12 minutes in length with two 5-minute play segments and a 2-minute period of conversation. Whilst standard assessment is free movement play, for this study researcher and participant sat across from each other. ASD Sample 1 was compared to NT group and ASD Sample 2 took	**Eye tracking:** Pivothead Kudo camera glasses worn by researcher, they contained an outward camera that recorded the movements and eyes of the participants. **Rater:** Five raters were involved in coding the video data using Mangold International's INTERACT analysis software. Unclear whether raters were all external to the study or naïve of a participant's group. **AOI & Other measures:** Primary AOI was the researcher's face.	<u>Sample 1:</u> Both ASD and NT groups made longer and more frequent gaze towards the researcher during the conversation than free-play. No sig. differences between groups. <u>Sample 2:</u> As above, ASD participants made longer and more frequent gaze towards the researcher during conversation than free-play. There was no difference between Time 1 and Time 2. <u>Comparison between ASD Sample 1 and Time 1 of ASD Sample 2:</u> Sig. interactions between duration of gaze towards researcher and social difficulty rating from the ADOS and score on the SRS-II for the conversation only (not free-play).	Novel finding that there was less gaze made towards an interaction partner in <u>both ASD and NT children</u> during free-play. Highlights that gaze should be assessed in a number of different contexts. Consistent with previous findings, consideration should be given to the types of toys used in assessment. Results could be driven by the availability of toys (free-play) and no toys (conversation). Amount of gaze linked to severity of difficulties associated with ASD, and behaviour difficulties across groups.

					part in a longitudinal comparison comparing initial performance (Time 1) with another 8-weeks later (Time 2).	Performance from Sample 1 and Sample 2 considered separately. Proportion of time and rate of eye contact toward the researcher coded for analysis. Type of toy selected and whether that impacted on gaze toward the researcher. Gaze behaviour considered in relation to scores on ADOS and SRS.		
Mirenda, Donnellan, & Yoder, 1983 **CCAT Score:** 50%	ASD NT	4 (-) 4 (-)	6-12 6-15	ASD and NT groups not matched	Monologue and dialogue interactions used. Monologue - child was asked to tell researcher a recent story. Researcher was not verbally active but did use body language (e.g. nodding) and paralinguistic expressions (e.g. "oh?"). Dialogue - both child and researcher exchanged questions, although the researcher guided this. No further explanation given.	**Eye tracking:** No formal eye-tracking but videos of conversation coded afterward by a number of raters. **Rater:** More than one rater involved in coding video data, reliability assessed. **AOI & Other measures:** Primary AOI was the researcher's face. Frequency and duration of eye-to-face gazes made by children were coded.	Both groups spent an equal amount of time making eye-to-face gaze overall. The length of each individual gaze was also similar. However, variability within ASD children was greater. ASD children tended to look more frequently and for longer during the monologue interaction than NT children, with the opposite trend occurring during dialogue. However, neither trend was sig. different between groups. Across both groups frequency and duration of eye-to-face gaze increased with age.	Findings might suggest that the difference for ASD children as compared to NT is to quality of eye contact rather than quantity of eye contact. Thus, older children and adults might not demonstrate a gaze avoidance but rather do not show the same quality of eye contact as a NT individual.
Nadig, Lee, Singh, Bosshart, & Ozonoff, 2010 **CCAT Score:** 80%	ASD NT	20 (4) 17 (2)	Mean 10:10 Mean 11:0	Age, WASI	Conversation consisted of two topics: specific interest/hobbies and generic (e.g. pet, siblings). Researcher only provided to prompting questions if a participant's answer was unrelated or conversation stopped. Data only available from 12 ASD participants and 11 NT participants.	**Eye tracking:** ASL head mounted eye tracker, magnetic marker used to correct data in relation to head movement. **Rater:** Two raters involved in coding video data using Eyenal software. Unclear if raters were independent from the study or naïve to a participant's group. **AOI & Other measures:** AOI were defined as researcher's face, body, and non-body areas (e.g. wall behind researcher and table).	No sig. difference between groups for time spent looking towards the researcher's face. Significant difference between topics overall, with longer time spent looking towards the face of the researcher during the specific interest/hobby topic. No difference between groups for gazes toward non-body areas of the researcher. Overall, there was less gazes made to non-body areas during the hobby topic. ASD participants who scored higher on the ADOS made less fixations on the researcher's face. Furthermore, ASD participants who made more fixations towards the researcher's face on the hobby topic made less atypical utterances.	In contrast to what was hypothesised, ASD participants were not more motivated to make gazes towards the researcher's face during the hobby topic than the generic topic. However, it did have an impact on the quality of conversation, with the ASD group producing more monologue-like, scripted conversation during the specific interest/hobby topic.
Riby, Doherty-Sneddon, & Whittle, 2012 **CCAT Score:** 77% **<u>Only ASD data reported.</u>**	ASD NT	19 (2) 19 (9)	12-17 5-15	BPVS	Question and answer style conversation using mental arithmetic questions. Through prior discussion with parents and teachers	**Eye tracking:** Camera set up behind researcher, facing toward the participant. Researcher and participant sat facing each other.	<u>Task Accuracy:</u> Significant difference in question accuracy between two phases of interaction across ASD and NT groups, with lower levels of response accuracy in the maintained eye contact condition. No sig. difference between groups.	The requirement to direct gaze towards the face of another person has a cognitive impact on both ASD and NT individuals. Asking individuals with ASD to make eye contact while they are thinking (something

Children with William Syndrome also used.					of participants the questions were designed to be 'moderately' difficult. Two phases of interaction: first phase participants received no instruction in terms of gaze, second phase participants were explicitly asked to try and maintain eye contact during the interaction.	**Rater:** No mention of who coded the video data. **AOI & Other measures:** Primary AOI was defined as the researcher's face. Conversation took between 15 and 20 minutes in total (across both phases). For analysis the interaction was broken down into listening (researcher asked question), thinking (period before participant answered) and talking (participant answered) stages. Percentage of accurate answers and percentage of time spent averting gaze from the researcher's face were two key measures.	Gaze behaviour: Sig. difference between groups overall in terms of averted gaze, with the ASD group spending a greater percentage of time averting gaze from the researcher's face. Understandable sig. difference between phases of interaction with smaller percentage of gaze aversion overall in the maintained gaze phase. Sig. difference between all three stages of interaction: greatest percentage of time spent averting gaze in the thinking stage, with less aversion in the speaking stage, and the least in the listening stage. In the maintained gaze phase, there was still a sig. difference between thinking stage and the other two stages in terms of percentage of time spent averting gaze. Greatest sig. difference for the ASD group when no instructions were given in terms of gaze. No sig. correlation between gaze behaviour and age, verbal ability or level of functioning in ASD group, or age and verbal ability in NT group. Sig. positive correlation between gaze aversion in the thinking stage of the no gaze instruction phase across both groups. Namely, the higher the percentage of gaze aversion the greater the accuracy on the arithmetic question.	which can happen across contexts) can interfere with concentration. However, it is unclear from this study whether this is connected to dual tasking or the face itself. Potential issue with arithmetic as source of conversation, as it may involve the activation of mental spatial cues and a legitimate need to avert gaze. Some research to rule this out in NT individuals but not those with ASD. Findings suggest atypical levels of gaze aversion for ASD children during the listening stage of a conversation (i.e. when an interaction partner is talking). Two possible explanations are that thinking/processing information needs to start earlier than for NT children, or that the significance of visual/social cues are less recognised. However, the data did not suggest that ASD children were averse to eye contact.
Adult								
Falkmer, Bjällmark, Larsson, & Falkmer, 2011 **CCAT Score:** 70%	ASD NT	15 (6) 15 (6)	*Mean Age (SD)* 26.6 (9.6) 26.3 (10.1)	Age, gender	All participants first participated in two static computer-based tasks (face recognition and emotion recognition) before taking part in a face-to-face interaction with the researcher. The interaction focused on how the participants perceived the static face tasks, whether they would take part on such a study again. They were not aware at the time that this was part of the study.	**Eye tracking:** SMI iView X HED 60Hz eye-tracker. **Rater:** No mention of who coded the video data. **AOI & Other measures:** AOI defined as mouth, eyes, and 'other face areas'. Average fixation time on each AOI used for analyses.	With the exception of one ASD participant, none of the ASD group demonstrated different gaze strategies between the computer-based tasks and the face-to-face interaction. Quite a number of the ASD participants made no fixations on the mouth region during the face-to-face interaction. The NT group made a higher percentage of fixations to the mouth area in the computer-based tasks than the face-to-face interaction. Specifically, there was also longer fixation duration on the mouth area during the static emotion recognition task than the interaction. The majority of the NT group did not view the mouth area during the interaction. The ASD group had longer fixation durations to the eyes during the face recognition task than the emotion recognition task. In contrast, the NT group had longer fixation durations to 'other face areas' in the face recognition task than the emotion recognition task.	These findings suggest that visual strategies of individuals with ASD are consistent across static and dynamic 'real-world' faces. This could be taken as support for the generalisation of findings from static computer-based tasks. The findings could also be taken to show that neither ASD nor NT individuals rely on information from the mouth during face-to-face interactions. This is in contrast to results from dynamic videos of social interactions (Klin et al., 2002).

Freeth & Bugembe, 2019 **CCAT Score:** (AR) 70%; (CR) 75%; (EB) 68%	ASD NT	12 (1) 13 (3)	22-57 19-57	Age, WASI, AQ	Conversation consisted of four pre-determined topics: living in Sheffield; weekend plans; national traits; and hobbies. If a participant conversed for less than 30 seconds on a topic they were prompted to talk further. The participant then role-reversed and asked the researcher the same questions. The researcher manipulated gaze on each question in both roles (questioner and responder): twice they directed gaze toward the participant and twice directed gaze away. This was counterbalanced between participants.	**Eye tracking:** SMI 24Hz eye-tracking glasses **Rater:** No mention of who coded the video data. **AOI & Other measures:** AOI were defined as: eyes, mouth, outer face, body and background. Initial 30 seconds of conversation after question had been asked was used in analysis. Data converted into proportion of time spent directing gaze.	Eye contact: Sig. difference between ASD and NT groups in terms of when the researcher directed gaze towards the participant. ASD participants made sig. less gazes towards the researchers eyes when the researcher was directing gaze towards them. No difference between groups for when the researcher averted their gaze. Face region: NT participants spent a greater proportion of time directing gaze towards the researcher's eye region than mouth. No such difference existed for ASD participants. Conversational phase and proportion of fixations towards the eye: Participants spent a sig. greater percentage of time looking towards the researcher's eyes when listening than when speaking. Participants spent a reduced percentage of time looking towards the researcher's eyes when speaking rather than listening if the researcher was directing gaze directly at the participant. However, this difference did not occur if the researcher has averted her gaze. No sig. group differences. Visual exploration: No sig. difference between groups in terms of visual exploration during the face-to-face interaction.	Attention towards the researcher's face was sig. reduced for ASD participants when the researcher directed gaze towards them than when they did not. Reduced social attention towards a conversation partner with direct gaze could result in reduced ability or opportunity to notice important non-verbal cues (e.g. gaze following, intentions, mental state). Results of the study could support arguments that ASD individuals lack motivational response to eye contact or that they find eye contact aversive. Alternative explanations could include the influence of social status from the presence of a researcher.
Hanley et al., 2015 **CCAT Score:** 77%	ASD NT	11 (4) 11 (4)	20-46 20-46	Age, gender, verbal IQ & performance IQ (WASI)	Participants invited to a 'colour perception' study. After eye-tracker calibrated they were told it was not working and that they would have a short conversation with a researcher while it was fixed. The researcher led three topics of conversation: eye-tracker problems; Christmas; and exam preparation. Participants were asked a number of questions to ascertain whether they knew of the deception.	**Eye tracking:** SMI 50Hz head mounted camera. **Rater:** One rater coded all the video data. A second rater coded 20 percent of each video to ensure reliability. It was unclear whether they were external to the study. **AOI & Other measures:** AOI: defined as eyes, mouth, face, hair, and body of researcher; the wall behind researcher; and off-screen. The percentage of fixations towards a particular AOI during the interaction was used for analysis.	Gaze data: Overall, across both groups the face was viewed for a longer percentage of time than either the body or wall areas, which were both viewed equally. The NT group viewed the eye region for longer than the ASD group, and the ASD group viewed the mouth area for longer than the NT group. Correlations between participant characteristics and eye/mouth looking: Across both groups no correlation was found between age, gender, verbal IQ or performance IQ, and performance. For the ASD group there was a correlation between the Social Awareness component of the SRS and time spent looking towards the eyes. Greater Social Awareness was associated with longer time spent looking towards the eyes and poorer social awareness associated with longer time spent looking toward the mouth.	Reduced attention towards the eyes and increased attention towards the mouth is consistent with computer-based studies of social awareness. Face-to-face eye tracking could help to reveal the subtle social difficulties in ASD and indicate points during interactions where social signals and dynamics are missed.

Tantam, Holmes, & Cordess, 1993 **CCAT Score:** 55%	Exp. 1 ASD NT Exp. 2 ASD "Schizoid"	 9 (2) 9 (2) 6 (0) 6 (0)	*Mean age (SD)* 24.0 (5.5) Not matched 26.8 (7.1) 23.3 (5.2)	NT group not matched "Schizoid" group matched in age only	No guidelines stipulated for the conversation. Participants told that the aim was to find out "what people say when they meet each other for the first time". Therefore, it was most likely unstructured.	**Eye tracking:** Two cameras positioned to record full-length image of the researcher and participant. A third camera captured the eyes of the participant directly. **Rater:** One of the researchers was the main rater who coded video data. Two independent raters, who were psychology students, were used to check reliability. **AOI & Other measures:** The researcher's face was defined as the primary AOI. Head movement, gaze at other, vocalisations, gesturing, hand-to-body movements, posture shift, and smiling, were all categorised as 'acts'. Frequency, duration and proportion of interview were measures used for the analysis of each 'act'. For the purpose of comparison only 3 minutes and 50 seconds of interaction were compared across participants.	Overall, very little difference between ASD and NT groups in terms of 'acts' (e.g. posture, gestures, smiling) during the interaction. Slight increase in hand-to-body movements (described as self-stimulating) in ASD group as compared to the NT group. A trend towards less gaze towards the face of the researcher in the ASD group as compared to NT or "schizoid" groups but no sig. difference. Sig. difference was found for the researcher's use of 'other directed gaze' towards ASD group in both experiments. The researcher made more eye contact and spoke less than the ASD participants. Sig. difference between how the researcher spoke to ASD participants as compared to either the NT or 'schizoid' groups. There were also fewer back-and-forth interactions between the ASD group and the researcher than for either of the other two groups. Suggestive of a difficulty in the social interaction between ASD participants and the researcher. The NT group looked more towards the researcher when speaking, as when listening, for the ASD Group they looked sig. less when speaking as when listening. No sig. difference with 'Schizoid' group. ASD participants looked sig. more at the researcher when they were talking themselves; NT participants looked more towards the researcher when the researcher was talking. ASD participants were less likely to smile when the researcher smiled than either the NT or 'schizoid' groups.	The main significant difference in the study was in how the researcher's 'other directed gaze' was used between the ASD and NT groups. Lack of significant difference between groups in terms of gaze towards the researcher could be due to small sample of participants. However, qualitative difference between the use of non-verbal behaviours in ASD and NT groups is consistent with previous studies, as well as a difference in social behaviour for an interviewer between these two groups (e.g. Van Engeland et al., 1985). The findings of the study were suggestive that the use of non-verbal behaviours for ASD adults is appropriate and in line with the behaviours of NT adults. Rather than an avoidance of gaze in ASD adults there was simply not an increase of it when the researcher was speaking. Instead this could indicate a failure to orientate to human speech (a skill which is important during development for joint attention and perspective taking).

Notes:
ASD - Autism Spectrum Disorder; NT - Neuro-Typical; SLI - Specific Language Impairment; BPVS - British Picture Vocabulary Scale; WPPSI - Wechsler Pre-School and Primary Scale of Intelligence; WISC - Wechsler Intelligence Scale for Children; WAIS - Wechsler Adult Intelligence Scale; WASI - Wechsler Abbreviated Scale of Intelligence; SRS - Social Responsiveness Scale; SES - Social Economic Scale; DASS - Depression, Anxiety and Stress Scale; AQ - Autism Quotient

Results

Table 1 provides the data extracted from each of the fourteen studies included for synthesis. A summary for each of the main characteristics and results of the studies are given in the sections below.

Types of study

Each of the studies included were 'case-control', whereby a clinical group with ASD was compared to a NT group. In two of the studies another clinical group was also used for comparison, this included children with a specific language delay (SLD; Hanley et al., 2014); and adults with a previous diagnosis of psychosis (Tantam et al., 1993).

Group characteristics & Matching of groups

Of the 14 studies, 10 investigated face-to-face interactions with children and adolescents. The total number of included children and adolescents across studies was 359, with a median of 17 for both the ASD and comparison groups. The age across groups ranged from 4 to 17 years old. The remaining four studies investigated face-to-face interactions with adults whose total participants numbered at 107, with a median of 11 for both the ASD and comparison groups. The age of participants ranged from 19 to 57 years old.

The majority of studies reported that ASD participants had received a previous diagnosis and were recruited from local hospitals, classes or schools for children with additional needs, university disability services, national autism organisations, or from previously created research databases. The researchers frequently used clinically relevant measures to independently confirm ASD diagnoses, using versions of the Autism Quotient (AQ), Autism Diagnostic Observation Schedule (ADOS), Autism Diagnostic Interview (ADI), Social Communication Questionnaire (SCQ), Social Responsiveness Scale (SRS), and

Asperger Syndrome Diagnostic Scale. Two studies relied on previously reported diagnoses and written confirmation from parents or professionals (Falkmer et al., 2011; Hanley et al., 2014). One study provided undisclosed questionnaires to family (Tantam et al., 1993), and another (pilot) study made no reference to recruitment or ASD diagnoses (Mirenda et al., 1983).

Through the recruitment method or cognitive assessment, the ASD and comparison groups were all assessed to not have intellectual disabilities (namely, an IQ below 70). The majority of studies matched ASD and comparison groups on one or more of the following: age, gender, verbal abilities and/or non-verbal abilities. Commonly used measures were versions of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI), Wechsler Intelligence Scale for Children (WISC), Wechsler Abbreviated Scale of Intelligence (WASI), Wechsler Adult Intelligence Scale (WAIS), Stanford-Binet Intelligence Scale, Clinical Evaluation of Language Fundamentals (CLEF), and the British Picture Vocabulary Scale (BPVS). Only one study did not match its ASD and NT comparison group on any domain (Mirenda et al., 1983).

Types of interaction used

The types of interactions used varied widely across studies. The most common type of interaction consisted of questions and answers, led by the researcher who either asked explicit questions or provided prompts on a topic to keep a conversation going.

