

The Effect of Social Presence on Social Cognition in Autistic and Neurotypical Adults

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**Contents**

[**Chapter 1: General Introduction** 1](#_Toc28006732)

[*1.1. The Importance of a Social Presence* 1](#_Toc28006733)

[*1.2. The Effect of Social Presence in Autism Spectrum Conditions* 6](#_Toc28006734)

[*1.3. Dual Systems Theory of Mentalising* 10](#_Toc28006735)

[*1.4. Implicit Mentalising in Autism Spectrum Conditions* 15](#_Toc28006736)

[*1.5. The Effect of a Social Presence on Mentalising* 18](#_Toc28006737)

[*1.6. Overview of Thesis Chapters and Aims* 22](#_Toc28006738)

[**Chapter 2: Autistic adults are sensitive to social agency when interpreting patterns and forming predictions.** 24](#_Toc28006739)

[**2.1. Introduction** 24](#_Toc28006740)

[**2.2. Method: Main Experiment** 30](#_Toc28006741)

[*2.2.1. Participants* 30](#_Toc28006742)

[*2.2.2. Design* 32](#_Toc28006743)

[*2.2.3. Materials & Apparatus* 32](#_Toc28006744)

[*2.2.4. Procedure* 33](#_Toc28006745)

[**2.3. Results: Main Experiment** 35](#_Toc28006746)

[*2.3.1. Group Accuracy in the Social Agency Attribution and Non-Social Agency Attribution Condition* 35](#_Toc28006747)

[*2.3.2. Order Effects* 36](#_Toc28006748)

[*2.3.3. Ease of Completion* 37](#_Toc28006749)

[*2.3.4. Strategy Use in the Social Agency Attribution and Non-Social Agency Attribution Condition* 39](#_Toc28006750)

[*2.3.5. Social Responsiveness Scale Scores* 40](#_Toc28006751)

[**2.4. Method: Control Experiment – Order Effects Check** 40](#_Toc28006752)

[*2.4.1. Participants* 40](#_Toc28006753)

[*2.4.2. Design* 41](#_Toc28006754)

[*2.4.3. Procedure* 41](#_Toc28006755)

[**2.5. Results: Control Experiment – Order Effects Check** 41](#_Toc28006756)

[**2.6. Discussion** 42](#_Toc28006757)

[*2.6.1. Conclusion* 47](#_Toc28006758)

[**Chapter 3: Social Presence, Mentalising and Autistic Traits** 48](#_Toc28006759)

[**3.1 Introduction** 48](#_Toc28006760)

[*3.1.1. Social Presence Metholodology* 48](#_Toc28006761)

[*3.1.2. Executive Functions* 50](#_Toc28006762)

[*3.1.3. Autistic Traits* 50](#_Toc28006763)

[*3.1.4. The Current Study* 51](#_Toc28006764)

[**3.2. Methods** 53](#_Toc28006765)

[*3.2.1. Participants* 53](#_Toc28006766)

[*3.2.2. Design and Data Handling* 54](#_Toc28006767)

[*3.2.3. Apparatus* 57](#_Toc28006768)

[*3.2.4. Procedure* 61](#_Toc28006769)

[**3.3. Results and Discussion** 62](#_Toc28006770)

[*3.3.1. Implicit Mentalising* 63](#_Toc28006771)

[*First Fixation Analysis* 63](#_Toc28006772)

[*Preferential Looking Score* 64](#_Toc28006773)

[*3.3.2. Implicit Mentalising Error Analysis* 65](#_Toc28006774)

[*First Fixation Errors* 65](#_Toc28006775)

[*Preferential Looking Errors* 66](#_Toc28006776)

[*3.3.3. Explicit Mentalising* 67](#_Toc28006777)

[*3.3.4. Autistic Traits and Executive Functions* 67](#_Toc28006778)

[**3.4. Discussion** 68](#_Toc28006779)

[*3.4.1. Conclusion* 70](#_Toc28006780)

[**Chapter 4: Social Presence, Mentalising and Autism Spectrum Conditions** 71](#_Toc28006781)

[**4.1. Introduction** 71](#_Toc28006782)

[**4.2. Study 3a: Method** 74](#_Toc28006783)

[*4.2.1. Participants* 74](#_Toc28006784)

[*4.2.2. Design* 75](#_Toc28006785)