A number of studies adapted tasks commonly used in teaching or clinical assessments: two studies used mental arithmetic questions (Doherty-Sneddon et al., 2013; Riby et al., 2012); and two studies used an adapted version of the Digit Span task. In one study the researcher's gaze was manipulated (Falck-Ytter et al., 2015), and in the other study, participants use of eye gaze during the Digit Span was compared to a task where they were required to listen to a story (Falck-Ytter, 2015). Another study adapted the Brief Observation of Social Communication Change, which consisted of a 12-minute interaction containing two 5-minute play segments separated by 2-minutes of open conversation (Jones et al., 2017).

Six studies used short conversations based around one to four topics relevant to the participants, such as a recent story, hobby, plans for Christmas or pets (Freeth & Bugembe, 2019; Hanley et al., 2014, 2015; Mirenda et al., 1983; Nadig et al., 2010; Tantam et al., 1993). Two of these studies used deception to initiate the conversation, participants were originally asked to take part in another task but something went wrong with equipment (Hanley et al., 2015) or they were asked to give feedback on a 'magician's' performance (Hanley et al., 2014). For the latter, eye-gaze was compared between participants' having a short conversation about themselves with a task whereby they had to listen to a poem in the presence of a distracter (a puppet) and an unexpected interruption (by a confederate).

Two studies required the completion of an initial task before having a conversation about it. One study required participants to watch two short video clips before answering questions about them, after one video the questioner was the researcher and after the other video the questioner was someone familiar (Doherty-Sneddon et al., 2012). The second study required participants to complete two tasks with computer-based static faces (Falkmer et al., 2011). The use of gaze for static faces was then compared to a face-to-face interaction with the researcher, participants were asked to answer a few brief questions about their experience of the study.

The last type of interaction was used by Birmingham et al. (2017) with ASD and NT children, participants were asked to take part in two, hour-long games: one with a board game and one with a card game. Participants could choose the game they wished to play. The researcher either deliberately directed gaze towards a participant or averted gaze during different periods of play.

Measures and Areas of Interest (AOI)

In total, eight studies used some form of head-mounted eye-tracker with participants (Falck-Ytter, 2015; Falck-Ytter et al., 2013; Falkmer et al., 2011; Freeth & Bugembe, 2019; Hanley et al., 2014, 2015; Jones et al., 2017; Nadig et al., 2010). The benefit of using an eye-tracker is that it can provide a more precise measurement of how participants utilise gaze. Of the remaining studies five used external cameras to capture participants use of gaze (Doherty-Sneddon et al., 2013; Doherty-Sneddon et al., 2012; Mirenda et al., 1983; Riby et al., 2012; Tantam et al., 1993); and one study used an eye-tracker but due to technical difficulties had to rely on an external camera (Birmingham et al., 2017).

Across all of the studies the interaction partner's face was the main Area of Interest (AOI) for analysis. Seven studies were interested in the frequency, timing and duration of fixation gaze towards the interaction partner's face (Birmingham et al., 2017; Falck-Ytter et al., 2015; Falck-Ytter, 2015; Jones et al., 2017; Mirenda et al., 1983; Nadig et al., 2010; Tantam et al., 1993), two of those studies were also interested in gaze towards non-partner objects (Falck-Ytter, 2015; Nadig et al., 2010). Three studies were interested in the percentage of time spent averting gaze from an interaction partner's face (Doherty-Sneddon et al., 2013; Doherty-Sneddon et al., 2012; Riby et al., 2012). The four remaining studies were interested in the timing, frequency and duration of gaze towards an expanded selection of AOI, including: whole face, eyes, mouth, nose, hair, hands, clothing, body, wall behind interaction partner, items of clothing, and other areas defined as 'off screen' (Falkmer et al., 2011; Freeth & Bugembe, 2019; Hanley et al., 2014, 2015).

Nine of the studies used a second rater (or more) to increase the reliability of the encoding of video data (Birmingham et al., 2017; Doherty-Sneddon et al., 2013; Doherty-Sneddon et al., 2012; Hanley et al., 2014, 2015; Jones et al., 2017; Mirenda et al., 1983; Nadig et al., 2010; Tantam et al., 1993). Five studies gave little or no description of who coded video data (Falck-Ytter et al., 2015; Falck-Ytter, 2015; Falkmer et al., 2011; Freeth & Bugembe, 2019; Riby et al., 2012).

Gaze behaviour during face-to-face interactions

Overall, only two studies found significant differences between groups in the overall amount of gaze directed towards an interaction partner (Riby et al., 2012; Tantam et al., 1993). This did not appear to be influenced by whether the primary AOI was the whole face or whether there were AOI for specific regions of the face, body or environment. Nevertheless, the majority of studies did report differences between groups in terms of the quality or use of gaze. These will be discussed further in relation to the overall findings for each age group in the sections below.

Children and adolescents

From the ten studies in which the participants were children and adolescents, nine found little difference in the overall use of gaze between ASD and NT groups. In a comparison of gaze behaviour between monologues (i.e. children told a recent story) and a dialogue (i.e. exchange of questions in a conversation), Mirenda (1983) found no difference between groups in the frequency and duration of gaze towards an interaction partner's face. The ASD group made longer and more frequent gazes during the monologue as compared to dialogue but this did not reach significance. Nadig et al. (2010) compared children as they engaged in an open conversation about a topic-of-interest or a generic topic (e.g. pets or siblings). No difference was found between ASD and NT groups for time spent looking at an interaction partners face. Both groups had increased gaze during the topic-of-interest conversation, which the author's viewed as more of a monologue, than the generic topic (this will be explained further in the discussion). Interestingly, similar to Mirenda's study above, gaze towards the face was higher for the ASD group during the topic-of-interest but not significantly so. The ASD group also had more qualitative differences during the generic topic, giving less appropriate information and making more atypical utterances than the NT group. The authors query whether the topic-of-interest was easier to engage in for the ASD group due to simply finding it more interesting or that it is a more rehearsed conversation.

The two studies that utilised play as part of their interactions found no overall group differences in the frequency and duration of gaze towards the interaction partner. Jones et al. (2017) compared children's use of gaze towards an interaction partner's face during joint play and short interactions without toys. Neither ASD nor NT children engaged in much eye contact during the interactive play, while both groups made more frequent eye contact when the toys were not present. However, Jones et al. (2017) found the amount of eye contact for the ASD group was significantly correlated with symptom severity. In the context of playing a card game and a board game, Birmingham et al. (2017) were interested in children and adolescents ability to match an interaction partner's gaze by either adjusting gaze and jointly looking towards a non-social object or adjusting towards another person (i.e. social object). No group differences were found in the frequency of gaze-matching. However, children and adolescents with ASD were significantly slower to match the interaction partner's gaze and made gazes of longer duration when the interaction partner looked towards non-social objects. Interestingly, the ASD group also made more vocalisations towards the interaction partner when their gaze was directed to non-social objects. The authors discussed whether the longer gaze duration and increased vocalisations were connected to a discomfort or frustration that social expectations were not being followed or had become less predictable as there were a number of potential non-social objects.

Three studies investigated children's level of gaze aversion during interaction (i.e. the percentage of gaze directed away from the face of an interaction partner). Gaze aversion refers to a shift in gaze away from an interaction partner's face and is viewed as a typical and expected component of communication (Ehrlichman, 1981; Mcgurk & Macdonald, 1976). It is typically not used when we listen to an interaction partner, as it is thought to hinder our perception of visual cues, but is thought to help with pulling information from memory or concentrating when we are planning answers or speaking. Doherty-Sneddon et al. (2013) were interested in the level of gaze aversion for a familiar interaction partner (e.g. teacher, parent) versus an unfamiliar interaction partner (e.g. researcher). Overall, no significant difference in the amount of gaze aversion between groups. Both ASD and NT children averted gaze more when thinking of a response to a question than when either listening or answering. NT children averted gaze more often when thinking with an unfamiliar interaction partner, no such difference existed for children with ASD. In an earlier paper, Doherty-Sneddon et al. (2012) investigated gaze aversion during mental arithmetic questions of different difficulties (e.g. easy, medium and hard). Overall, children with ASD did not avert gaze more than NT children, with both groups showing increased gaze aversion as question difficulty increased. A specific difference between the groups was that NT children averted more when thinking than children with ASD, and children with ASD averted more when listening than the NT group. Although no group differences were found in performance for the arithmetic questions, increased gaze aversion during the listening phase could result in children with ASD missing non-verbal social cues. In another study by the same colleagues, Riby et al. (2012) manipulated participants' gaze (i.e. asked them to maintain direct eye contact or to make eye contact as they wish) during a mental arithmetic task and, again, measured gaze aversion. They found an overall difference in the level of gaze aversion between ASD and NT groups, with children from the ASD group making more gaze aversion regardless of whether eye contact was maintained or freely chosen. Children with ASD found it more difficult to maintain gaze than NT children, with elevated aversion whilst listening than NT children.

Hanley et al. (2014) investigated gaze behaviour across two tasks whereby children were asked to answer questions about themselves and a task whereby they were asked to listen to a poem in the presence of a distractor (i.e. puppet) and an interruption (i.e. puppet removed suddenly by a confederate). Whilst answering questions, children with ASD spent a similar amount of time looking towards an interaction partner's face as both a Specific Language Impairment and NT comparison group. No group differences were found for the mouth region of the interaction partner's face, which contrasts with previous findings using computer-based stimuli (e.g. Pelphrey et al., 2002; Spezio et al., 2007). However, whilst listening to a poem the children with ASD spent longer periods of time fixating on the interaction partner's body or non-partner areas than either comparison group. In contrast to the authors' predictions, no group differences were found when the puppet was introduced during the storytelling task; namely, children in all three groups shifted their gaze towards the puppet. However, when the puppet was suddenly and unexpectedly removed, children with ASD were slower than either comparison group to shift their gaze to the interaction partner to acknowledge its removal. Furthermore, after the removal, children with ASD again spent a greater percentage of time than either comparison group directing their gaze towards the partner's body or non-partner areas rather than face. The authors' argue that this demonstrates reduced social monitoring in ASD, a crucial component of perspective taking, and could result in children missing important non-verbal cues with peers or professionals.

Falck-Ytter at al. (2015) investigated children's use of gaze during an adapted Digit Span task when the researcher made direct eye contact or when the researcher looked away (i.e down at their notes on the table). Overall, no difference was found in the amount of gaze made towards the researcher, with increased gaze across groups when 'encoding' (i.e. listening) than answering. Interestingly, performance in the Digit Span was negatively affected by the researcher's gaze aversion for NT children but not children with ASD. In another study, Falck-Ytter (2015) compared performance in an adapted Digit Span task with a story listening task. Whilst listening to the story, children with ASD made fewer gazes towards the face of the interaction partner than NT children. Children from the ASD group made significantly more gazes towards the interaction partners face in the Digit Span task than the story listening task. No difference between groups in the use of gaze in the Digit Span task, which could indicate that individuals with ASD are not fundamentally impaired in visual attention. The authors queried whether this context dependent difference in gaze behaviour for children with ASD was linked to motivation (i.e. less motivation to make eye contact while the only requirement is to listen). Interestingly, it took the researcher longer to tell the story for the ASD group potentially suggestive that they were unconsciously aware of less overt attention (eye contact) in this group.

Adults

Tantam, Holmes and Cordess (1993) conducted short, unstructured conversations across two studies: the first with ASD and NT adults, the second with adults who have ASD and adults who had a diagnosis of psychosis (termed: "schizoid"). Across both studies the ASD participants engaged in less gaze towards an interaction partner's face than either comparison group. Interestingly, this is the only study in this review where the interaction partner was blind to a participant's group. The author's report that the interaction partners' own conversational styles differed for the ASD group as compared to the comparison groups, making more gazes towards adults with ASD and talking less. The authors argued that the results did not indicate a fear or aversion of eye contact but rather that adults with ASD did not increase gaze at any stage during the conversation.

Falkmer et al. (2011) compared the performance of NT adults and adults with ASD in two commonly used computer-based static faces tasks (emotion recognition and face recognition) with performance in a face-to-face conversation with a researcher about their experiences of the study. Overall, the amount of gaze directed towards the static faces or the face of the researcher did not significantly differ between groups. Adults with ASD appeared to consistently use gaze between the computer-based and face-to-face tasks. Both groups looked towards the mouth region less in the face-to-face conversation as compared to static faces. The duration of gaze towards the eye region was actually shorter for NT adults in the face-to-face interaction as compared to the static faces during emotion recognition. Adults with ASD made more fixations on the eyes of static faces during face recognition than emotion recognition. The authors note that individual performance appears to be consistent across stimuli. They make the case that differences between groups in other studies, regardless of whether computer-based or face-to-face, are driven by large variability between individuals.

The final two studies for inclusion in this review used topical conversation between a researcher and ASD or NT adults. Hanley et al. (2015) found that their ASD participants spent a similar amount of time attending to the face of an interaction partner as NT adults. However, when regions of the face were considered, it was found that adults with ASD had a reduced amount of gaze towards the eyes and an increased level of gaze towards the mouth as compared to NT adults. This finding would appear to support previous findings from computer-based studies of gaze in adults with ASD (e.g. Klin et al., 2002; Riby & Hancock, 2009). Freeth and Bugembe (2019) manipulated the researcher's gaze during their interaction to be either direct or averted from participants. Overall, both groups made fewer fixations towards their interaction partner's eyes when speaking than when listening. This would suggest that adults with ASD could appropriately adapt their gaze during different phases of an interaction. No evidence of reduced visual exploration for adults with ASD as compared to NT adults, the only significant difference was that NT adults made a higher proportion of fixations on the eyes as compared to the mouth, adults with ASD made an equal proportion of fixations between the eyes and mouth. A further finding from this study was that adults with ASD had a reduced level of gaze towards the face region when their interaction partner looked directly at them as compared to when they looked away. The authors query whether this could indicate an aversion or a lack of motivational response to eye contact.

Discussion

The purpose of this review was to collate the findings of eye-tracking studies that have investigated face-to-face interactions with individuals who have ASD. It was hoped that the review would identify whether there is a consistent, global deficit in the use of eye contact; or, alternatively, whether differences are less consistent and more dependent on individual differences and the types of interaction used. The results, at least at the surface level, were quite homogenous. The majority of studies reported that children, adolescents and adults with ASD obtained a similar overall percentage of gaze duration towards (or averted from) the face of an interaction partner as individuals within comparison groups (Birmingham et al., 2017; Doherty-Sneddon et al., 2013; Doherty-Sneddon et al., 2012; Falck-Ytter et al., 2015; Falck-Ytter, 2015; Falkmer et al., 2011; Freeth & Bugembe, 2019; Hanley et al., 2015; Jones et al., 2017; Mirenda et al., 1983; Nadig et al., 2010). Indeed a number of the studies found that individuals with ASD modulated their gaze behaviour similarly to NT individuals, at least to some degree, during the different conversational phases of an interaction (Doherty-Sneddon et al., 2013; Doherty-Sneddon et al., 2012; Falck-Ytter et al., 2015; Freeth & Bugembe, 2019; Riby et al., 2012). This would suggest that there is not a global deficit in social attention and the appropriate use of gaze per se.

However, it is important to note that the majority of studies did report some level of difference between groups in how gaze was utilised during the interactions. For instance NT individuals consistently increased their gaze towards an interaction partner whilst listening as compared to speaking, for individuals with ASD this consistency was not present across studies (Doherty-Sneddon et al., 2012; Freeth & Bugembe, 2019; Riby et al., 2012). Indeed, the two studies that employed a task requiring participants to listen to an interaction partner without responding found that ASD participants made more fixations towards non-partner areas than NT participants (Falck-Ytter, 2015; Hanley et al., 2015). As noted in the introduction, there are currently a number of hypotheses as to how the use of gaze might be different within the ASD population. One of these hypotheses is that individuals with ASD simply find social eye contact aversive due to hyper-arousal (e.g. Kliemann et al., 2012; Tanaka & Sung, 2016).

Underlying mechanisms

The two studies that encouraged the maintenance of gaze discovered that it was particularly challenging for ASD participants. This could be taken as support for the gaze aversion hypothesis. For example, Riby et al. (2012) found that children with ASD struggled to keep fixation throughout an interaction as compared to NT children. Furthermore, Freeth and Bugembe (2019) found that adults with ASD made less eye contact than NT adults if their interaction partner deliberately stared towards them during an interaction. However, despite the maintenance of gaze being encouraged in these studies and the potential aversion this caused, participants with ASD still maintained some level of eye contact and adjusted similarly to NT participants.

A reduced social motivation (e.g. Chevallier et al., 2012) or a lack of automatic motivational response to eye contact (e.g. Dalton et al., 2005; Kylliäinen et al., 2012) are potential alternative or additional hypotheses to gaze aversion. However, if one or more were to hold true, the fact that ASD participants made a comparable overall percentage of eye contact to comparison groups would suggest that they are doing so consciously. So, what can be learned from the present group of studies and under what circumstances do individuals' with ASD lose motivation or the ability to consciously maintain eye contact?

Type of interaction used

Two of the studies identified differences in the use of gaze between monologues (i.e. participants speaking about an interesting topic of their choosing) and dialogues (i.e. a more generic back and forth conversation). One suggestion made by the researchers was that monologues are perhaps more motivational as they are of interest and, therefore, eye contact comes more easily (Mirenda et al., 1983; Nadig et al., 2010). Alternatively, topics that are of interest are also more likely to be rehearsed and predictable. This is likely to reduce any underlying social anxiety and free up cognitive resources to attend to, or remember, eye contact. A number of the studies also found similar levels of eye contact for participants with ASD when a task required academic performance (e.g. mental arithmetic or adapted Digit Span task), this again could underlie motivation as a possible factor (Doherty-Sneddon et al., 2013; Falck-Ytter, 2015; Falck-Ytter et al., 2013).

It would appear, from present findings, that individuals with ASD consciously make eye contact during interactions where specific but predictable answers are expected of them (e.g. interesting personal story, hobbies, arithmetic). From studies of emotion recognition it has been suggested that individuals with ASD consciously use a rule-based strategy, and as a consequence are more likely to struggle with the more subtle expressions of emotion encountered in day-to-day life (Rutherford & McIntosh, 2007). If such a rule-based strategy is used for eye contact in social situations, one rule might be: if I am speaking then I must make eye contact, as it is expected/polite/a social norm etc. As noted in the introduction, directing our gaze away from others is thought to help manage cognitive load when planning a response (e.g. Glenberg et al., 1998; Ho et al., 2015). If individuals with ASD try to consciously manage eye contact, their own verbal response, and anticipate the behaviour of an interaction partner, this could represent a much greater load than what might be experienced by NT individuals. Thus, increased avoidance of eye contact whilst listening to another person may be a consequence in this context.

At present it is difficult to untangle the potential influence of low social motivation, hyper-arousal or hypo-arousal on the use of gaze during face-to-face interactions. However, if a great deal of cognitive resources are being used to follow rules or predict the flow of an interaction; a future hypothesis for investigation would be differences in the latency of turn taking whilst discussing topics of interest, and whether individuals with ASD can pick up verbal or non-verbal cues from their interaction partner. Alternatively, a second hypothesis would be to compare the latency of turn taking where the conversation is both predictable and motivational (e.g. topic of interest, academic performance) with an interaction that is less predictable (e.g. a discussion of a new/novel topic for the participant).