[*4.2.3. Apparatus and Procedure* 77](#_Toc28006786)

[**4.3. Study 3a: Results** 77](#_Toc28006787)

[*4.3.1. Implicit Mentalising* 77](#_Toc28006788)

[*First Fixation Analysis* 77](#_Toc28006789)

[*Preferential Looking Score* 78](#_Toc28006790)

[*4.3.2. Implicit Data Error Analysis* 79](#_Toc28006791)

[*Implicit Mentalising First Fixation Error Analysis* 79](#_Toc28006792)

[*Preferential Looking Errors* 80](#_Toc28006793)

[*4.3.3. Explicit Mentalising* 82](#_Toc28006794)

[*4.3.4. Autistic Traits* 82](#_Toc28006795)

[**4.4. Study 3b: Method** 83](#_Toc28006796)

[*4.4.1. Participants* 83](#_Toc28006797)

[*4.4.2. Design* 84](#_Toc28006798)

[*4.4.3. Apparatus and Procedure* 84](#_Toc28006799)

[**4.5. Study 3b: Results** 85](#_Toc28006800)

[*4.5.1. Implicit Mentalising* 85](#_Toc28006801)

[*First Fixation Analysis* 85](#_Toc28006802)

[*Preferential Looking Score* 86](#_Toc28006803)

[*4.5.2. Implicit Data Error Analysis* 87](#_Toc28006804)

[*Implicit Mentalising First Fixation Error Analysis* 87](#_Toc28006805)

[*Preferential Looking Errors* 87](#_Toc28006806)

[*4.5.3. Explicit Mentalising* 88](#_Toc28006807)

[**4.6. Discussion** 89](#_Toc28006808)

[*4.6.1. Conclusion* 92](#_Toc28006809)

[**Chapter 5: General Discussion** 93](#_Toc28006810)

[**5.1. Summary of Findings** 93](#_Toc28006811)

[**5.2. Implications** 96](#_Toc28006812)

[*5.2.1 The Importance of a Social Presence* 96](#_Toc28006813)

[*5.2.2 Social Stimuli and Autism* 99](#_Toc28006814)

[*5.2.3 Executive Functions and the Dual System Theory of Mentalising* 103](#_Toc28006815)

[**5.3. Methodological Considerations** 104](#_Toc28006816)

[**5.4. Current Issues in Implicit Mentalising Research** 108](#_Toc28006817)

[**5.5. Future Directions** 111](#_Toc28006818)

[**5.6. Conclusion** 113](#_Toc28006819)

[**References** 114](#_Toc28006820)

**List of Tables**

**Table 1.** Participant characteristics…………………………………………………………….…32

**Table 2.** Percentage of participants in the autistic and NT groups who used each strategy to identify the chosen design in the social and non-social condition……………………………..39

**Table 3.** Participant characteristics………………………………………………………………..54

**Table 4**. Percentage of errors to each AOI in the indirect task………………………………...65

**Table 5**. Percentage of participants preferentially attending to each AOI for the indirect task……………………………………………………………………………………………………66

**Table 6.** Participant characteristics…………………………………………………………….….74

**Table 7.** Percentage of neurotypical and autistic participants who first fixated each AOI on the incorrect trials for the indirect task in the live and recorded condition in Study 3a…………..…79

**Table 8.** Percentage of participants preferentially attending to each AOI for the error trials for the indirect task……………………………………………………………………………………...81

**Table 9.** Participant characteristics………………………………………………………………..84

**Table 10.** Percentage of neurotypical and autistic participants who first fixated each AOI on the incorrect trials for the indirect task in the live and recorded condition………………….….87

**Table 11.** Percentage of participants preferentially attending to each AOI for the error trials for the indirect task…………………………………………………………………………………..….88

**List of Figures**

**Figure 1.** The trial procedure. Designs were presented at random in each trial…………..…33

**Figure 2.** The probability of identifying the correct design for each group in each condition (social/non-social, ASC/NT). Error bars show +/−1 within-subject standard error of the mean (S.E.M). The dashed line indicates chance………………………………………………………36

**Figure 3.** The probability of identifying the correct design for the first and second half of trials in each condition. Error bars show +/−1 within-subject standard error of the mean (S.E.M)……………………………………………………………………………………………….37

**Figure 4.** The ease of identifying the correct design in each condition for each group (social/non-social, autistic/NT). Error bars show +/−1 within-subject standard error of the mean (S.E.M)…………………………………………………………………………………………...…..38