Consistency across stimuli

As discussed in the introduction, much of the previous research investigating the use of gaze towards faces in ASD has utilised two dimensional, computer-based stimuli in the form of static images or videos of social scenes (e.g. Corden et al., 2008; Klin et al., 2002; Nakano et al., 2010; Riby & Hancock, 2009). One of the main criticisms of this methodology concerned the generalisability of the findings to real-world, face-to-face interactions (Chisholm et al., 2014; Kingstone et al., 2005). From the studies included in this review, only one directly compared computer-based stimuli with a face-to-face interaction (Falkmer et al., 2011). Whilst the researchers noted that the use of gaze appeared generally consistent for ASD and NT adults across static stimuli and the face-to-face interaction, they did not find any significant difference in the proportion or use of gaze overall. Furthermore, in contrast to findings from computer-based stimuli (e.g.

Pelphrey et al., 2002; Spezio et al., 2007), no difference was found in the use of gaze between the eyes, mouth or other regions of an interaction partner's face. In addition, of the six studies that applied specific AOI to different regions of the face, only one reported ASD participants looked significantly more towards the mouth than the eye region as compared to NT participants (Hanley et al., 2015).

A lack of power

A lack of power was cited as a potential underlying factor in the lack of group differences, with the similar overall percentage of gaze between groups being driven by individual differences (e.g. Falkmer et al., 2011; Freeth & Bugembe, 2019). Falkmer et al. (2011) proposed that sub-groups of gaze abilities could exist within the ASD population, that it is individuals themselves that are consistent in gaze selection across static stimuli and face-to-face interactions. Indeed, Jones et al. (2017) found a significant correlation between amount of eye contact and symptom severity in children with ASD. Whilst small sample sizes are not uncommon within clinical populations, the likelihood of type II errors does increase. Furthermore, even subtle differences in social attention have been linked to an individual's communication abilities (Dawson et al., 2004). Thus, future studies should have a sufficient sample size to detect subtle differences between groups.

Connected with the idea of individual differences above, by their very nature face-to-face interactions are more complex and difficult to standardise than other stimuli (Hayward et al., 2017). During a face-to-face interaction, beyond managing our own overt attention (i.e. gaze), we are required to respond fluidly, engage with social norms, interpret non-verbal cues (e.g. facial expressions, body language), manage our own verbal/non-verbal cues, and adapt to the environment. This is a complex process for NT individuals even without the extra cognitive load that could potentially be experienced by individuals with

ASD. Something yet to be considered is the mental state of participants and their interaction partner, who is usually a researcher, on the day of the interaction. It is possible that we could respond differently to some individuals than others due to personality or circumstances (e.g. if someone reminds you of a friend, you have shared interests, health, tiredness, caffeine-induced anxiety, research deadlines). Two of the studies reported unplanned differences in the behaviour of researchers' between ASD and NT groups (Falck-Ytter, 2015; Mirenda et al., 1983). To the best of the current authors' knowledge, only one recent study has explored self-reported accounts of eye contact for adults and teens with ASD (Trevisan et al., 2017). While it is not always feasible to predict or control for potential confounds, consideration of participants' own perceptions of the current interaction and their day-to-day experiences of eye contact would be an intuitive means of gaining a richer understanding of the data (e.g. what did you find yourself attending to? Did you become distracted at all? Does maintaining eye contact take conscious effort? Are there situations where eye contact is more difficult? Did family or health professionals try to reinforce/remind you of eye contact?).

Conclusion

The purpose of this systematic review was to provide a detailed synthesis of studies investigating the use of gaze during face-to-face interactions by children, adolescents and adults with ASD. While differences were found in terms of how individuals with ASD use gaze in certain interactions, there was also evidence to suggest a lack of group differences in the frequency or percentage of attention towards the face of an interaction partner. The results were considered in relation to current hypotheses regarding the use of eye contact in ASD (e.g. gaze aversion, a lack of automatic motivational process, low social motivation). The findings from previous computer-based studies of facial emotion recognition were also considered in relation to the present findings. Despite some similarities in the data, there is not enough evidence to support the generalising of findings across methodologies, with a number of the included studies reporting low power. Nevertheless, there is scope to expand on the current methodology to investigate differences in topic (i.e. monologue versus dialogue), subsamples of ability within the ASD population (e.g. relating to age, alexithymia), or the impact of different interaction partners.

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Conflict of Interest

The authors have no conflicts of interest to declare.

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Chapter 3 - Supplementary information for the Systematic Review

The focus of this supplementary chapter is to discuss information that could not be explored within a publication-style framework. Two sections will be covered which include: a summary of the initial scoping review used to develop the Boolean search strategy and an expanded discussion of the hypotheses relating to gaze and emotion recognition difficulties in ASD.

Initial scoping review

As stated in the previous chapter, an initial search was conducted of key words and their synonyms related to the three core aspects of this review: namely, autism spectrum disorder, eye-tracking and face-to-face interactions. The following Boolean search strategy was created:

(autism OR ASD OR "autism spectrum disorder" OR Asperger*) AND ("eye-tracking" OR "eye tracking" OR "eye tracker" OR "eye movement measurement" OR "eye movement" OR gaze) AND ("social interaction" OR "social communication" OR "face-to-face" OR "face to face" OR conversation OR "social skills").

A search was conducted on the 5th of October 2019 across all EBSCO databases (this included PsycINFO and PsycARTICLES), the Scopus database, and the Web of Science database. Articles were filtered to only include those using the English language and there was no limit placed on date of publication. This resulted in an initial collection of

1135 articles, which were imported into the referencing software Zotero. After duplications were excluded this left a collection of 900 articles.

A title and abstract search by the first author (AR) revealed that the majority of studies gathered in the initial search, approximately 98%, did not fit the inclusion criteria. Whilst the majority came from unrelated disciplines (e.g. genetics, computer science, neuroscience, robotics), a great number of the studies (approx. 48%) were relevant but computer-based (e.g. images, videos, virtual reality), used interaction partners known to the participant, or used participants too young to hold a two-way conversation (i.e. children under the age of two).

The search strategy was then refined in relation to the inclusion criteria. Twenty-six key words from the articles in the initial search were used to expand the Boolean search strategy to exclude potentially unrelated articles.

Hypotheses relating to gaze and emotion recognition difficulties in ASD

Over the last number of decades quite a varied selection of hypotheses have been put forward to explain difficulties in emotion recognition and the use of gaze in ASD. A number of the most prominent hypotheses will be summarised in the following paragraphs. To begin, two of the most prominent hypotheses contrast with each other. The first proposes a reflexive avoidance of the eyes due to a hyper-arousal (e.g. Kliemann et al., 2012; Tanaka & Sung, 2016), while the second refers to a lack of reflexive motivation to make eye contact due to a hypo-arousal (e.g. Dawson et al., 2005; Kylliäinen et al., 2012).

From both standpoints, eye contact for NT individuals is considered to generate activation in the arousal systems within the brain, starting in subcortical areas like the amygdala, leading to endocrine and autonomic changes in the body (Adolphs, 2003; Pfaff et al., 2008). However, those who have investigated the hyper-arousal hypothesis have suggested that the same activation process occurs in ASD but in heightened manner, increasing withdrawal and anxiety. This results in a reflexive aversion to the eyes of others and, thus, gaze aversion is viewed as an adaptive response (Corden et al., 2008; Hutt & Ounsted, 1966; Kliemann et al., 2012; Kylliäinen & Hietanen, 2006; Richer & Coss, 1976; Tanaka & Sung, 2016). While NT infants may learn through positive reinforcement that eye contact and mutual gaze with others can lead to nurturing experiences and interactions, an infant with ASD is potentially unable to attach such a reward value to eye contact. Some proponents of the hyper-arousal hypothesis have gone further to suggest that individuals with ASD learn to attach a negative reward value to eye contact due to the repeated increased anxiety (Hutt & Ounsted, 1966; Tinbergen & Tinbergen, 1972). In turn this results in maladaptive social behaviours and difficulties in reciprocal communication.

In contrast, those who have investigated the hypo-arousal hypothesis have stipulated that the failure to develop a positive reward value for eye contact in infancy stems from an under-activation of subcortical areas like the amygdala (Dawson et al., 2005; Grelotti et al., 2002; Kylliäinen et al., 2012). As a consequence little saliency is attached to the emotional expressions of others and the development of cortical 'social' networks and ultimately social competency is stunted (Grelotti et al., 2002).

Perhaps one of the more well known and widely cited hypotheses, also relating to cognition, concerns poor Theory of Mind (e.g. Baron-Cohen et al., 1985; Frith & Frith, 1999; Pelphrey et al., 2005; Redcay, 2008). This refers to the ability to infer the emotional state of others. Proponents of this model have argued for the existence of specific cognitive mechanisms that are absent in individuals with ASD (e.g. Baron-Cohen, 1997). Namely, NT individuals have something like a 'shared attention mechanism' that coordinates information between an area used to detect the direction of an interaction partner's eyes and an area that is specifically used for Theory of Mind (dubbed the Theory of Mind Mechanism). Something common across the three cognitive hypotheses proposed so far, is that there should be no variance in physiological stimulation across different emotions (other than what is proposed by the hypotheses due to eye contact) and there should be no behavioural adaption through repeated exposure. In other words, it should not be possible to teach or improve emotion recognition abilities (for a discussion, see Senju & Johnson, 2009).

One further hypothesis specifically relating to cognition, which is the most recent, has focused on the role of alexithymia (e.g. Bird et al., 2010, 2011; Brewer et al., 2015; Gaigg et al., 2018), an inability to recognise your own emotions which in turn impacts your understanding of others emotions. Unlike the other cognitive hypotheses, alexithymia is not viewed as a mechanism that is specifically disrupted in ASD but something that can occurs alongside it on a continuum (it has also been linked to difficulties with mood, substance misuse, eating disorders, and trauma. For examples, see Haviland et al., 1994; Kinnaird et al., 2020; Lenzo et al., 2020; Zorzella et al., 2020). There is growing evidence of physiological arousal to affective stimuli in ASD, even though participants are not able to subjectively name the emotions (e.g. Ben Shalom et al., 2006; Gaigg et al., 2018). Thus, alexithymia could suggest a disruption or disconnection between physiological arousal and how a person subjectively experiences emotions. In contrast to the previous hypotheses, if alexithymia holds true then psychological interventions that promote greater awareness between the body, thoughts and feelings could help to alleviate some of the reported social and emotional difficulties.

Finally, another proposed hypothesis refers simply to a low social motivation in ASD (e.g. Chevallier et al., 2012). While cognition-specific hypotheses refer to top-down processing (i.e. cortical mechanisms influencing the formation of social behaviour), this hypothesis approaches from the bottom up (i.e. early low social motivation influencing the formation of social cognition). Evidence used to support this hypothesis stemmed from studies of NT children who were socially deprived from an early age with deficits in Theory of Mind abilities and the development of similar difficulties to ASD (Hoksbergen et al., 2005; Wellman et al., 2004). From the standpoint of this hypothesis, if interventions are developed to promote social attention and motivation, then the corresponding social cognition can also be enhanced and reinforce social development (even into adulthood). A number of studies have indicated that if explicitly asked to do so (by a researcher), adults with ASD are capable of attributing a mental state to others (Senju, Southgate, et al., 2009); follow the gaze of others if asked to solve a purposeful task (Ristic et al., 2005); and can match the vocal and facial expressions to different emotions if the faces are familiar or of a favourite character (Senju, Kikuchi, et al., 2009).

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Chapter 4 - Major Research Project

The use of eye contact during a naturalistic face-to-face interaction in Autism Spectrum Disorder

Alasdair Iain Ross[1], Christian Ryan[1] & Jason Chan[1]
[1]University College Cork, Republic of Ireland

Corresponding author:
Christian Ryan, School of Applied Psychology, Cork Enterprise Centre, North Mall Campus, University College Cork, Cork, Republic of Ireland
Email: christian.ryan@ucc.ie

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This chapter is in the process of being formatted for the journal 'Autism'. Journal guidelines can be found in Appendix C. The word limit for this journal is 6,000 words, including tables, abstract but excluding references.

Abstract

Social and emotional difficulties in Autism Spectrum Disorder (ASD) have been linked to differences in the use of social attention as compared to neurotypical (NT) individuals. Much of the evidence for this assertion has stemmed from studies that have used two-dimensional stimuli and eye-tracking (e.g. static images of faces, videos of social scenes). To date, a small number of studies have attempted to investigate the use of gaze by ASD and NT individuals during face-to-face interactions. Using eye-tracking with ten ASD participants and ten NT participants, this study investigated how eye contact was used during a conversation that covered three topics (holidays, preferred mode of transport, and hobbies). In line with recent findings we found that both groups adjusted their total proportion of fixation duration on the eyes depending on whether they were speaking or listening during the interaction. However, the ASD group were found to have an overall lower total fixation duration, made fewer fixations towards the eyes, but were more consistent in their time to make a first fixation on the eyes as compared to the NT group.

This study provides a snapshot of how social attention and eye contact is utilised by adults with ASD, offering a number of new avenues for future investigation.

Keywords

Autism; eye-tracking; gaze; overt attention; social attention; face-to-face; interaction; conversation; emotion recognition; static faces

Introduction

By their very nature, social interactions are fluid and require the continual monitoring of those around us. Our visual system is well designed for this task, making a saccade to a new location approximately three-to-five times per second (Krekelberg, 2011). Directing our attention towards the faces of others, particularly towards their eyes, forms an important social mechanism (Emery, 2000; Ristic et al., 2005; Tomasello, 1995). For instance, through our eyes and facial expressions we can communicate aspects of our personality, convey humour, indicate our current emotional state, and where we are currently directing our attention. Furthermore, during face-to-face interactions neurotypical (NT) participants have been found to fixate towards the eyes of an interaction partner when listening rather than speaking, when information is ambiguous, or to indicate that their turn has finished (Ho et al., 2015; Macdonald & Tatler, 2013).

Given the importance of how and where our eyes are directed during everyday social interactions, it is perhaps unsurprising that studies have made links between social and relational difficulties in certain groups of individuals and their use of gaze (e.g. Bögels & Mansell, 2004; Dawson et al., 2004; Hills & Lewis, 2011; Horley et al., 2003; Langdon et al., 2006; Sasson et al., 2016; Senju & Johnson, 2009; Shean & Heefner, 1995; Wieser et al., 2009). One such group are individuals with autism spectrum disorder (ASD; e.g.

Dawson et al., 2004; Senju & Johnson, 2009). While investigating the ability to identify emotions or attend social scenes, it was found that individuals with ASD tend to fixate more towards the mouth region of the face than towards the eyes, and tend to demonstrate reduced visual exploration, as compared to NT individuals (Chita-Tegmark, 2016; Fletcher-Watson et al., 2009; Freeth et al., 2010; Heaton & Freeth, 2016). As a result, individuals with ASD have been shown to experience greater difficulty in identifying negative emotions, such as fear or anger, which are thought to rely more heavily on communication through the eyes.

Nevertheless, the types of stimuli commonly used in the above studies, such as static images of faces or videos of social scenes, have faced criticism (e.g. Chisholm et al., 2014; Cole et al., 2016; Kingstone, 2009; Kingstone et al., 2005). Namely, two-dimensional stimuli tend to lose contextual information, such as body language and non-verbal gestures, and increase the risk of being under-stimulating. Furthermore, questions have been raised as to whether social attention is engaged in a similar manner if a social partner is physically present or not (e.g. Freeth & Bugembe, 2019; Risko et al., 2016). Consequently, although difficulties in the appropriate use and timing of gaze during social interactions have been self-reported (Trevisan et al., 2017), it is difficult to identify whether the findings from two-dimensional stimuli can be taken to represent a global deficit in social attention and the use of gaze, or whether it is situation or stimuli specific.

Attempts have been made to investigate the use of gaze during face-to-face interactions within ASD and NT individuals. These studies have primarily employed a form of eye-tracking with a predetermined interaction between a participant and a researcher. Examples have included a discussion of hobbies, listening to a story, or the completion of an increasingly challenging arithmetic task (e.g. Freeth & Bugembe, 2019; Hanley et al., 2015; Nadig et al., 2010). Indeed a number of studies have sought to manipulate components of an interaction, such as specifically encouraging direct or averted gaze by a participant or researcher (Birmingham et al., 2017; Falck-Ytter et al., 2015; Freeth & Bugembe, 2019; Riby et al., 2012), or employed deception to disguise recording and encourage interaction (Falkmer et al., 2011; Hanley et al., 2014, 2015). In a recent review of these studies, Ross, Byrne, Chan & Ryan (unpublished) sought to bring together the current evidence of how eye contact is used during face-to-face interactions within the ASD population.

At a surface level the overall findings appeared quite homogenous. The majority of the fourteen studies identified, reported that children, adolescents and adults with ASD had a similar percentage of gaze duration towards (or averted from) the face of an interaction partner as NT individuals (Birmingham et al., 2017; Doherty-Sneddon et al., 2013; Doherty-Sneddon et al., 2012; Falck-Ytter et al., 2015; Falck-Ytter, 2015; Falkmer et al., 2011; Freeth & Bugembe, 2019; Hanley et al., 2015; Jones et al., 2017; Mirenda et al., 1983; Nadig et al., 2010). Indeed a number of the studies found that individuals with ASD modulated their gaze behaviour similarly to NT individuals, at least to some degree, during the course of an interaction (Doherty-Sneddon et al., 2013; Doherty-Sneddon et al., 2012; Falck-Ytter et al., 2015; Freeth & Bugembe, 2019; Riby et al., 2012).

However, it is important to note that the majority of these studies did report some level of difference between groups in terms of how gaze was utilised during these interactions. For example, while NT participants consistently increased their gaze towards an interaction partner while listening as compared to speaking, this consistency was not found across studies for ASD participants (Doherty-Sneddon et al., 2012; Freeth & Bugembe, 2019; Riby et al., 2012). Indeed, when asked to listen and not respond, ASD participants were found to make more fixations towards areas away from their interaction partner as compared to NT participants (Falck-Ytter, 2015; Hanley et al., 2015).

There are a number of hypotheses regarding the use of eye contact in ASD, which could be used to explain group differences in the use of eye contact. For example, that it simply reflects a low social motivation (e.g. Chevallier et al., 2012) or a lack of reflexive motivation to make eye contact (e.g. Dalton et al., 2005; Kylliäinen et al., 2012). Another example stipulates that a reduced level of eye contact could function as a means of managing cognitive load for individuals with ASD, linked to a reflexive avoidance of the eyes (e.g. Kliemann et al., 2012; Tanaka & Sung, 2016). For NT individuals averting gaze has long been viewed as a means of managing cognitive load (Glenberg et al., 1998). As it has been self-reported by individuals with ASD that eye contact is challenging and takes conscious effort (Trevisan et al., 2017), overly manipulating components of an interaction rather than using a naturalistic task could hypothetically alter social expectations, increase anxiety, and the cognitive load required to consciously manage eye contact.

Aim of the present study

In the following study we aimed to conduct a naturalistic face-to-face interaction with a group of adults with ASD and group of NT adults. In order to make the interaction as natural and engaging as possible we chose to centre the conversation around three topics (e.g. holidays, preferred mode of transport, and hobbies). As noted above, while a number of studies have attempted to separate the speaking and listening phases of an interaction or manipulated how gaze is utilised (e.g. Falck-Ytter et al., 2015; Falck-Ytter, 2015; Freeth & Bugembe, 2019; Riby et al., 2012), in the present study the researcher asked a participant about a topic and then provided their own response once a participant had finished. The present authors anticipated that this 'dialogue'-like structure of interaction would be more sensitive to social and emotional difficulties experienced in day-to-day life within the ASD group. We hypothesised that ASD participants would make some level of adjustment to their eye contact with an interaction partner depending on conversational phase. However, we anticipated that the quality of eye contact would differ between groups, such as the timing or proportion of eye contact.

Methodology

Ethics, Recruitment & Participants

This study received ethical approval from the Clinical Psychology Research Ethics Committee, School of Applied Psychology, University College Cork (copies of approval documents can be viewed in Appendix D). Potential participants for the ASD group were recruited through a local government-funded support service for individuals with high functioning ASD or through a University Disability and Support Service (UDSS). They were approached by either their key worker from the local support service or by email from the UDSS. A poster was also put up within the UDSS office (a copy of the poster can be found in Appendix E). Participants for the NT group were emailed through departmental email-lists by two of the authors (JC & CR). Through their email, poster or key worker, potential participants were provided with a link to an online information sheet and consent form, along with the first author's (AR) email address.

Initially, 10 individuals with ASD and 14 NT individuals expressed an interest in the study. In total, 10 adults with high-functioning ASD (3 female) and 10 NT adults (3 female) participated (for participant characteristics, see Table 2 below). Both groups were matched in terms of gender. All ASD participants had received a formal clinical diagnosis through multidisciplinary assessment in order to access the services that were used for recruitment (e.g. local support service, UDSS). Except for two ASD participants, all had attained, or were working towards, college-level education.

Table 2

Characteristics of both groups

	ASD participants	NT participants
Gender (male:female)	7:3	7:3
Age (years)		
Mean (SD)	32.7 (12.2)	29.5 (5.7)
Range	19 - 54	19 - 41
Verbal IQ		
Mean (SD)	95.9 (14.7)	104.7 (7.9)
Range	79 - 123	99 - 125
AQ-10		
Mean (SD)*	6.9 (2.1)	1.7 (2.0)
Range	4 - 10	0 - 6
EQ-Short		
Mean (SD)*	11.1 (6.7)	34.0 (8.0)
Range	0 - 20	19 - 44
TAQ		
Mean (SD)*	63.1 (8.2)	35.0 (8.8)
Range	50 - 75	27 - 55

Note. *Significant difference between groups ($p < .001$)

Apparatus, Materials, and Procedure

All of the recordings were conducted by the first author (AR) and located within the same room in the Department of Applied Psychology, University College Cork (for images of the experimental setup, please see Figure 2 below). Upon arrival, participants were given an opportunity to read the information sheet, ask the researcher questions regarding participation, and (if they had not already done so) complete an online consent form (examples of information sheets and consent forms for both groups can be viewed in Appendix F).

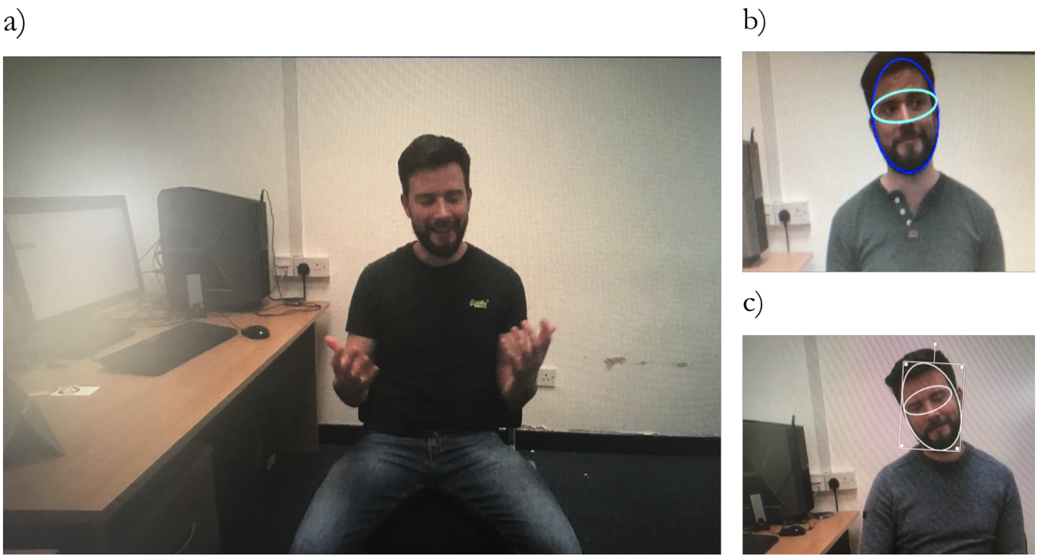
Participants sat 100 cm from the researcher during the face-to-face interaction, and approximately 20 cm from the computer screen during the completion of an emotion recognition task and a series of questionnaires. In order to measure gaze during the study, participants were asked to wear the eye-tracker Tobii Pro Glasses 2. Through corneal reflection the glasses sample eye movements at a rate of 100 Hz. An external scene-viewing camera provided a video recording of the participant's perspective at 25 fps. The glasses were worn during both the face-to-face interaction and the emotion recognition task.

The face-to-face interaction was semi-structured with each participant being asked the same questions regarding three topics: had they been, or were they planning to go on holiday; what was their preferred means of travelling; and what were their main hobbies or interests (a flow diagram of the conversation can been found in Appendix G).

Participants were then asked to complete an emotion recognition task and a series of questionnaires, which were completed on a Dell 1680 x 1050 screen, 60 Hz, and presented through the website Qualtrics (Qualtrics, 2014). The emotion recognition task required participants to identify the emotions of static faces, which were each shown for 500 ms. Participants were required, after each face was presented, to select from seven emotion-related responses: neutral, angry, sad, happy, surprise, disgust and fear. In total 42 faces were pseudo-randomly presented, showing six different people displaying the seven emotional expressions. The faces of three males and three females were used, taken from Ekman's 'Pictures of Facial Effects' (Ekman, 1976). Participants then completed three questionnaires to investigate group differences: Autism Spectrum Quotient-10 (AQ-10), Empathy Quotient-Short (EQ-Short), and the Toronto Alexithymia Questionnaire (TAQ). These took approximately 10 minutes to complete. The final part of study was the completion of the Peabody Picture Vocabulary Inventory (PPVI), which was used to assess Verbal IQ. The majority of participants completed the whole study within 60 minutes.

Figure 2

Photographs giving an overview of a) the experimental setup, b) how AOIs were drawn, and c) how AOIs were adjusted. All images were captured using the Tobii glasses 2, front-facing scene camera.



Data analysis

In line with previous studies, analysis of the eye-tracking data for the face-to-face interaction was focused on four 10-second segments for each participant. These four Times of Interest (TOI) coincided with a participant's response (talking phase) and the researcher's response (listening phase) for two of the three topics. The topics chosen were the holiday and hobbies topics as they represented time samples from the start and end of the face-to-face interaction. For each TOI, an Area of Interest (AOI) was drawn around the researcher's eyes (an example can be seen in Figure 2 above). Using a limited number of AOIs is not uncommon, only four of the previous fourteen studies that have used face-to-face interactions have included an expanded selection of AOIs (Falkmer et al., 2011; Freeth & Bugembe, 2019; Hanley et al., 2014, 2015).

Participant characteristics, such as verbal IQ, were analysed using independent samples t-tests. In one instance Mann-Whitney U-tests were also used. The eye-tracking data was analysed using 2 (Time Point: holiday vs. hobbies) x 2 (Phase: speaking vs. listening) repeated-measures ANOVAs. Across all methods, an alpha (α) of 0.05 was used. For post hoc testing, the Benjamini-Hochburg correction was used to manage the false discovery rate that can accompany multiple comparisons (Benjamini & Hochberg, 1995). A false discovery rate (α_{FDR}) of 0.05 was used; any significant post hoc comparisons have been presented with their raw, uncorrected p-values.

Results

Participant characteristics

A visual summary of the participant characteristics can be seen in Figure 3 below. In terms of Verbal IQ, with the exception of two individuals in the ASD group who fell within the Moderately Low range all other participants scored within the Average range. No significant difference was found between groups, $t(18) = -1.67$, $p = 0.11$, $d = -0.75$ (ASD group: M = 96, SD = 15; NT group: M = 105, SD = 8).

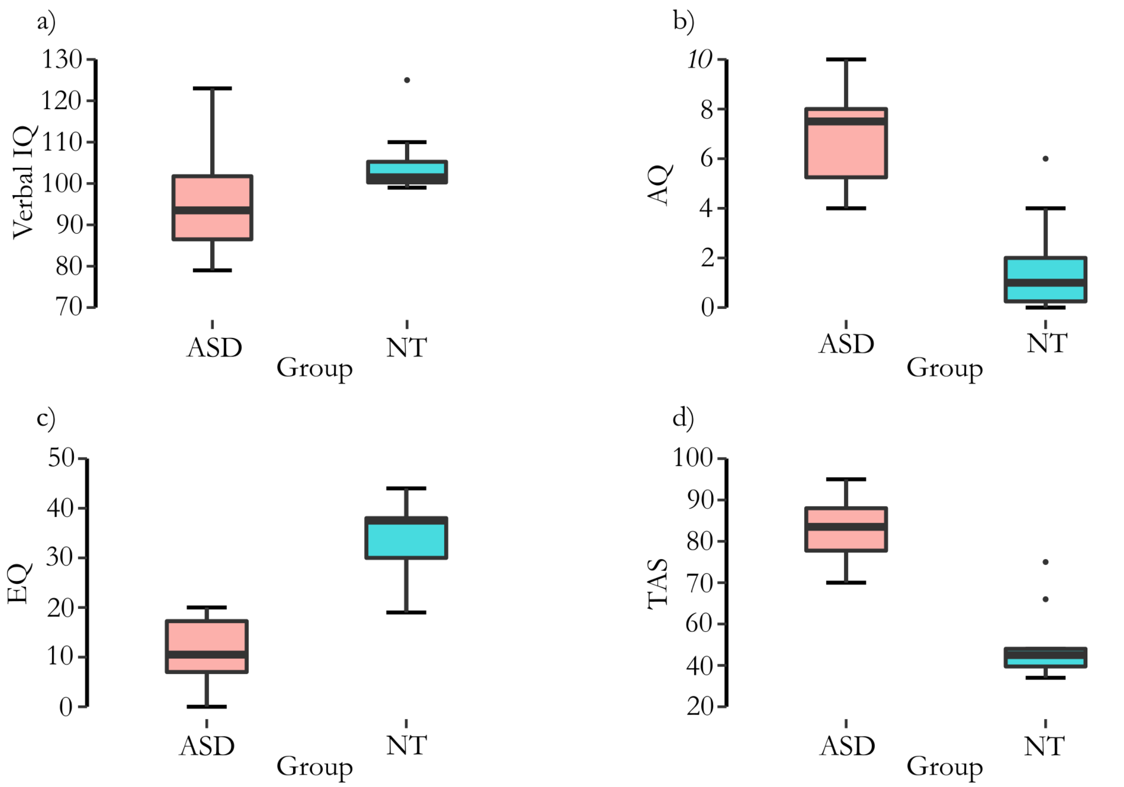
As would be expected, the ASD group achieved significantly higher scores on the AQ-10, $t(18) = 5.77$, $p < .001$, $d = 2.58$ (ASD group: M = 6.9, SD = 2.1; NT group: M = 1.7, SD = 1.9). This indicated that the ASD group as a whole fell in or near-to the clinical range for a diagnosis of ASD and the NT group did not. The ASD group were also found to have greater difficulties with empathy, scoring significantly lower on the EQ-

Short as compared to the NT group, $t(18) = -6.92$, $p < .001$, $d = -3.10$ (ASD group: M = 11.1, SD = 6.7; NT group: M = 34.0, SD = 8.0).

In terms of the TAS, the ASD group scored significantly higher scores than the NT group overall, $t(18) = -7.40$, $p < .001$, $d = 3.31$ (ASD group: M = 63.1, SD = 8.2; NT group: M = 35.0, SD = 8.8). Suggesting that the ASD group had greater difficulties with alexithymia, an inability to recognise their own emotions which in turn can impact their understanding of others emotions. A score over 61 provides a strong indication of alexithymia. Furthermore, significant differences were also found in terms of the three subgroups of the TAS, again with higher scores for the ASD group as compared to the NT group. Firstly, in terms of the subscale Difficulty Identifying Feelings, $t(18) = -1.67$, $p = 0.11$, $d = -0.75$ (ASD group: M = 25.9, SD = 5.3; NT group: M = 11.0, SD = 4.6). Secondly, in terms of Difficulty Describing Thinking, $t(18) = -1.67$, $p = 0.11$, $d = -0.75$ (ASD group: M = 17.8, SD = 3.7; NT group: M = 10.5, SD = 4.1). Thirdly, in terms of Externally Oriented Thinking, $t(18) = -1.67$, $p = 0.11$, $d = -0.75$ (ASD group: M = 19.4, SD = 3.9; NT group: M = 13.5, SD = 2.6).

Figure 3

Boxplots showing the overall participant characteristics for each group. The figures show the results for a) Verbal IQ, b) AQ, c) EQ, and d) TAS.



Emotion recognition task

The purpose of this task was to investigate the overall ability of both groups in correctly identifying the emotional expressions of static faces. As noted in the introduction, this is a task that ASD participants have frequently been shown to experience some level of difficulty (e.g. Pelphrey et al., 2002). Illustrative examples of where significant group differences were found can be seen in Figure 4 below. Differences were found for the total accuracy across emotional expressions; angry and happy emotional expressions; and the neutral expression.

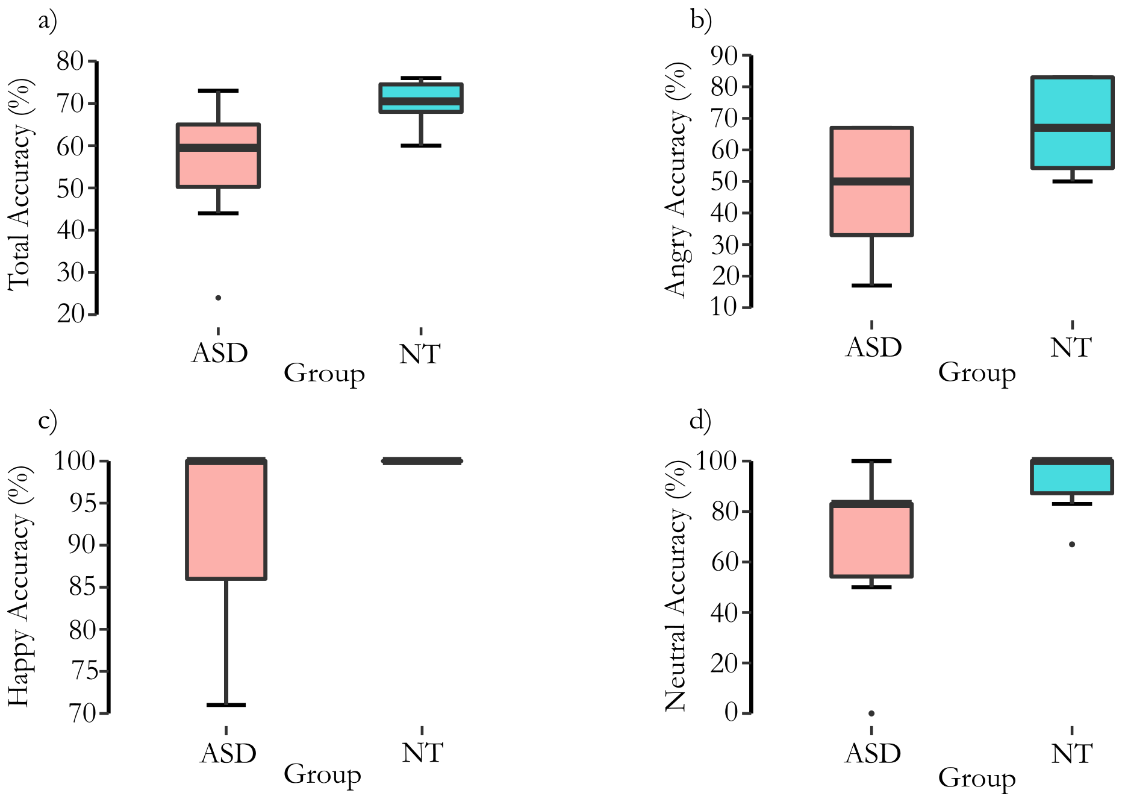
A significant difference was found between groups for the angry emotional expression, $t(18) = -2.68$, $p = .015$, $d = -1.19$, with NT more accurately identifying the face as angry

(ASD group: M = 48.4%, SD = 18.5%; NT group: M = 68.3%, SD = 14.4%). The total accuracy across emotional expressions, the happy emotional expression and the neutral expression were all found to violate Levene's assumption of equal variances (all $p < .045$). A Mann-Whitney test indicated that the NT group (M = 70.0%, SD = 5.4%) achieved a significantly higher total accuracy than the ASD group (M = 56.0%, SD = 14.2%), U = 13.50, $p = .006$, $d = -1.30$. The NT group (M = 100.0%, SD = 0.0%) also achieved significantly higher accuracy than the ASD group (M = 92.9%, SD = 10.1%) for the happy emotional expression, U = 30.00, $p = .034$, $d = -0.99$. Finally, the NT group (M = 93.3, SD = 11.6%) also achieved significantly higher accuracy for the neutral expression as compared to the ASD group (M = 69.9%, SD = 30.2%), U = 21.50, $p = .024$, $d = -1.024$.

No significant differences were found between groups for the sad, fearful, surprised or disgusted emotional expressions (all $p > .09$). Finding no group differences across a number of the emotional expressions is not uncommon in this research area (for a discussion see, Uljarevic & Hamilton, 2013). Furthermore, some level of group differences across expressions, particularly for the negative emotional expression of anger, is quite consistent with the broad research base (e.g. Humphreys et al., 2007). However, any interpretation should proceed with caution given the relatively small sample size and corresponding increased risk of type II error.

Figure 4

Boxplots of group performance in the emotion recognition task for a) total accuracy across all emotional expressions b) accuracy for angry emotional expression c) accuracy for happy emotional expression, and d) accuracy for neutral expression.