**Figure 5.** The probability of identifying the correct design for each group (non-social/social). Error bars show +/−1 within-subject standard error of the mean (S.E.M). The dashed line indicates chance…………………………………………………………………………………….42

**Figure 6.** The experimental procedure……………………………………………………...……55

**Figure 7.** The areas of interest for the anticipatory gaze data analysis. (A) At the start of the interest period, as the seeker emerges from behind the screen. (B) At the end of interest period, whilst the seeker remains behind the table……………………………………………...61

**Figure 8.** Average number of indirect-task correct first fixation responses in the recorded and live conditions. Error bars show +/−1 within subject standard error of the mean (S.E.M)……………………………………………………………………………………………….63

**Figure 9.** Average preferential looking score in the recorded and live conditions. Error bars show +/−1 within-subject standard error of the mean…………………………………………...64

**Figure 10.** Average number of direct-task correct responses in the recorded and live conditions. Error bars show +/−1 within subject standard error of the mean (S.E.M)…...............................................................................................................................67

**Figure 11.** The experimental procedure………………………………………………………….76

**Figure 12.** The areas of interest for the anticipatory gaze data analysis. (A) At the start of the interest period, as the seeker steps forward from the bookcase. (B) At the end of interest period, whilst the seeker remains behind the table……………………………………………...77

**Figure 13.** Average number of indirect-task correct first fixation responses in the recorded and live conditions. Error bars show +/−1 within subject standard error of the mean (S.E.M)………………...…………….……………………………………………………………….78

**Figure 14.** Average preferential looking score in the recorded and live conditions. Error bars show +/−1 within subject standard error of the mean (S.E.M)………………………………...…79

**Figure 15.** Average number of direct-task correct responses in the recorded and live conditions in Study 3a. Error bars show +/−1 within subject standard error of the mean (S.E.M)……………….…………………………………….………………………………………...82

**Figure 16**. Average number of indirect-task correct first fixation responses in the recorded and live conditions for the neurotypical and ASC group… Error bars show +/−1 within subject standard error of the mean (S.E.M)…………………..……………………………………………85

**Figure 17.** Average preferential looking score in the recorded and live conditions for the neurotypical and ASC group. Error bars show +/−1 within subject standard error of the mean (S.E.M)……………………………………………………………………………………………….86

**Figure 18.** Average number of direct-task correct responses in the recorded and live conditions for the neurotypical and ASC group. Error bars show +/−1 within subject standard error of the mean (S.E.M)………………………………………………………………………….89

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**Abstract**

Humans are remarkably sensitive to the behaviour of our social partners. This skill allows an understanding of the preferences and mental states of others, and is thought to arise from theory-of-mind (ToM) processing. However, individuals with an autism spectrum diagnosis typically show difficulties in ToM processing, and are thought to be less sensitive to detecting social behaviours. Sensitivity to social stimuli is critical to the development of adaptive social behaviours and our behaviour is frequently influenced by those around us, yet the majority of social cognition research is conducted using paradigms where there is no social partner physically present. The aim of this PhD was therefore to investigate the effect of a social presence, whether real or implied, on cognitive tasks in both neurotypical and autistic adults.

Study 1 aimed to investigate whether autistic adults are sensitive to social agency. This study used a prediction task featuring an animated cue (a red dot). The agency of the cue was manipulated across two parts of the study; in the first part it was described as a computer algorithm, and in the second as representing the eye movements of another participant. Both neurotypical and autistic participants were significantly more accurate at the prediction task when they believed the cue represented the eye movements of another participant. This therefore demonstrates that autistic participants showed a social facilitation effect, and were strongly influenced by the perception of a cue as social.

Studies 2, 3a and 3b aimed to investigate whether the physical presence of a social partner influences a participant’s ability to track intentions during a mentalising task. Study 2 used a first-order theory of mind task with neurotypical adults; Studies 3a and 3b used a more challenging second-order theory of mind task. Study 3a recruited neurotypical adults, whereas study 3b tested adults with a diagnosis of an autism spectrum condition. Both studies aimed to test implicit and explicit mentalising behaviour across two conditions: *live*, where the task protagonists were physically present acting out the task, or *recorded*, where the same task protagonists were depicted in a video recording. Across all three studies, the results revealed that implicit mentalising is highly sensitive to a real-time social presence, with both neurotypical and autistic participants performing significantly better when the protagonists were live than presented in a pre- recorded video.

Taken together, these studies clearly demonstrate the importance of acknowledging social presence as a crucial factor in our understanding of social cognition in neurotypical and clinical populations.

# **Chapter 1: General Introduction**

# *1.1. The Importance of a Social Presence*

As humans we are a very social species and, as such, are predisposed to attend to social information within our environment. Social information arises as a result of those around us, and we pay close attention to our social partners; their communications, actions and body movements. This type of attention is known as ‘social attention’. This preference emerges from a very early age, with new-born babies shown to preferentially attend to biological motion displays, as compared to non-social point light displays, and to clearly direct their attention to the eyes and faces of others (Simion, Regolin & Bulf, 2008; Maurer, 1985). A preference for social stimuli continues into adulthood, with neurotypical adults demonstrating a clear preference to attend to social stimuli over and above non-social stimuli within their environment (Fletcher-Watson, Findlay, Leekam & Benson, 2008; Birmingham & Kingstone, 2009).

However, our preference to attend to social information moves beyond simply allocating attention to social stimuli. By attending to social stimuli, we access a wealth of information regarding our social partners; observing their behaviours and interactions grants us valuable insights into their actions and intentions and can also help to inform our own behaviour. Sensitivity to social stimuli and the ability to recognise patterns of social behaviour is critical to the development of adaptive social skills (Mattson, 2014). For example, being able to interpret behaviour arising from our social partners is believed to be critical to the development of language and speech (Frost, Siegelman, Narkiss & Afek, 2013). Indeed, research has demonstrated that we spontaneously track the mental states of our social partners during discourse, even when there is no explicit reason for doing so (Ferguson & Breheny, 2012). From an evolutionary perspective, the ability to interpret a social partner’s behaviour, or understand social scenarios, or even to predict the most likely reaction to our own behaviours and overtures, all assist social integration with others (Mattson, 2014). Therefore, difficulties in this ability could lead to substantial difficulties when attempting to participate as an active member of a social group.

Our social partners’ behaviour can both inform and alter our own behaviours, however, many social cognition paradigms are conducted in the absence of social others. A current concern within social cognition research therefore relates to the appropriateness of paradigms conducted with socially isolated stimuli. Of key interest, much research has demonstrated that participants are sensitive to the social agency of stimuli used within lab experiments (Risko, Laidlaw, Freeth, Foulsham & Kingstone, 2012; Risko, Richardson & Kingstone, 2016; Gobel, Kim & Richardson, 2015). The perception of a stimulus as possessing social agency, or representing a social entity, can lead to a stimulus acting as a social presence i.e. instilling a participant with an awareness of the presence of a social partner. This is a critical consideration when discussing human cognition, as participants have been shown to display significantly different patterns of behaviour depending upon their perception of a stimulus. For example, participants have been found to synchronise their own eye movements to the movements of a red dot when they believe it to represent the eye movements of another participant (Gobel, Tufft & Richardson, 2017), and display significantly stronger gaze cueing effects when they believe the eyes of a robot to be controlled by a human, as compared to a computer (Wiese, Wykowska, Zwickel & Muller, 2012).

Further to this, despite being an inherently social species, traditionally many of our cognitive behaviours have been investigated using sparse, two-dimensional lab-based paradigms, lacking in ecological validity. This is important as participants have been shown to display further changes in social attention if they believe a paradigm to depict a social partner in real-time, rather than as a pre-recorded stimulus. In such cases the stimuli presented to the participants can be identical, for example, if they believe a Skype conversation to be live or a pre-recording and yet participants consistently demonstrate different patterns of behaviour if they believe the stimulus to depict a person in real-time (Cole, Skarratt & Kuhn, 2016). One potential explanation for this difference in behaviour lies in the perceived potential for social interaction. In support of this claim, a more recent study using a webcam scenario found that it was not just the implied presence of a social partner that led to changes in gaze behaviour, but a critical factor was the perceived potential for a social interaction (Gregory & Antolia, 2018). Therefore, this suggests that more naturalistic experiments, with the potential for social interaction, can lead to different results to lab experiments, and that these differences could be a critical consideration for future research.