Face-to-face interaction

Data integrity. No significant difference was found between groups for the percentage of gaze data collected during the face-to-face interactions, $t(18) = -1.43$, $p = 0.17$, $d = -0.64$ (ASD group: M = 80%, SD = 16%; NT group: M = 88%, SD = 7%). The one NT and two ASD participants who were the most visibly and audibly anxious on the day of testing had the lowest percentage of gaze data across both the interaction and emotion recognition task. Nevertheless, variability in the amount of data collected is not uncommon (e.g. Freeth & Bugembe, 2019), a measure that has commonly been employed is to convert data into a proportion for analysis. Namely, by dividing the total duration of fixation for an AOI by the total amount of data collected within that 10-second period. This will be used in the following section.

Proportion of fixation duration on the eyes. The data revealed a significant main effect of Phase, F(1,18) = 14.44, p = .001, η_p^2 = .445, whereby participants had a higher proportion of fixation duration while listening as compared to speaking. As can be surmised from Figure 5 below, across both Groups and Time Point the mean proportion of fixation duration for the Listening Phase was 0.260 (SD = 0.198) and for the Speaking Phase was 0.115 (SD = 0.104). Evidence of increased proportion of fixation duration for the Listening Phase as compared to the Speaking Phase across both Groups is in line with previous research (e.g. Freeth & Bugembe, 2019).

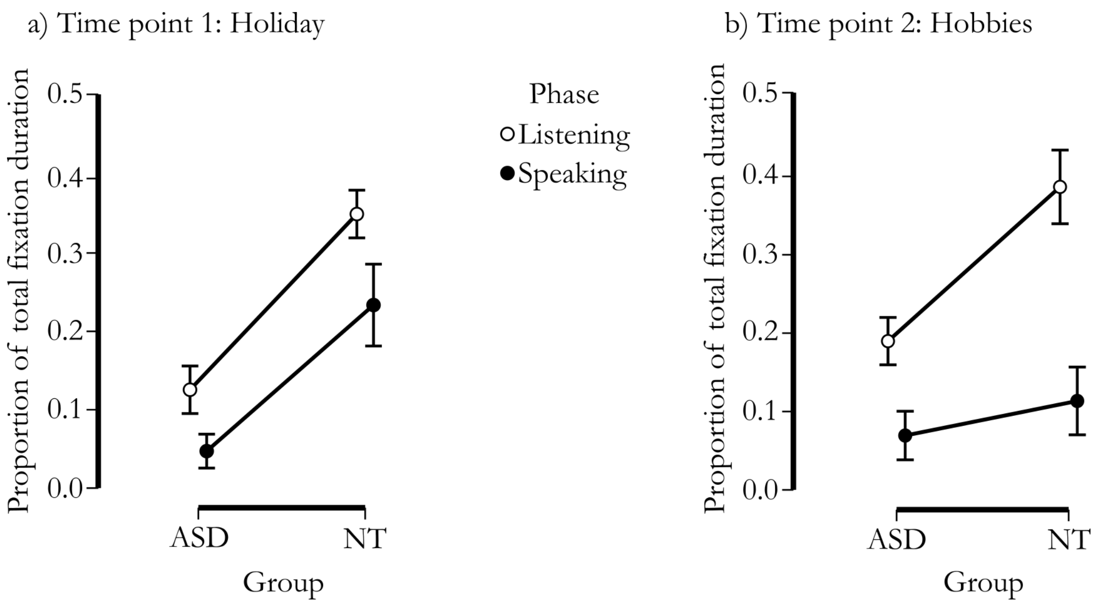
A significant between-subjects effect was found for Group, F(1,18) = 8.08, p = .011, η_p^2 = .310, indicating that the ASD Group achieved a significantly lower proportion of total fixation duration overall as compared to the NT Group.

A significant interaction was found between Group and Time Point, F(1,18) = 7.69, p = .013, η_p^2 = .299, see Figure 5. Post hoc comparisons revealed that compared to the NT group during the Holiday Time Point, the ASD group attained significantly lower proportions of fixation duration for both the Holiday Time Point (p = .002) and Hobbies Time Point (p = .012). Furthermore, the NT Group were also found to have a higher proportion of total fixation duration in the Hobbies Time Point as compared to the ASD group during the Holidays Time Point (p = .013).

A further significant interaction was also revealed between Time Point and Phase, F(1,18) = 7.43, p = .014, η_p^2 = .292. Post hoc comparisons revealed that across Groups the proportion of total fixation duration was significantly higher for the Listening Phase as compared to the Speaking Phase regardless of Time Point (Holidays: p = .031; Hobbies: p < .001). Furthermore, the Listening Phase within each Time Point was found to be significantly higher than the Speaking Phase in the opposite Time Point (both p = .002). For example, as might be deduced from Figure 5 below, the Listening Phase of the Holiday Time Point was significantly higher in terms of proportion of total fixation duration than the Speaking Phase of the Hobbies Time Point and vice versa.

Figure 5

The mean proportion of total fixation duration for a) Time Point 1: Holiday and b) Time Point 2: Hobbies. Error bars depict ±1 SEM (between subjects).

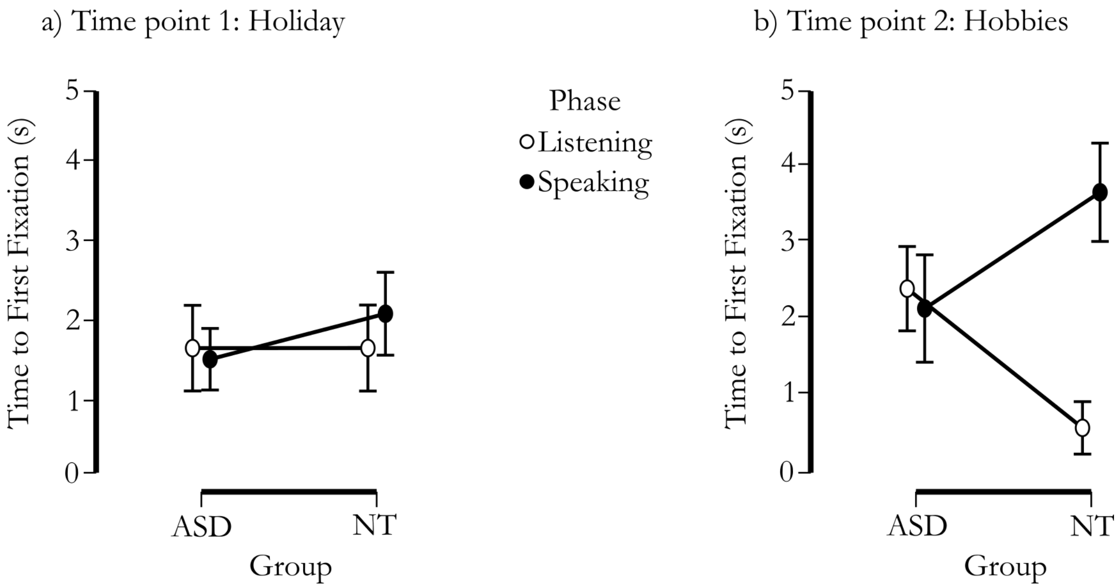


Time to first fixation on the eyes. The data for time to first fixation did not reveal any significant main effects or interactions (all p > .077). Furthermore, as can be gathered from Figure 6 below, no significant between-subjects effect was found for Group (p = .898).

Therefore, across Group, Time Point and Phase participants were quite consistent in their time to make a first fixation towards the eyes of an interaction partner. Perhaps unsurprisingly, as can be surmised from Figure 5 below, the only post-hoc comparison to reach significance was the difference in time to first fixation for the NT group during the Hobbies Time Point, between the Listening and Speaking Phases (*p* = .001).

Figure 6

The mean time to make first fixation on the eyes of an interaction partner for a) Time Point 1: Holiday and b) Time Point 2: Hobbies. Error bars depict ±1 SEM (between subjects).

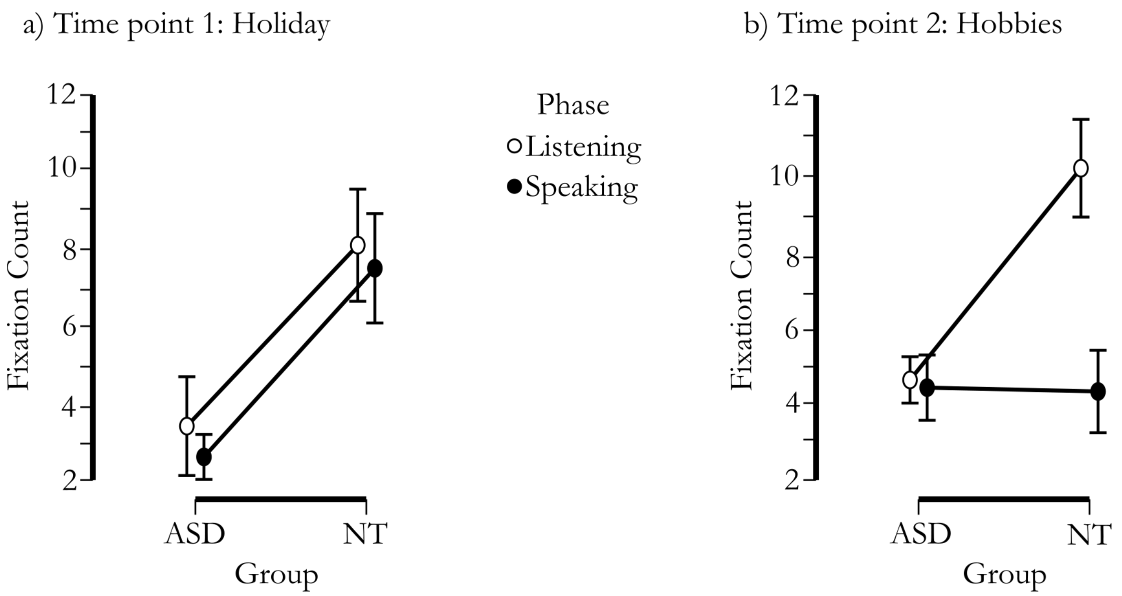


Fixation count to the eyes. The data for the total fixation count on the eyes revealed no significant main effects of Time Point or Phase (both p > .103). This would indicate that across Groups the mean number of fixations was quite consistent between Time Points and between Phases. Nevertheless, a significant between-subjects effect was found in terms of Group, $F(1,18) = 8.09$, $p = .011$, $\eta_p^2 = .310$. As can be seen from Figure 7 below, the ASD Group made a significantly lower total number of fixations overall as compared to the NT Group.

A marginal significant interaction was found between Time Point and Phase, F(1,18) = 4.47, p = .049, η_p^2 =.199. However, post hoc comparisons failed to reveal any significant differences (all p > .020). A significant three-way interaction was found across Group, Time Point and Phase, F(1,18) = 7.11, p = .016, η_p^2 = .283. As can be surmised from Figure 7 below, post hoc comparisons revealed a significant difference for the NT Group in the Hobbies Time Point between the Listening and Speaking Phases (p = .002). Furthermore, the total number of fixations for the NT Group during the Listening Phase in the Hobbies Time Point was found to be significantly higher than for the corresponding Listening and Speaking Phases of the ASD Group across both Time Points (all p < .007). Finally, the total number of fixations for the NT Group during the Speaking Phase in the Holiday Time Point was found to be significantly higher than their corresponding Speaking Phase in the Hobbies Time Point (p = .010) and the ASD Speaking Phase of the Holiday Time Point (p = .013).

Figure 7

The mean total number of fixations for a) Time Point 1: Holiday and b) Time Point 2: Hobbies. Error bars depict ±1 SEM (between subjects).



Discussion

The purpose of the current study was to investigate how two groups of adults, one with high-functioning ASD and another who are NT, use eye contact during a naturalistic face-to-face interaction. To this end, we utilised eye-tracking during a discussion of three topics (e.g. holidays, preferred mode of transport, and hobbies). Two time points were used in the analysis, representing two of the topics at the start (holidays) and end (hobbies) of the conversation. Our findings indicate that ASD participants adjusted their proportion of total fixation duration towards the eyes of an interaction partner in a similar manner to NT participants. Namely, both groups demonstrated a higher proportion of total fixation duration for the listening phase of a conversation as compared to the speaking phase. Adjustment of eye contact depending on the conversational phase is a seemingly robust finding within the NT population (e.g. Cook, 1977; Ehrlichman, 1981; Freeth et al., 2013; Ho et al., 2015). Furthermore, although not consistent across studies, observing an adjustment of fixations depending on conversational phase has also been reported in ASD participants (e.g. Doherty-Sneddon et al., 2013; Falck-Ytter et al., 2015; Freeth & Bugembe, 2019).

Nevertheless, the specifics of how eye contact was utilised was quite different for the ASD group. Namely, the overall duration of fixations was lower than NT participants; the overall number of fixations was lower than NT participants regardless of speaking or listening phase; and, the time to make their first fixation on the eyes was quite consistent regardless of topic, time point in the interaction, or conversational phase. Finding some level of difference between groups in how gaze is directed towards an interaction partner is consistent with the majority of studies that have employed face-to-face interactions with ASD and NT groups (e.g. Doherty-Sneddon et al., 2013; Freeth & Bugembe, 2019; Hanley et al., 2015; Mirenda et al., 1983).

Type of topics used

Interestingly, the interactions found within our data appeared to be driven by differences within the second time point or topic, hobbies, specifically for the NT group. Firstly, the proportion of total fixation duration, across both groups, for the listening phase of hobbies was significantly higher than any other phase in either time point. Secondly, the only significant post hoc comparison for time to first fixation came from the listening and speaking phases for the NT group during hobbies. The NT group had a relatively rapid mean time to first fixation for the listening phase, and a relatively slow mean time to first fixation for the speaking phase. Thirdly, the NT group achieved a significantly higher total number of fixations for the listening phase of hobbies as compared to the speaking phase.

At a surface level, our data would appear to indicate that ASD participants are relatively consistent in how they utilise eye contact regardless of time point in the conversation or topic. On the other hand, NT participants would appear to make more eye contact overall, and modulate how eye contact is used during the duration of a conversation or within different topics. However, any such interpretation of this data should be done with caution. As we did not alter the order of the topics across participants the data is vulnerable to the presence of an order effect. Furthermore, as data was not sampled across all three topics, it is also not possible to establish the emergence of a trend for either group.

Nevertheless, two previous studies that have employed similar face-to-face interactions have queried whether group differences in terms of eye contact might be found depending on the types of conversation used (Mirenda et al., 1983; Nadig et al., 2010). Certain topics or styles of conversation may elicit more of a monologue from participants while others may maintain more of a dialogue. In turn, each could influence how eye contact or indeed gaze aversion is utilised. One tentative hypothesis is that a topic like holidays represents a more common source of small talk with strangers, much like the weather, and as such is treated as more of a monologue for both groups. Hence a broadly similar pattern of eye contact between groups for this topic. However, given the restricted and repetitive interests within ASD, topics of interest (such as, hobbies) could be more rehearsed or treated simply as matter-of-fact information to be communicated. Thus, for ASD individuals it is also treated more like a monologue. Alternatively, for NT individuals a topic, such as hobbies, might be more varied in terms of choice or closely tied with social norms and expectations. A NT individual could be more inclined to pick a hobby that presents them in a certain way or invites certain questions. Thus, becomes more of a dialogue for this population and their interaction partners. In future, studies could begin to address this by asking participants to rate a list of topics on level of interest, using the least and most interesting topics as the basis of an interaction for each participant.

Lack of power

Previous studies have cited a lack of power as an underlying factor for the lack of reported differences between ASD and NT individuals during face-to-face interactions (Falkmer et al., 2011; Freeth & Bugembe, 2019). The median number of participants in each group within the previous four studies to use adult participants stands at eleven (Falkmer et al., 2011; Freeth & Bugembe, 2019; Hanley et al., 2015; Tantam et al., 1993).

Thus, the current study achieved a similar number of participants, but yet found group differences in how eye contact was used. However, given that the amount of eye contact towards an interaction partner has been shown to correlate with symptom severity, could suggest that some difference between groups in terms of eye contact is quite a robust finding and that subsamples of differing ability could exist within the ASD population (e.g. Hanley et al., 2015; Jones et al., 2017). In the present study, the distinct findings between both groups in both the assessment battery and face-to-face interaction resulted in not enough variance to use covariates, such as verbal IQ, AQ or TAS, to gain a deeper understanding of the data.

Qualitative feedback of how eye contact and non-verbal behaviour are experienced

Finally, to the best of our knowledge no study employing a face-to-face interaction or emotion recognition task has explicitly asked participants how they use eye contact and experience the eye contact of an interaction partner. An interesting aspect of this study, which became apparent during the debrief, was the verbal descriptions provided by ASD participants as to how they experience eye contact. Many of the participants commented on how eye contact required conscious effort and was felt as an "invasion of privacy" or "very intimate and personal". Eye contact was something that had been reinforced by family from an early age. Interestingly a couple of the participants felt quite confident in their eye contact and ability "to pass as neurotypical". Although beyond the scope for further investigation in this study, it was the experience of the lead author (AR) that some of this confidence was not always well placed.

Indeed previous studies have suggested that researchers, who pose as interaction partners, may be more sensitive to picking up subtle differences between groups that are not necessarily apparent via recordings: such as non-verbal gestures, atypical utterances, and their own use of gaze (e.g. Falck-Ytter, 2015; Tantam et al., 1993). It was proposed that varying pools of ability (e.g. Hanley et al., 2015; Jones et al., 2017) or contextual differences exist within the ASD population (e.g. group differences for a listening task but not within an arithmetic task, Falck-Ytter, 2015). There is real scope for this paradigm to be utilised in order to investigate discrepancies in ASD individuals' self-perceptions of eye contact and the different circumstances under which they struggle or strive during real-life interactions.

In conclusion, the results of this study provide a further insight into the use of gaze during naturalistic face-to-face interactions within ASD and NT populations. Consistent with previous studies we found a similar adjustment in the proportion of eye contact across groups depending on the conversational phase, but specific differences in how eye contact was utilised in terms of the number or timing of fixations towards the eyes of an interaction partner. We believe this study opens up a number of new avenues for future studies to explore social attention with the ASD population.

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Chapter 5 - Supplementary information for the Major Research Project

The focus of this supplementary chapter is to discuss information that could not be explored within a publication-style framework. Two sections will be covered which include: why certain data collected during the study that could not be included in the final write-up and a discussion of qualitative feedback that was received when discussing eye contact with the ASD participants.

Details on the eye-tracker

As mentioned in the previous chapter the Tobii Pro Glasses 2 were worn during the face-to-face interaction and the emotion recognition task. The glasses track eye movements through corneal reflection using an infrared sensor for each eye. These sensors have a sample rate of 100 Hz. An external scene-viewing camera provided a video recording of the participant's perspective at 25 fps. The glasses are controlled via a electronic tablet and the resulting data is processed via a dedicated software provided by Tobii.

Whilst wearing an eye-tracker could make a participant quite self-aware of their eye movements, there was no deception with regard to this being an aspect of the study. Thus, participants were likely already quite aware of this component prior to participating. The glasses are simple to calibrate, participants were instructed to fixate on a single black dot on a small card that the researcher holds up. In all this can take only a few seconds to complete. Participants are able to wear their own glasses underneath the eye-tracker (if required, although not ideal) and contact lenses work without issue. Due to the infrared sensors the glasses can have difficulty in the presence of UV light (e.g.

near windows), as such a room without windows was deliberately chosen to conduct the study.