With developments in mobile eye tracking techniques, studies are able to place a greater emphasis on the use of more naturalistic paradigms. One key finding from these types of paradigms is that individuals can show different patterns of gaze behaviour depending on whether social partners are physically present (Risko et al., 2012). In particular, participants have been found to attend less to individuals’ faces in real world environments than they do to pre-recorded video stimuli of the same faces on a computer screen (Foulsham, Walker & Kingstone, 2011; Kuhn, Teszka, Tenaw & Kingstone, 2016). The authors suggest that this could be due to the influence of social norms (‘it’s rude to stare’) which are only relevant in a real-world context. Further evidence for this pattern of behaviour can be drawn from a ‘waiting room’ type paradigm, in which participants believed they were awaiting the arrival of an experimenter (Laidlaw, Foulsham, Kuhn & Kingstone, 2011). Joining them in the waiting area could be either a confederate, or a monitor displaying a confederate waiting in another waiting area. It was found that participants frequently examined the monitor display of the confederate (i.e. where there was no potential for social interaction), but that this result was not replicated in the real-confederate condition (where a potential for social interaction existed). This suggests that an individual’s bias to look towards another person is affected by the possibility of a social interaction and therefore, social presence. Everyday social behaviour does not occur in isolation, based on the studies discussed above it is therefore likely that behaviours presented in the lab would differ under naturalistic social settings with all the nuances and norms inherent to those scenarios.

It is apparent that an important factor in social cognition research is the inclusion of a social presence. This has led to an increased focus in the literature to increase the validity of social cognition paradigms, and to attempt to understand how cognitive mechanisms differ when measured as part of social interactions, rather than in isolation (Cole et al., 2016; De Jaegher, Di Paolo & Gallagher, 2010; Reader & Holmes, 2016). A key understanding now emerging is that interactive processes are not just merely a context in which behaviour happens, they are a critical component of human cognitive processing and can drive and instigate cognitive mechanisms in their own right (De Jaeger et al., 2010). Even using complex, dynamic stimuli such as videos can elicit different patterns of behaviour than when completing the same task with real social partners (Reader & Holmes, 2015). It is claimed that whilst videos provide an approximation of a naturalistic scenario, the use of a screen places restrictions on a participant’s viewing behaviour, whereas viewing a task live is more likely to reflect how actions are observed in our daily lives (Reader & Holmes, 2015).

Interestingly, behavioural changes have been shown to occur even when a participant is made aware that a social partner will not engage in a social interaction; it appears that the mere potential for an interaction is enough to drive these changes in behaviour. Gregory, López, Graham, Marshman, Bate and Kargas (2015) showed participants footage of a confederate sitting in a waiting room. Participants were either informed that the footage was live, or a recording. In all cases the participants were aware that the confederate would not be able to view them, and therefore would not engage in a social interaction. It was found that participants showed decreased gaze following and visual orienting to confederates in the live condition, but that this effect was not apparent in the recorded, baseline condition. Therefore, despite the confederates being unable to view the participant, the participant displayed gaze behaviour typically associated with live interactions. This finding has been found to replicate at the cortical level, whereby even simply viewing a social interaction between others leads to increased cortical excitability – even if there is no potential for the participant themselves to interact (Aihara, Yamamoto, Mori, Kushio & Uehara, 2015). This suggests that social interactions are not just limited to our own personal interactions, but also encompass another person’s potential interactions with a different social partner (Reader & Holmes, 2016).

Attempts to study the effects of social interaction and the presence of social partners at a neural level has led to the use and development of new techniques, such as hyperscanning. Hyperscanning allows the scanning of two brains engaged in social interaction at the same time. The modalities of hyperscanning can encompass several technologies, such as fMRI or functional Near-Infrared Spectroscopy (fNIRS). The range of such technologies allows an understanding of the neural effects of social interactions within differing social environments, although each technique has associated positives and negatives. For example, fNIRS allows a measurement of cortical activity within naturalistic surroundings of greater ecological validity but is limited by its temporal resolution and penetration depth. By contrast, adaptations of traditional fMRI methods to allow dual scanning (scanning social partners at the same time) allows an understanding of social interactions at a deeper neural level, but only within constrained, artificial environments.

Such techniques can involve the use of either a real or implied social presence but significantly, and supporting the findings of behavioural paradigms, these types of experiments have demonstrated that social interactions can lead to observable differences in neural responding (Redcay & Schilbach, 2019). For example, fNIRS has revealed that different brain regions are involved when completing a task with a social partner compared to when completing the same task alone (Liu, Mok, Witt, Pradhan, Chen & Reiss, 2016). Further, hyperscanning during fMRI has revealed brain areas that are unique to synchronisation with a social partner during real-time social interactions (Redcay & Schilbach, 2019). These studies therefore provide additional support for the importance of social partners in social cognition research. Both the potential for a social interaction (even when the participant is aware that the social interaction is unlikely to occur) and observing the social interactions of others drives changes at both a behavioural and neural level.

# *1.2. The Effect of Social Presence in Autism Spectrum Conditions*

Autism Spectrum Conditions (ASC) are characterised by deficits in social communication and social interactions across multiple contexts, including deficits in non-verbal behaviours that are used for social interaction (such as eye contact and body language (DSM-5). It is estimated that approximately 1% of the population are autistic (Baron-Cohen, Scott, Allison, Williams, Bolton, Matthews & Brayne, 2009), with a prevalence of 1 in 68 in children (Center for Disease Control and Prevention, 2016). Further, ASC are genetically hereditable (Hoekstra, Bartels, Verweij & Boomsma, 2007), with prevalence rising to 18% amongst siblings of autistic individuals (Ozonoff et al., 2011). Of key interest, ASC display a large degree of heterogeneity; as a spectrum condition, individuals can display differing levels of autistic traits across differing domains, with greater levels of autistic traits generally associated with greater levels of social impairment. Further, as a spectrum condition, individuals within the neurotypical population can also demonstrate traits associated with the Broad Autism Phenotype. Such individuals may display characteristics associated with a diagnosis of an ASC, and yet remain below the clinical cut-off for diagnosis (Hurley, Losh, Parlier, Reznick & Piven, 2007).

The characteristics of autism spectrum conditions are tightly linked to an individual’s social behaviour and interactions. Individuals with a diagnosis of an ASC have been shown to attend atypically to social stimuli, including atypical reciprocal eye gaze, atypical attention to faces and a preference to attend to non-social stimuli within their environment (Freeth & Bugembe, 2019; Chita-Tegmark, 2016; Dawson, Meltzoff & Brown, 1998). Further, more recent research has revealed that autistic individuals, and neurotypical individuals high in autistic traits, show atypical patterns of eye movements in response to social stimuli, often showing reduced visual exploration, significantly more fixations and significantly more revisits to target areas than neurotypical participants (Benson, Castelhano, Howard, Latif & Rayner, 2015; Vabalas & Freeth, 2016). However, whilst the social difficulties associated with ASC are very much a social phenomenon, much previous research investigating these characteristics has been conducted in lab environments lacking a social presence. This raises the very real concern that results found in these studies may not extrapolate to the real world (Lind & Bowler, 2009; Lehmann, Maliske, Böckler & Kanske, 2019). This is an important issue, as lab-based studies often inform theories and interventions developed for people with a diagnosis of an autism spectrum condition. Further, a large amount of research investigating the social difficulties associated with autism has focussed on infant and child populations (Cole, Slocombe & Barraclough, 2018). However, much less research has been conducted with adult populations and, as such, it is less clear how these difficulties present throughout development. Of key interest, a number of previous studies have indicated that certain abilities and skills can be affected by experience, leading to improved performance in adulthood (Schuwerk, Vuori & Sodian, 2015; Webster & Potter, 2008). In Chapter 2 I will therefore investigate whether autistic adults are sensitive to social agency, and the effects of the implied presence of a social partner on task performance.

There is a clear movement within the literature to examine the social impairments associated with neurodevelopmental disorders or psychiatric disorders by placing them within the perspective of social interactions. It is proposed that a distinct emphasis should be made that neuropsychiatric disorders or neurodevelopmental disorders (such as ASC) are disorders of social interaction not social observation (Schilbach, 2016). This distinction refers to the finding that individuals with neurodevelopmental disorders can display typical patterns of social cognition within isolated lab-based settings where they merely observe behaviour, but that significant social difficulties emerge in real life functioning when required to interact within a social environment (Schilbach, 2016; Lehmann et al., 2019). Such observations have led to the call for ‘second-person’ approaches to investigating social cognition (Lehmann et al., 2019; Redcay & Schilbach, 2019). A ‘second-person’ approach involves the participant as an active member of a social interaction, contrasting with traditional ‘third-person’ approaches, which have been criticised as focussing upon the individual mind of the participant as an observer (Lehmann et al., 2019). The key argument behind such discussions posits that in order for research to be of clinical relevance, and predictive of real-life functioning, it is a necessity to increase the ecological validity of social cognition paradigms (Schilbach, 2016).