The analysis software provided by Tobii allows the research to define Time Points of Interest (TPI) as well as Areas of Interest (AOI) within a participant's field of vision. Through playing back the videos for each participant a research can manually mark the TPI, in this case the start and end of each 10-second sample used for analysis (e.g. when a participant started speaking about their hobbies). Within the TPI, AOIs can be marked out and then used for analysis. For the major research project the focus was on the eyes but many other AOIs can also be marked out if desired. As both the participant and researcher were able to freely move, the AOI also constantly moved throughout the resulting video recording. While the software attempts to extrapolate (i.e. make its best guess) as to how the AOI moves within TPI, it is ultimately up to the research to go through the video frame-by-frame and adjust the AOI into the correct position manually. For a 10-second snapshot across four TPIs, like in the previous chapter, that represents 1000 individual frames for each participant. Understandably, this is very time consuming and is ultimately why snapshots are used within the literature. Nevertheless, as a result of the above, the software is able to calculate a number of different metrics much more efficiently than a researcher could manually. For the major research project the focus was placed on: the proportion of time spent fixating on the eyes, the overall number of fixations on the eyes, and the time to make the first fixation on the eyes.

Data not included in the final write-up

Something that we did not fully account for when setting up the study was the sheer volume of data that we would collect during testing. Making a decision about what to include was certainly an enviable dilemma but inevitably some data could not be fully processed for a single publication. This was further complicated by the on-going circumstances relating to Covid-19 and the shutdown of University College Cork. Ultimately, data was processed for two out of the three topics, holidays and hobbies, for all twenty participants. As noted in the previous chapter, whilst this provided an overview of the start and end of the interaction, it did not allow us to investigate whether there was a trend across the three topics. Regrettably at the time of writing, no further opportunity had presented to be able to process the middle topic of 'preferred means of travelling' or allow for an independent rater to assess the recordings and check the processing of AOIs. This is something I would hope to be able to include in the final publication, should restrictions and time allow during the summer of 2020.

Furthermore, to date, only one study has directly compared a computer-based emotion recognition task, like those discussed in the previous chapter, with a face-to-face interaction (Falkmer et al., 2011). Interestingly, the researchers noted that the use of gaze appeared generally consistent for ASD and NT adults across static stimuli and the face-to-face interaction. Furthermore, they did not find any significant difference in the proportion or use of gaze overall. In the present study we asked participants to complete a similar emotion recognition task, using static images of faces taken from Ekman's 'Pictures of Facial Effects' (Ekman, 1976). It was our intention to similarly compare the use of gaze across both tasks. Furthermore, we had hoped to compare the use of gaze between groups with the accuracy data for the different emotional expressions (we found clear group differences in terms of accuracy, please refer back to page 83). There was a good level of gaze sampling accuracy from the emotion recognition task, $t(18) = -1.46$, $p = 0.16$, $d = -0.65$ (mean ASD group: 89%±13%; mean NT group: 95%±5%). It is hoped that this data could be processed for an additional research article in the near future.

Qualitative feedback on the use of eye contact

None of the previous studies employing face-to-face interactions or emotion recognition tasks have reported explicitly asking participants how they use social attention or how they experience the social attention of an interaction partner. One study outwith the experimental paradigm had reviewed online self-reports of adolescents and adults around how they use or experience gaze during social interactions (Trevisan et al., 2017). While conducting our study we were not only interested in what was attended to overtly during the interaction (e.g. in terms of eye movements and verbal responses). We were also interested in what might be attended to covertly (e.g. whether a participant was distracted by thoughts). Following the completion of the face-to-face interaction, participants were asked a small number of questions about their use of social attention, which was termed as a 'check-in'. However, the richest data ultimately stemmed from the debrief, whereby ASD participants were very open and honest about their experiences of eye contact. Information from the check-in and debrief are summarised in Table 1 below.

Some overlap was found with the themes outlined by Trevisan et al. (2017). Participants frequently commented that family from an early age had encouraged eye contact, and that NT individuals expect eye contact during interactions or it could be perceived as rude or impolite. Eye contact was described as an "invasion of space" and "very intimate and personal", even with people that were known well. One participant (Participant 7) alluded to sensory overload in busy or stressful environments, such as a pub. These explanations could match well with the hyperarousal hypothesis (e.g. Kliemann et al., 2012; Tanaka & Sung, 2016). Indeed many of the participants stated that maintaining eye contact was most challenging: when meeting new people for the first time, in situations where they felt there were judgments being made of them (e.g. a meeting with a line manager), very busy public environments, or situations where people are met unexpectedly or out-of-context.

The examples of difficult situations appeared to coincide with scenarios whereby anxiety would be heightened and impact upon the strategies used to manage eye contact and the interaction itself. The majority of the participants spoke of an attempt to 'predict' the course of an interaction, with Participant 10 expressing frustration when an interaction partner's facial expression does not match the content of the speech (e.g. sarcasm, passive aggression). It is known from research with NT individuals that eye contact can serve as a means of managing cognitive load (e.g. Glenberg et al., 1998). For example, a doctoral student may look away from their Viva examiners whilst contemplating the answer to a challenging question but re-establish mutual gaze whilst giving an answer. It could be hypothesised that if ASD individuals are trying to actively predict the course of a conversation that the cognitive load could be higher than for NT individuals. Thus, even the already conscious effort to maintain eye contact could result in requiring even more effort in stressful or anxiety provoking situations. This could result in ASD individuals missing crucial verbal and non-verbal cues in important situations (e.g. a professional meeting with a manager or during an academic tutorial).

A couple of the participants commented specifically on their strategies, such as directing their gaze just above an interaction partner's eye or in-between the eyes. A further interesting outcome was the apparent mismatch between the confidence of some individuals in maintaining eye contact, and to quote Participant 9: "pass as a neurotypical". I experienced the eye contact of several participants as especially intense and direct, so much so that at times I found it difficult to maintain my own. Interestingly, one of the only studies to consider the performance of researchers found differences in their use of gaze between groups (Tantam et al., 1993). Something that would be interesting to explore further is how different methods of trying to maintain eye contact work for individuals and at what point during interactions do they (or their interaction partners) experience difficulties. To the best of my knowledge this is the first study to include some first hand, in-person accounts of individuals experiences of eye contact. This is quite surprising given the considerable research base. However, it would certainly be a highly relevant avenue for future research on its own or included with similar experimental designs.

Table 3

Participants' comments on social abilities and use of eye contact

ASD group (gender)	
Participant 1 (male)	Eye contact very difficult when anxious. Felt that he would often overthink answers socially, which often impacts on the flow of conversations.
Participant 2 (female)	Eye contact and the flow of conversations very challenging with strangers. Often struggles to remember to ask reciprocal questions.
Participant 3 (male)	Eye contact, reciprocal questions and attempting to predict an interaction partner's responses become very challenging if he felt he was being judged. For example, meeting new people or conversations with his line manager. He would often try to avoid these situations. AR experienced his eye contact and social skills as similar to that of a NT participant.
Participant 4 (male)	Conscious effort to make eye contact, as he "know(s) neurotypical people find it rude if I look away". He described experiencing eye contact as an "invasion of space". AR perceived the participant as quite self-confident, but intense and with monologue-like speech.
Participant 5 (male)	Eye contact takes conscious effort for him but he does so as he has been told it is 'polite'. Eye contact would be most difficult in situations where he feels judged. For example, with his line manager. Limited social engagement outside of his family.
Participant 6 (male)	Received a late diagnosis in his mid-40's. However, from a young age he was encouraged by family to make eye contact with others, which he tries to maintain throughout a conversation. AR experienced the eye contact as intense. Eye contact would be most difficult for this individual with more than one person or out of context. For example, if someone looked over in his local café he might ask himself lots of questions and become anxious: "why is this person looking over? Do I know them? Do they want to speak to me? Is it what I am wearing?" Limited social engagement outside family.
Participant 7 (male)	Eye contact takes conscious effort, and beyond one-on-one becomes impossible as his focus turns to trying to 'predict' the path of the conversation. He described crowded places, such as pubs, as being particularly uncomfortable and overwhelming. In these locations his "mask slips" and he can no longer make eye contact. As a result he primarily avoids social situations that are not focused on a set task (e.g. he attends workshops).
Participant 8 (male)	Eye contact takes conscious effort and is particularly challenging with new people. He was the most visibly anxious of the participants. He acknowledged having the interaction at the start of the study as particularly challenging for him. His main social contact stemmed from online gaming.
Participant 9 (female)	Eye contact requires conscious effort, focusing on a point just above the eyes, but was confident in her ability to "pass as a NT". AR experienced her eye contact as uncomfortable and struggled to maintain his own. This resulted in the participant asking AR if he had his own difficulties with eye contact. Participant maintained face-to-face social contact with a small group of friends.
Participant 10 (female)	Described the eyes of others as under-stimulating for her, eye contact required conscious effort. Eye contact felt "very intimate and personal". Felt social difficulties are more apparent when younger, as she has become older she can 'fit in' more easily due to lower anxiety or more confidence in certain situations. Attempts to use patterns to predict people's social behaviour, dislikes when someone's facial expression does not match their content of speech.

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Chapter 6 - General discussion

The focus of this thesis has concerned gaze and its use by individuals with Autism Spectrum Disorder (ASD) during face-to-face social interactions. Two research projects were presented (Chapters 2 and 4). The first focused on a systematic review carried out on the current research-base that has used eye-tracking during face-to-face interactions in children, adolescents, and adults with ASD. The second project focused on a study using eye-tracking during a face-to-face interaction with two groups of adults, one with ASD and one neurotypical (NT, a term commonly used within the literature for individuals without a diagnosis of ASD). In this chapter, I would like to provide a brief summary of the main findings stemming from the two projects, before proposing a number of clinical implications and suggestions for future developments.

As noted throughout, over the last number of decades a considerable research base has explored the ability of individuals with ASD to attend to social and emotional stimuli (e.g. Corden et al., 2008; Klin et al., 2002; Nakano et al., 2010; Riby & Hancock, 2009). While not consistent across studies (see, Uljarevic & Hamilton, 2013), one of the key findings was a difficulty in accurately identifying the six basic emotional expressions as compared to NT individuals (e.g. Corden et al., 2008; Gross, 2008; Pelphrey et al., 2002; Spezio et al., 2007). This has widely been attributed to an atypical use of gaze within the ASD population. Namely, a reduced level of fixation towards the eyes as compared to NT individuals, and an increased level of fixation towards the mouth or other areas of a visual scene. With atypical gaze in infancy being linked to functioning in later life, poor eye contact has been considered a potential mechanism underlying wider social and emotional difficulties in ASD (W. Jones et al., 2008; Papagiannopoulou et al., 2014). This appears to match well with self-reports by adolescents and adults with ASD, who stipulated that they experience frequent difficulty in relation to the appropriate timing and use of gaze during everyday face-to-face social interactions (Trevisan et al., 2017).

Much of the research investigating social or emotional recognition difficulties has stemmed largely from two-dimensional stimuli. Studies of both ASD and NT individuals that have tried to make inferences from two-dimensional stimuli, such as static images or videos of social scenes, have faced criticism (e.g. Chisholm et al., 2014; Kingstone et al., 2005). Conclusions made using highly standardised stimuli or scenarios do not always translate to real world behaviours (Risko et al., 2016). A range of factors may be present in real world scenarios that simply are not elicited by two-dimensional static or pre-recorded stimuli (for example, feelings of self-consciousness, social anxiety, or differences in speed of response).

Thus, it has been argued that studies using more natural settings and scenarios are vital to gaining a proper understanding of the mechanisms behind social attention (Kingstone et al., 2008; Macdonald & Tatler, 2018). As a result, a slowly emerging research-base investigating the use of gaze by ASD participants during face-to-face interactions has emerged. To date there have been fourteen such studies, ten investigating children and adolescents (Birmingham et al., 2017; Doherty-Sneddon et al., 2013; Doherty-Sneddon et al., 2012; Falck-Ytter et al., 2015; Falck-Ytter, 2015; Hanley et al., 2014; R. M. Jones et al., 2017; Mirenda et al., 1983; Nadig et al., 2010; Riby et al., 2012) and four investigating adults (Falkmer et al., 2011; Freeth & Bugembe, 2019; Hanley et al., 2015; Tantam et al., 1993). The purpose of the systematic review was to provide a synthesis of these studies in the context of the broader research area.

The results of the review, at least at the surface level, appeared quite homogenous. The majority of studies reported that children, adolescents and adults with ASD obtained a similar overall percentage of gaze duration towards (or averted from) the face of an interaction partner as individuals within comparison groups (Birmingham et al., 2017; Doherty-Sneddon et al., 2013; Doherty-Sneddon et al., 2012; Falck-Ytter et al., 2015; Falck-Ytter, 2015; Falkmer et al., 2011; Freeth & Bugembe, 2019; Hanley et al., 2015; R. M. Jones et al., 2017; Mirenda et al., 1983; Nadig et al., 2010). Indeed a number of the studies found that individuals with ASD modulated their gaze behaviour similarly to NT individuals, at least to some degree, during the different conversational phases of an interaction (Doherty-Sneddon et al., 2013; Doherty-Sneddon et al., 2012; Falck-Ytter et al., 2015; Freeth & Bugembe, 2019; Riby et al., 2012). Taken together, this would suggest that there is not a global deficit in social attention and the appropriate use of gaze per se.

However, crucially, the majority of studies did report some level of difference between groups in how gaze was utilised during the interactions. For instance NT individuals consistently increased their gaze towards an interaction partner whilst listening as compared to speaking, for individuals with ASD this consistency was not present across studies (Doherty-Sneddon et al., 2012; Freeth & Bugembe, 2019; Riby et al., 2012). Indeed, the two studies that employed a task requiring participants to listen to an interaction partner without responding found that ASD participants made more fixations towards non-partner areas than NT participants (Falck-Ytter, 2015; Hanley et al., 2015).

There were two crucial components to explanations as to why differences in gaze may occur but not always stand out within face-to-face interactions for ASD participants. Firstly, differences could stem from the types of interaction utilised. Namely, certain interactions may promote more of a monologue response (i.e. participants speaking about an interesting topic of their choosing) as compared to others that may promote more of a dialogue between interaction partners (i.e. a more generic back and fourth conversation). One suggestion made by the researchers was that monologues are perhaps more motivational as they are of interest and, therefore, eye contact comes more easily (Mirenda et al., 1983; Nadig et al., 2010). Secondly, differences could underlie pools of ability or subgroups within the ASD population. A number of the studies found relationships between the performance of ASD participants and aspects of group characteristics, such as age or level of ASD (e.g. Hanley et al., 2015; R. M. Jones et al., 2017). Both of the points highlighted in this paragraph became pertinent for the major research project.

The motivation behind the major research project was to expand on the four previous adult studies that were uncovered during the systematic review, and employ a more naturalistic topic-based interaction between participants and myself. To this end, the performance of adults with ASD and NT adults was compared in a face-to-face interaction using eye tracking. Three topics were discussed: holidays, preferred mode of transport and hobbies. Due to time constraints the start of the holidays and hobbies topics were used as time points for analysis.

In contrast to a number of previous studies, I found significantly different levels in the overall percentage of fixations on the eyes of an interaction partner. Furthermore, although not a consistent finding across the research area, I observed a similar adjustment of fixations depending on conversational phase between groups (e.g. Doherty-Sneddon et al., 2013; Falck-Ytter et al., 2015; Freeth & Bugembe, 2019).

Namely, both ASD and NT groups achieved a greater proportion of fixations towards the eyes when listening to an interaction partner as to when they spoke themselves.

However, what was consistent between the major research project and the studies found within the systematic review was the presence of group differences in how eye contact was utilised (e.g. Doherty-Sneddon et al., 2013; Freeth & Bugembe, 2019; Hanley et al., 2015; Mirenda et al., 1983). For ASD participants, the overall duration of fixations was lower than NT participants; the overall number of fixations was lower than NT participants regardless of speaking or listening phase; and, the time to make their first fixation on the eyes was less variable to topic, time point in the interaction, or conversational phase.

At a surface level the interactions found within the data appeared to be driven by the performance of the NT group, who differed in performance between the two topics. The ASD group on-the-other-hand appeared quite consistent in their performance regardless of the topic. Tentatively, in Chapter 4's discussion, I came back to the idea of differences depending on the type of topic or interaction used. Given the restricted and repetitive interests within ASD, topics of interest (such as hobbies) could be more rehearsed or treated simply as matter-of-fact information to be communicated. Thus, for ASD individuals it is treated more like a monologue than a dialogue. Nevertheless, I will return to this point of discussion, and what it might mean for future studies, in the next section.

A lack of power has previously been cited across the research area as a potential underlying factor in the lack of group differences. This certainly remained a possibility within the major research project. However, despite the study having roughly the same number of participants as the median for the research area, I was able to observe clear group differences in terms of the eye contact data and in terms of the assessment battery. Furthermore, although a link between atypical gaze in infancy and functioning in later life has been interpreted as a good indicator that group differences may be a robust finding; as noted earlier, others studies have also observed correlations within ASD groups for covariates like age, level of ASD or social functioning (e.g. Hanley et al., 2015; R. M. Jones et al., 2017). In a study focused on rich, detailed, naturalistic data stemming from eye-tracking in a real-world interaction, the sample size is inevitably going to be smaller as compared to those using highly standardised stimuli or scenarios. While this does not detract from the value of the methodology or the contribution to the wider research area, a larger sample gathered through additional studies or combined datasets could potentially strengthen the current findings.

Future developments and clinical implications

With the above in mind, I would like to use this final section to propose the scope for future studies stemming from the two projects within this thesis. Broadly, all suggestions can be tied to one specific theme. Namely, that difficulty with the social use of gaze in ASD could be situation specific or there could be subgroups of ability. In my opinion, there is an opportunity for this experimental paradigm to be adapted in order to help identify specific points of difficulty during an interaction, providing individualised feedback, or at least used to outline patterns within subgroups or specific situations. Historically, clinical interventions for difficulties with eye contact have utilised some form of conditional reinforcement to broadly promote social attention (e.g. Carbone et al., 2013; Foxx, 1977; Krstovska-Guerrero, 2015; Krstovska-Guerrero & Jones, 2013; Rao et al., 2008). If different subgroups, specific situations, or differing time points of difficulty exist, this would question the validity of such interventions. Thus, I strongly believe in the potential clinical relevance of this paradigm.

Firstly, as outlined in Chapter 5, there is real scope for studies in this research area to explicitly ask participants with ASD how they use and experience eye contact. This can appear like common sense at write-up but it is not something that has been widely considered as yet. As the full importance of it became apparent after I had started testing, I was not able to formally record responses during the debrief. However, this is something that could be easily remedied and included, especially for studies using a form of recording equipment (e.g. eye-tracker).

Secondly, another potential theme that began to emerge during the debrief was the impact of different scenarios or interaction partners on the ability to maintain eye contact. For example, increased stress or anxiety during a conversation with a line manager or entering a busy social environment. With this in mind, there are two interesting additions: a measure of anxiety, such as the State Trait Anxiety Inventory, could be used. Anecdotally, the participants that had the lowest accuracy for the eye-tracking data appeared to be the most audibly and visibly anxious. This could suggest that as anxiety increased the use of gaze also became increasingly difficult to maintain (reflecting increased cognitive load or hyperarousal?). A second addition might involve comparing performance across groups between familiar and unfamiliar interaction partners. A feasible adaption could be to allow a period of time for some participants to become familiar with an interaction partner prior to the main interaction and others not (counterbalancing between and within groups).

Thirdly, a particular drawback to using an eye-tracker, as the sole source of recording, is that it cannot pick up on other non-gaze related behaviours of the participants, such as body language or facial expressions. In this instance it would be helpful to have an external camera in addition to the eye-tracking. It is possible that participants could acknowledge an interaction partner through other means if not eye contact, possibly accounting for a previous lack of group differences. At present two of the previous studies have indicated differences between groups in terms of other non-gaze related behaviour, such as increased atypical utterances or exaggerated body language by ASD participants (Birmingham et al., 2017; Nadig et al., 2010). Interestingly, a further two studies have also suggested that an interaction partner's non-gaze related behaviour could be different between NT and ASD groups as well (Falck-Ytter, 2015; Tantam et al., 1993). Specifically, reduced verbal duration and a reduction in eye contact. As I reported in the section above, I found it especially difficult to maintain eye contact with certain participants. Therefore, it would be of interest to give equal consideration to the verbal and non-verbal behaviours of interaction partners between groups.

Fourthly, in contrast to unintended differences in behaviour, a deliberate alteration of my own verbal responses and gestures in relation to certain topics was something I had considered whilst designing the study. During clinical assessments, such as the Autism Diagnostics Observation Schedule (ADOS), one aspect considered is an individual's response to 'social presses'. These are points in a conversation where one person reacts in a certain manner expecting a reciprocal response from a social partner. For example, if an adult puts forward a suggestion during a joint task they might, rightfully, expect another adult to consider it rather than have it ignored or disregard (as might be expected classically in ASD). While designing this study it proved challenging to incorporate without confounding or altering the flow of the conversation. However, I believe it could be achievable and certainly an avenue for a future study to consider.

A fifth consideration is the topic of conversation used. A number of previous studies have proposed that ASD participants might be more able or motivated depending on the topic of conversation. Crucially, previous findings have indicated that ASD participants make more eye contact and are more engaged for topics of interest (Mirenda et al., 1983; Nadig et al., 2010). It was argued that this might coincide with more monologue-like speech content, rather than dialogue. Whilst the content or duration of speech was not the focus in the previous chapter, one hypothesis for the potential group differences were the topics we employed. While designing the experiment we presumed that the three topics (e.g. travel, preferred method of transport, and hobbies) would be of general interest and quite motivating for both groups. However, while the ASD group appeared quite consistent in their use of eye contact across the travel and hobbies topics; the NT group were slower and made a lower proportion of eye contact when speaking but appeared more attentive when listening (as compared to their performance in hobbies).
We hypothesised that discussing travel is potentially a more common topic of informal conversation between strangers, much like the weather, this could be quite a rehearsed topic for both groups. Given that restricted interests and activities is a hallmark of ASD, hobbies could also represent quite a rehearsed conversation within this group, hence the similar performance across both topics. On the other hand, for NT participants hobbies could be more varied, deemed more personal, or tied to social expectations in terms of how they would like to be perceived. Another consideration for future studies could be to expressly ask participants their experience of discussing certain topics (e.g. were the topics engaging? Was it difficult to think of examples?). Alternatively, all participants could be asked to rate a pre-selected list of potential topics from least interesting to most interesting, with the lowest and highest used as the basis for the interaction. This could be used to investigate low social motivation hypothesis.

As a sixth and final consideration, in the previous chapter I stated the possibility of differences between time points during an interaction. Due to the potential presence of an order effect and an inability to investigate a trend across all three topics it remains unclear. However, an aspect not considered by previous studies is the potential for ASD participants to fatigue if they are to consciously maintain eye contact over a period of time. The majority of previous studies have focused on relatively short interactions. It would be interesting to monitor for changes in the use of eye contact across a fifteen-minute interaction as compared to five minutes.

In summary, the two studies and supplementary information contained within this thesis have provided a synthesis of the current literature and have expanded upon previous methodology. By employing a topic-based interaction that more closely resembled a conversation that individuals with ASD could experience in their day-to-day lives, I believe I have provided a meaningful contribution to the wider research area and a solid grounding for future studies to build upon.

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Appendix A - Publishing guidelines for the journal Research in Autism Spectrum Disorders

Types of Articles

Research in Autism Spectrum Disorders publishes the following types of manuscripts:

Brief reports: Papers of no more than 2,500 words that report an original piece of research of limited scope and/or that serves as proof-of principle for larger-scale studies.
Regular Articles: Papers of up to 6,000 words that report a substantive piece of research that makes a significant contribution and has clear implications for practice. Manuscripts reporting the results of randomized trials or interventions must demonstrate adherence to the CONSORT guidelines (http://www.consort-statement.org/) and include the relevant flow diagram and completed checklist.
Reviews: Papers of up to 10,000 words that provide a comprehensive overview of a significant area of research. Quantitative (e.g., meta-analyses) and qualitative reviews are welcome as long as they go beyond a mere description of the available literature and synthesise new knowledge with clear implications for future directions and practice. For systematic reviews and meta-analyses, authors must demonstrate adherence to the PRISMA guidelines (www.prisma-statement.org) and include the relevant flow diagram and checklist.
Commentaries: We welcome brief commentaries of no more than 1,000 words that offer new insights on papers published in RASD or elsewhere. Commentaries on government policy and/or items in the media are also welcome.

NOTE: Word limits do not include the title page, abstract, figure legends, tables and reference list.

Manuscript Format

All manuscripts must include a Title, Abstract and Highlights on separate pages, followed by the main manuscript text. The main manuscript text of brief reports, regular articles and quantitative reviews should include subsections carrying the headings Introduction, Methods, Results, Discussion & Implications. Reviews may deviate from this structure but must include a methods section that provides details on how the relevant literature was searched. The structure of commentaries is at the discretion of authors.

Essential Title Page Information

Title: Titles must be concise and informative and should have no more than 20 words. Titles are often used in information–retrieval systems. Avoid abbreviations and formulae where possible.

Author names and affiliations: Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. Present the author's affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lowercase superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e–mail address of each author.

Corresponding author: Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. Ensure that the e–mail address is given and that contact details are kept up to date by the corresponding author.

Present/permanent address: If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main affiliation address. Superscript Arabic numerals are used for such footnotes.

Abstract & Keywords

The abstract page must include a structured abstract of no more than 250 words that includes the following subsections:
Background: A brief summary of the research question and rationale for the study.
Method: A concise description of the methods employed to test the stated hypotheses, including details of the participants where relevant.
Results: A brief description of the main findings.
Conclusions: This section must include a clear statement about the implications of the findings for practice.

Immediately after the abstract, a maximum of 6 keywords should be provided, avoiding general and plural terms and multiple concepts (for example, avoid 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible (e.g., ADOS, ASD, etc). These keywords will be used for indexing purposes.

Introduction

The introduction should develop a clear rationale for the presented work on the basis of a concise overview of the relevant literature. Detailed literature reviews should be avoided.

Methods

This section will typically include sub–headings for a description of the Participants, Materials & Design, Procedures and Analysis. However, alternative sub–headings may be used to suit particular research approaches (e.g., case–studies, meta–analyses, imaging studies etc.)

The participants section should provide demographic information (age, sex, ethnicity, socio–economic status, etc.), and include details on where and how participants were recruited and how relevant clinical diagnoses were verified. Additional clinical information (e.g., intellectual functioning, co–morbidities, use of medication etc.) is desired and may be necessary for some research designs. Sample sizes should be justified by suitable power calculations although it is appreciated that it is not always feasible to obtain desired numbers of participants.

The materials, design and procedures must be described in sufficient detail for the work to be replicable. Authors must also include a statement confirming that the work was carried out in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Declaration of Helsinki as revised in 2000. In this context confirmation should also be given that participant or guardian informed consent was obtained where appropriate.

The analysis section should provide details of the statistical methods used including information on the significance thresholds and the methods used to correct for multiple comparisons where necessary. Information on inter–rater reliability and any data filtering / transformation that was applied should also be included here.

Results

The results should be set out transparently and in full and should conform to the formatting style of the American Psychological Association (http://www.apastyle.org/). Effect sizes must be reported for all significant and non–significant effects, and sufficient descriptive statistics must be provided for the effect size calculations to be replicated.

Tables

Please submit tables as editable text and not as images. Tables can be placed either next to the relevant text in the article, or on separate page(s) at the end. The formatting of tables should conform to APA guidelines (http://www.apastyle.org/).

Figures & Artwork

General points

• Make sure you use uniform lettering and sizing of your original artwork.
• Embed the used fonts if the application provides that option.
• Aim to use the following fonts in your illustrations: Arial, Courier, Times New Roman, Symbol, or use similar fonts.
• Number the illustrations according to their sequence in the text.
• Use a logical naming convention for your artwork files.
• Provide captions to illustrations separately.
• Size the illustrations close to the desired dimensions of the published version.
• Submit each illustration as a separate file.

For Vector drawings, the recommended file format is EPS or PDF (embed all used fonts).

For all other artwork, please use TIFF or JPEG file formats with the following resolutions:
• Colour or grayscale photographs (halftones): 300 dpi

• Pure black & white line drawings: 1000 dpi
• Combination halftone and black & white: 500dpi

Please do not:

•Supply files that are optimized for screen use (e.g., GIF, BMP, PICT, WPG)
•Supply files that are too low in resolution.
•Submit graphics that are disproportionately large for the content.

If, together with your accepted article, you submit usable colour figures, Elsevier will ensure, at no additional charge, that these figures will appear in colour online (e.g., ScienceDirect and other sites) regardless of whether or not these illustrations are reproduced in colour in the printed version. **For colour reproduction in print, you will receive information regarding the costs from Elsevier after receipt of your accepted article**. Please indicate your preference for colour: in print or online only. For further information please see https://www.elsevier.com/artworkinstructions.

Discussion and Implications

The discussion section should draw together the findings and must end with a clear indication of the implications of the findings for practice under a separate subheading (Implications).

Acknowledgements

Collate acknowledgements in a separate section at the end of the main manuscript text and before the references. List here any sources of funding (including grant numbers where relevant) and briefly describe the role of the sponsor(s), if any, in study design; the collection, analysis or interpretation of data; the writing of the report; and the decision to submit the article for publication. If the funding source(s) had no such involvement then this should be stated.

Conflict of interest

At the end of the main manuscript text and before the references,authors must disclose any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work. If no such conflict of interest exists, this must be clearly stated. For further information and examples of conflict of interest statements please visit the following: https://www.elsevier.com/conflictsofinterest http://service.elsevier.com/app/answers/detail/a_id/286/supporthub/publishing A decision may be made by the Journal not to publish on the basis of the declared conflict.

References

In–text citations should conform to the formatting style of the American Psychological Association (http://www.apastyle.org/). Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full

Reference

Appendix B - Example Crowe Critical Appraisal Tool (CCAT) Form (v1.4)

This form must be used in conjunction with the CCAT User Guide (v1.4); otherwise validity and reliability may be severely compromised.

Citation

Research design (add if not listed)

❑ Not research		Article | Editorial | Report | Opinion | Guideline | Pamphlet | …
❑ Historical		…
❑ Qualitative		Narrative | Phenomenology | Ethnography | Grounded theory | Narrative case study | …
☑ Descriptive, Exploratory, Observational		A. Cross-sectional | Longitudinal | Retrospective | Prospective | Correlational | Predictive | …
		B. Cohort | Case-control | Survey | Developmental | Normative | Case study | …
Experimental	❑ True experiment	Pre-test/post-test control group | Solomon four-group | Post-test only control group | Randomised two-factor | Placebo controlled trial | …
	❑ Quasi-experiment	Post-test only | Non-equivalent control group | Counter balanced *(cross-over)* | Multiple time series | Separate sample pre-test post-test [no Control] [Control] | …
	❑ Single system	One-shot experimental *(case study)* | Simple time series | One group pre-test/post-test | Interactive | Multiple baseline | Within subjects *(Equivalent time, repeated measures, multiple treatment)* | …
❑ Mixed Methods		Action research | Sequential | Concurrent | Transformative | …
❑ Synthesis		Systematic review | Critical review | Thematic synthesis | Meta-ethnography | Narrative synthesis | …
❑ Other		…

Variables and analysis

Intervention(s), Treatment(s), Exposure(s)	Outcome(s), Output(s), Predictor(s), Measure(s)	Data analysis method(s)

Sampling

Total size		Group 1		Group 2		Group 3		Group 4		Control	
Population, sample, setting											

Data collection (add if not listed)

Audit/Review a) Primary | Secondary | … b) Authoritative | Partisan | Antagonist | … c) Literature | Systematic | …	Interview a) Formal | Informal | … b) Structured | Semi-structured | Unstructured | … c) One-on-one | Group | Multiple | Self-administered | …
Observation a) Participant | Non-participant | … b) Structured | Semi-structured | Unstructured | … c) Covert | Candid | …	Testing a) Standardised | Norm-ref | Criterion-ref | Ipsative | … b) Objective | Subjective | … c) One-on-one | Group | Self-administered | …

Scores

Preliminaries		Design		Data Collection		Results		Total [/40]	
Introduction		Sampling		Ethical Matters		Discussion		Total [%]	

General notes

Categor y Item	Item descriptors [❒ Present; ✗ Absent; ■ Not applicable]	Description [Important information for each item]	Score [0–5]
1. Preliminaries			
Title	1. Includes study aims ❑and design ❑		
Abstract (assess last)	1. Key information ❑ 2. Balanced ❑and informative ❑		
Text (assess last)	1. Sufficient detail others could reproduce ❑ 2. Clear/concise writing ❑,table(s) ❑,diagram(s) ❑,figure(s) ❑		
		Preliminaries [/5]	
2. Introduction			
Background	1. Summary of current knowledge ❑ 2. Specific problem(s) addressed ❑and reason(s) for addressing ❑		
Objective	1. Primary objective(s), hypothesis(es), or aim(s) ❑ 2. Secondary question(s) ❑		
	Is it worth continuing?	**Introduction [/5]**	
3. Design			
Research design	1. Research design(s) chosen ❑and why ❑ 2. Suitability of research design(s) ❑		
Intervention, Treatment, Exposure	1. Intervention(s)/treatment(s)/exposure(s) chosen ❑and why ❑ 2. Precise details of the intervention(s)/treatment(s)/exposure(s) ❑for each group ❑ 3. Intervention(s)/treatment(s)/exposure(s) valid ❑and reliable ❑		
Outcome, Output, Predictor, Measure	1. Outcome(s)/output(s)/predictor(s)/measure(s) chosen ❑and why ❑ 2. Clearly define outcome(s)/output(s)/predictor(s)/measure(s) ❑ 3. Outcome(s)/output(s)/predictor(s)/measure(s) valid ❑and reliable ❑		
Bias, etc	1. Potential bias ❑,confounding variables ❑,effect modifiers ❑,interactions ❑ 2. Sequence generation ❑,group allocation ❑,group balance ❑,and by whom ❑ 3. Equivalent treatment of participants/cases/groups ❑		
	Is it worth continuing?	**Design [/5]**	
4. Sampling			
Sampling method	1. Sampling method(s) chosen ❑and why ❑ 2. Suitability of sampling method ❑		
Sample size	1. Sample size ❑,how chosen ❑,and why ❑ 2. Suitability of sample size ❑		
Sampling protocol	1. Target/actual/sample population(s): description ❑and suitability ❑ 2. Participants/cases/groups: inclusion ❑and exclusion ❑criteria 3. Recruitment of participants/cases/groups ❑		
	Is it worth continuing?	**Sampling [/5]**	
5. Data collection			
Collection method	1. Collection method(s) chosen ❑and why ❑ 2. Suitability of collection method(s) ❑		
Collection protocol	1. Include date(s) ❑,location(s) ❑,setting(s) ❑,personnel ❑,materials ❑,processes ❑ 2. Method(s) to ensure/enhance quality of measurement/instrumentation ❑ 3. Manage non-participation ❑,withdrawal ❑,incomplete/lost data ❑		
	Is it worth continuing?	**Data collection [/5]**	
6. Ethical matters			
Participant ethics	1. Informed consent ❑,equity ❑ 2. Privacy ❑,confidentiality/anonymity ❑		
Researcher ethics	1. Ethical approval ❑,funding ❑,conflict(s) of interest ❑ 2. Subjectivities ❑,relationship(s) with participants/cases ❑		
	Is it worth continuing?	**Ethical matters [/5]**	
7. Results			
Analysis, Integration, Interpretation method	1. A.I.I. method(s) for primary outcome(s)/output(s)/predictor(s) chosen ❑and why ❑ 2. Additional A.I.I. methods (e.g. subgroup analysis) chosen ❑and why ❑ 3. Suitability of analysis/integration/interpretation method(s) ❑		
Essential analysis	1. Flow of participants/cases/groups through each stage of research ❑ 2. Demographic and other characteristics of participants/cases/groups ❑ 3. Analyse raw data ❑,response rate ❑,non-participation/withdrawal/incomplete/lost data ❑		
Outcome, Output, Predictor analysis	1. Summary of results ❑and precision ❑for each outcome/output/predictor/measure 2. Consideration of benefits/harms ❑,unexpected results ❑,problems/failures ❑ 3. Description of outlying data (e.g. diverse cases, adverse effects, minor themes) ❑		
		Results [/5]	
8. Discussion			
Interpretation	1. Interpretation of results in the context of current evidence ❑and objectives ❑ 2. Draw inferences consistent with the strength of the data ❑ 3. Consideration of alternative explanations for observed results ❑ 4. Account for bias ❑,confounding/effect modifiers/interactions/imprecision ❑		
Generalisation	1. Consideration of overall practical usefulness of the study ❑ 2. Description of generalisability (external validity) of the study ❑		
Concluding remarks	1. Highlight study's particular strengths ❑ 2. Suggest steps that may improve future results (e.g. limitations) ❑ 3. Suggest further studies ❑		
		Discussion [/5]	
9. Total			
Total score	1. Add all scores for categories 1–8		
		Total [/40]	

Appendix C - Publishing guidelines for the journal Autism

Types of Article

The Journal considers the following kinds of article for publication:

1. Research Reports. Full papers describing new empirical findings;
2. Review Articles
    (a) general reviews that provide a synthesis of an area of autism research;
    (b) critiques - focused and provocative reviews that may be followed by a number of invited commentaries, with a concluding reply from the main author.
    (c) Both full Research Reports and Review Articles are generally restricted to a maximum of 6,000 words, including all elements (title page, abstract, notes, tables, text), but excluding references. Editors may ask authors to make certain cuts before sending the article out for review.
3. Short Reports. Brief papers restricted to a maximum of 2,000 words with no more than two tables and 15 references. Short reports could include other approaches like discussions, new or controversial ideas, comments, perspectives, critiques, or preliminary findings. The title should begin with 'Short Report'.
4. Letters to the Editors. Readers' letters should address issues raised by published articles. The decision to publish is made by the Editors, in order to ensure a timely appearance in print. Letters should be no more than 800 words, with no tables and a maximum of 5 references.

Preparing your manuscript for submission

1. **Formatting**

Autism asks that authors use the APA style for formatting. The APA Guide for New Authors can be found on the APA website, as can more general advice for authors.

2. **Artwork, figures and other graphics**

For guidance on the preparation of illustrations, pictures and graphs in electronic format, please visit SAGE's Manuscript Submission Guidelines.

Figures supplied in colour will appear in colour online regardless of whether or not these illustrations are reproduced in colour in the printed version. For specifically requested colour reproduction in print, you will receive information regarding the costs from SAGE after receipt of your accepted article.

3. **Supplementary material**

This journal is able to host additional materials online (e.g. datasets, podcasts, videos, images etc) alongside the full-text of the article. For more information please refer to our guidelines on submitting supplementary files.

4. Terminology

Autism has researched and compiled their own Terminology Guidelineswhich all authors should follow.

5. Reference style

Autism adheres to the APA reference style. View the APA guidelines to ensure your manuscript conforms to this reference style.

6. English language editing services

Authors seeking assistance with English language editing, translation, or figure and manuscript formatting to fit the journal's specifications should consider using SAGE Language Services. Visit SAGE Language Services on our Journal Author Gateway for further information.

7. Submitting your manuscript

Autism is hosted on SAGE Track, a web based online submission and peer review system powered by ScholarOne™ Manuscripts. Visit http://mc.manuscriptcentral.com/autism to login and submit your article online.

IMPORTANT: Please check whether you already have an account in the system before trying to create a new one. If you have reviewed or authored for the journal in the past year it is likely that you will have had an account created. For further guidance on submitting your manuscript online please visit ScholarOne Online Help.

8. ORCID

As part of our commitment to ensuring an ethical, transparent and fair peer review process SAGE is a supporting member of ORCID, the Open Researcher and Contributor ID. ORCID provides a unique and persistent digital identifier that distinguishes researchers from every other researcher, even those who share the same name, and, through integration in key research workflows such as manuscript and grant submission, supports automated linkages between researchers and their professional activities, ensuring that their work is recognized.

The collection of ORCID iDs from corresponding authors is now part of the submission process of this journal. If you already have an ORCID iD you will be asked to associate that to your submission during the online submission process. We also strongly encourage all co-authors to link their ORCID ID to their accounts in our online peer review platforms. It takes seconds to do: click the link when prompted, sign into your ORCID account and our systems are automatically updated. Your ORCID iD will become part of your accepted publication's metadata, making your work attributable to you and only you. Your ORCID iD is published with your article so that fellow researchers reading your work can link to your ORCID profile and from there link to your other publications.

If you do not already have an ORCID iD please follow this link to create one or visit our ORCID homepage to learn more.

5. Information required for completing your submission

You will be asked to provide contact details and academic affiliations for all co-authors via the submission system and identify who is to be the corresponding author. These details must match what appears on your manuscript. At this stage please ensure you have included all the required statements and declarations and uploaded any additional supplementary files (including reporting guidelines where relevant).

Appendix D - Ethical Approval (letter from committee and approval email)

6th December 2018

University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Coláiste na nEalaíon, an Léinn Cheiltigh agus na nEolaíochtaí Sóisialta
College of Arts, Celtic Studies and Social Sciences

Scoil an Síceolaíochta Feidhmí
School of Applied Psychology

University College Cork,
Cork, Ireland.

T +353 (0)21 490 4551 / 4552
E infoapsych@ucc.ie
http://www.ucc.ie/en/apsych/

Dear Alasdair,

Clinical Psychology Research and Ethics Meeting 23.11.18

Autism and the Social Press: Self-Perception of Face-to-Face Interaction
Alasdair Ross

Thank you for presenting the above research proposal to the Research and Ethics panel. Based on your written proposal and further clarification and discussion during the meeting, the decision of the panel was:

- **Pass, conditional on required revisions**

In formulating a revised submission please attend to the following issues raised by reviewers on the current proposal:

1. **Method**

Needs further clarification of the process of matching/excluding participants. If consent is obtained and assessments completed on Qualtrics do all still participate in the study? Are they included/excluded at this point?
It reads as if the exclusion will be conducted later as verbal IQ is part of the assessment (and this is part of the matching process). How many participants will be required to participate before 15 matched in each group is achieved?
If participants are excluded, will they be informed of this?

Include power analysis for sample size.

2. **Informed Consent**

Part two, debrief, is audio recorded. Are participants aware of this and have they consented to being audio recorded? Is “debrief” the accurate term here?

This study uses deception. No details presented as to how this will be explained to them in the final debrief. Answering any questions and giving another copy of the Information Sheet is insufficient. Need to include a clear protocol on this.

3. Right to Withdraw

On Information Sheet – "after completion of the study" could imply when the study is finished rather than their participation in the study.
Include headings on Information Sheet.

4. Non-Harm

Risk of distress following deception. What is the protocol?

5. Data Storage

Clarify Qualtrics security and storage.

You may re-submit your revised proposal to n.hennessy@ucc.ie at any time but NO LATER THAN Friday 7 January 2019. Please also include a cover letter indicating how and where you have responded to these revisions.

Every best wish with making these revisions.

Yours sincerely,

Dr Mike Murphy
Chair Clinical Psychology Research and Ethics Panel

Copy: Christian Ryan

Ethics update

Hennessy, Nora <NHennessy@ucc.ie> Tue, Feb 5, 2019 at 10:33 AM
To: Alasdair Iain Ross <117221700@umail.ucc.ie>
Cc: "Ryan, Christian" <christian.ryan@ucc.ie>, "Murphy, Mike (Applied Psychology)" <Mike.Murphy@ucc.ie>

Dear Alasdair,

Many thanks for your updated form and cover letter.

This has been approved.

Kind Regards,

Nora

Nora Hennessy | Programme Administrator, DCLIN Psychology| School of Applied Psychology| Distillery House, North Mall Campus |UCC ||Ph: (021) 490 4512/ 490 4552

Appendix E - Recruitment Poster

Do you have time for a chat?

Participants needed for a psychology experiment

You will be asked to have a short conversation with the researcher while wearing these fancy eye-tracking glasses…

…Then you will be asked to look at some pictures of faces on a computer screen.

To take part you must have a previous diagnosis of Autism Spectrum Disorder (or Asperger's Syndrome).

The experiment is voluntary and should take no longer than 60 minutes. Located in the North Mall Campus of UCC.

For further information, please scan the QR code or take one of the tabs below

QR code:

Alasdair Ross
alasdair.ross@hse.ie

Alasdair Ross
alasdair.ross@hse.ie

Alasdair Ross
alasdair.ross@hse.ie

Alasdair Ross
alasdair.ross@hse.ie

Alasdair Ross
alasdair.ross@hse.ie

Alasdair Ross
alasdair.ross@hse.ie

Alasdair Ross
alasdair.ross@hse.ie

Appendix F - Participant information sheets and consent forms for both groups

Information Sheet - ASD Group

Thank you for considering participating in this research project. The purpose of this document is to explain to you what the work is about and what your participation would involve, so as to enable you to make an informed choice.

Purpose

Previous research has suggested that some individuals with autism spectrum disorder can experience difficulties in how they communicate socially with others and in how they identify emotions (such as, happy, sad or fearful). The purpose of this study is to examine whether adults with autism spectrum disorder and those without experience similar difficulties to those mentioned above or whether there are differences between these groups. This study involves a short social conversation, with one other person, and two short tasks involving pictures and identifying faces on a screen. During all of the tasks you will be wearing special eye-tracking glasses. Audio will be recorded during the short social conversation.

Participation

Participation in this study is completely voluntary. There is no obligation to participate, and should you choose to do so you can refuse to answer specific questions, or decide to withdraw from the study. All information you provide will be confidential and your anonymity will be protected throughout the study. It will be necessary to gather identifying information with the questionnaires so that we can link your responses to the questionnaires, social interviews, and photograph tasks. We will provide you with a code which will be known only to you and to the research team; details of the code will be stored separately from details of questionnaire responses, social interviews, and photograph task data, so your confidentiality will be protected.

You maintain the right to withdraw from the study at any stage up to one-week after taking part in the study.

Anonymity and what will happen with your data after participating

The anonymous data will be stored on the University College Cork server. The information linking codes to participant names will be stored on an encrypted computer. The data will be stored for a minimum of ten years. The information you provide may contribute to research publications and/or conference presentations. Furthermore, your data will also contribute to the write up of a Doctoral thesis.

Other information

We do not anticipate any negative outcomes from participating in this study**.** However, should you experience distress arising from participating in the research, we would ask in the first instance that you speak to the member of XXXXXX who referred you into this study. We have included the contact details for XXXXX and other community services below:

- **XXXXX**
  Telephone: XXXXX
  Website: XXXXXX
- **Samaritans Ireland**
  Freephone: 116 123
  Website: https://www.samaritans.org/how-we-can-help-you/contact-us
- **(For students within UCC) UCC Student Counselling**
  Telephone: (021) 490 3565
  Website: https://www.ucc.ie/en/studentcounselling/contact/

This study has obtained ethical approval from the UCC Clinical Psychology Research Ethics Committee.

If you have any queries about this research, you can contact Alasdair Ross at 117221700@umail.ucc.ie. You can also contact his research supervisor, Dr. Christian Ryan, at christian.ryan@ucc.ie.

If you agree to take part in this study, please complete the consent form on the next page.

Consent Form - ASD Group

I……………………………………agree to participate in **Alasdair Ross**' research study.

The purpose and nature of the study has been explained to me in writing.

I am participating voluntarily.

I understand that the study involves the use of eye-tracking and audio recording equipment.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that I can withdraw permission to use the data within one week of taking part in the study, in which case the material will be deleted.

I understand that anonymity will be ensured in the write-up.

I confirm that I can see within a radius of two meters from myself without the need for glasses (*note:* contact lenses are suitable as long as they are worn on the day you participate in the study) and, to my knowledge, do not have an eye movement disorder.

I confirm that I have a previous diagnosis of an autism spectrum disorder (for example, Asperger's Syndrome).

Signed: …………………………………….   Date: ………………..

PRINT NAME:…………………………………….

Information Sheet - Control Group

Thank you for considering participating in this research project. The purpose of this document is to explain to you what the work is about and what your participation would involve, so as to enable you to make an informed choice.

Purpose

Previous research has suggested that some individuals with autism spectrum disorder can experience difficulties in how they communicate socially with others and in how they identify emotions (such as, happy, sad or fearful). The purpose of this study is to examine whether adults with autism spectrum disorder and those without experience similar difficulties to those mentioned above or whether there are differences between these groups. This study involves a short social conversation, with one other person, and two short tasks involving pictures and identifying faces on a screen. During all of the tasks you will be wearing special eye-tracking glasses. Audio will be recorded during the short social conversation.

Participation

Participation in this study is completely voluntary. There is no obligation to participate, and should you choose to do so you can refuse to answer specific questions, or decide to withdraw from the study. All information you provide will be confidential and your anonymity will be protected throughout the study. It will be necessary to gather identifying information with questionnaires so that we can link your responses in them, the two short short social interviews, and the task involving photographs. We will provide you with a code which will be known only to you and to the research team; details of the code will be stored separately from details of questionnaire responses, social interviews, and photograph task data, so your confidentiality will be protected.

You maintain the right to withdraw from the study at any stage up to one-week after taking part in the study.

Anonymity and what will happen to your data after participating

The anonymous data will be stored on the University College Cork server. The information linking codes to participant names will be stored on an encrypted computer. The data will be stored for a minimum of ten years. The information you provide may contribute to research publications and/or conference presentations. Furthermore, your data will also contribute to the write up of a Doctoral thesis.

Other information

We do not anticipate any negative outcomes from participating in this study. However, should you experience distress arising from participating in the research, the contact details for support services provided below may be of assistance:

- **Samaritans Ireland**
  Freephone: 116 123
  Website: https://www.samaritans.org/how-we-can-help-you/contact-us

- **(For students within UCC) UCC Student Counselling**
  Telephone: (021) 490 3565
  Website: https://www.ucc.ie/en/studentcounselling/contact/

This study has obtained ethical approval from the UCC Clinical Psychology Research Ethics Committee.

If you have any queries about this research, you can contact Alasdair Ross at 117221700@umail.ucc.ie. You can also contact his research supervisor, Dr. Christian Ryan, at christian.ryan@ucc.ie.

If you agree to take part in this study, please complete the consent form on the next page. A researcher will be in touch in the following few weeks to confirm your eligibility to take part in the study

Consent Form - Control Group

I……………………………………agree to participate in **Alasdair Ross**' research study.

The purpose and nature of the study has been explained to me in writing.

I am participating voluntarily.

I understand that the study involves the use of eye-tracking and audio recording equipment.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that I can withdraw permission to use the data within one week of taking part in the study, in which case the material will be deleted.

I understand that anonymity will be ensured in the write-up.

I confirm that I can see within a radius of two meters from myself without the need for glasses (*note:* contact lenses are suitable as long as they are worn on the day you participate in the study) and, to my knowledge, do not have an eye movement disorder.

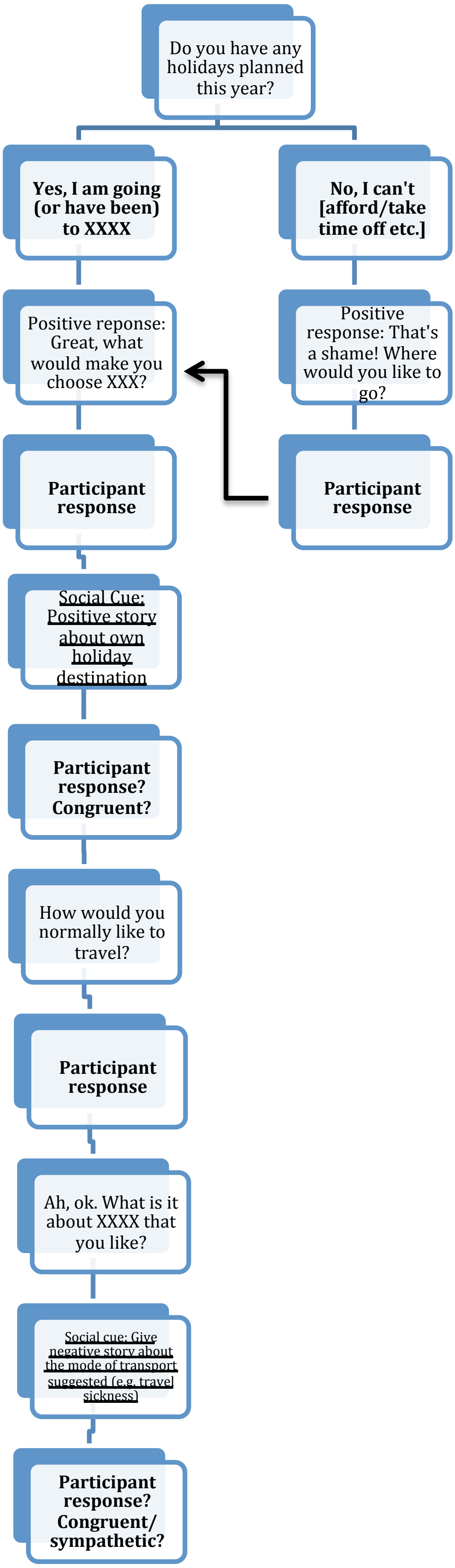
I confirm that I **do not** have a previous diagnosis of an autism spectrum disorder (for example, Asperger's Syndrome). ***Please tick this box to confirm*** ☐

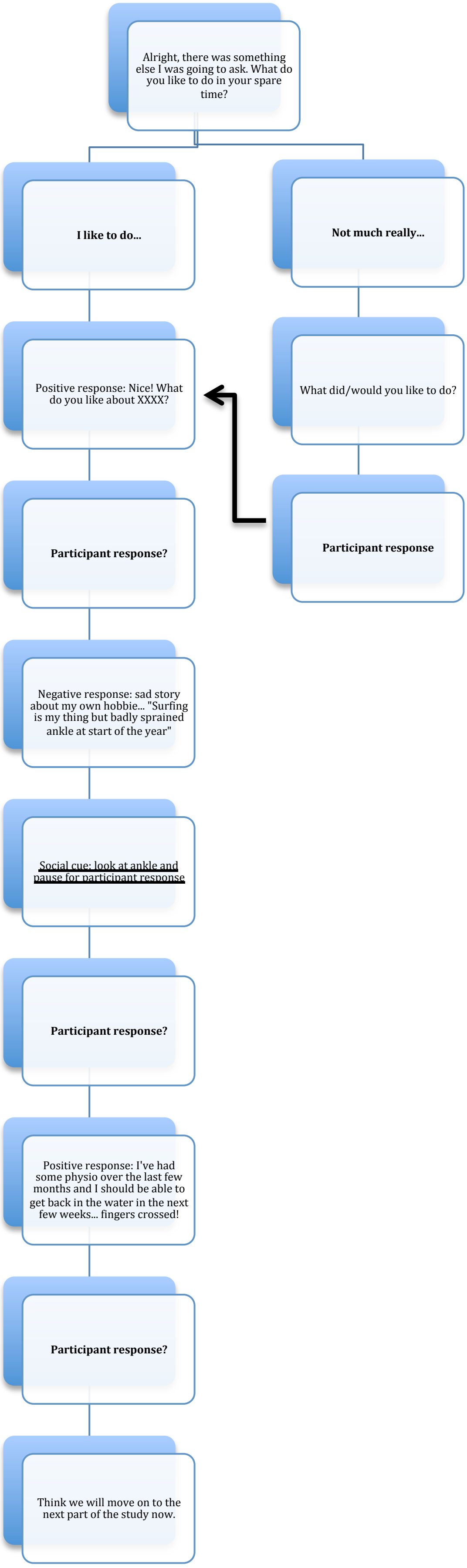
Signed: ……………………………………. Date: ………………..

PRINT NAME:………………………………………

Appendix G - Conversation flowchart

The conversation flowchart extends over the following two pages.





Alright, there was something else I was going to ask. What do you like to do in your spare time?
I like to do...
Not much really...
Positive response: Nice! What do you like about XXXX?
What did/would you like to do?
Participant response?
Participant response
Negative response: sad story about my own hobbie... "Surfing is my thing but badly sprained ankle at start of the year"
Social cue: look at ankle and pause for participant response
Participant response?
Positive response: I've had some physio over the last few months and I should be able to get back in the water in the next few weeks... fingers crossed!
Participant response?
Think we will move on to the next part of the study now.