From the studies discussed in section 1.1., it is evident that participants show differing patterns of behaviour depending upon whether a paradigm includes a social partner. However, to date, the effect of a social presence on social cognition in autistic individuals is a relatively understudied area, with such research providing conflicting results. Autism is a spectrum condition, meaning that individuals who are subclinical can still display traits associated with the broad autism phenotype. Whilst it would be expected that that there would be a negative correlation between autistic traits and attention to social stimuli, research investigating the effect of a social presence in relation to autistic traits often fails to provide evidence for this expectation. Using the Autism Quotient questionnaire (AQ) certain studies have found that social skills are positively correlated with looking towards live social partners, but not partners that are presented via recording (Laidlaw et al., 2011). Further, other studies have found that autistic traits are only associated with less looking to a partner’s face in a video condition (Freeth, Foulsham & Kingstone, 2013). One suggestion for why autistic traits do not inevitably lead to atypical patterns of social attention in live situations, is the suggestion that in face-to-face situations social cues are potentially so strong that they can overcome the atypicalities associated with autism. However, the studies discussed above tested neurotypical individuals without a clinical diagnosis of an ASC, therefore, different patterns of results may emerge from research with individuals with a clinical diagnosis of autism.

Indeed, one key finding which has emerged from research with autistic individuals is that the use of less ecologically valid stimuli, such as schematic images or faces in isolation, can lead to different patterns of behaviour than more naturalistic stimuli, such as videos. In a landmark study, Klin, Jones, Schultz, Volkmar and Cohen (2002) found that autistic individuals displayed different patterns of social attention to neurotypical participants when viewing complex, dynamic stimuli. Participants showed reduced attention to the eyes of a stimulus and increased focus on the nose, mouths and objects in the scene. The pattern of results shown by this paradigm presents a striking profile of the characteristics associated with autism. By showing an exaggerated focus to ‘non-eye’ areas the autistic participants missed key social information that was provided in each scene. If autistic individuals are not attuned to the everyday social cues around them, then they are potentially excluded from the wealth of social information available in their environment. These results therefore have serious real-world implications for allowing greater insight into the difficulties that autistic individuals have with processing social stimuli in the real world.

The results of this study suggest that information on autism that is gathered only from isolated lab experiments could be potentially misleading. Of particular relevance, a number of studies have found that autistic individuals only show atypical attention to faces when the stimulus is both dynamic, and not presented in isolation but within a social context (Speer, Cook, Mahon & Clark, 2007; Hanley, McPhillips, Mulhern & Riby, 2013). Further, studies that have included the use a real-time social presence have replicated this finding, revealing that autistic individuals have a tendency to attend more to a social partner’s mouth than nose, and to avoid direct eye contact when faced with a real-time social partner (Chita-Tegmark, 2016; Hanley et al., 2013; Hanley et al., 2015; Freeth & Bugembe, 2019). This demonstrates that the difficulties associated with an autism spectrum condition are increasingly prominent in more naturalistic paradigms featuring a social presence, and that previous studies using static stimuli may unwittingly mask these characteristics. Therefore, in combination with the research discussed in section 1.1., the results of these studies suggest that the use of naturalistic social stimuli can lead to quantifiable behavioural changes for both autistic and neurotypical individuals. However, much previous research has been dedicated to understanding the effect of a social presence on social attention and gaze behaviour, it remains to be investigated what effect a social presence has on other areas of social cognition research.

# *1.3. Dual Systems Theory of Mentalising*

The term ‘theory of mind’ is used to refer to the ability to recognise that others, beyond the self, possess desires, beliefs and intentions. The term ‘Theory of Mind’ was coined by Premack and Woodruff in 1978, resulting from research which revealed that chimpanzees can attribute mental states to others. Following this finding, much research was dedicated to investigating the development of a theory of mind (ToM) in humans, with a wealth of research revealing that human children can consciously and explicitly mentalise by four years of age (Perner, Leekam, & Wimmer, 1987). Commonly used paradigms to study theory of mind are ‘false belief’ tasks, such as the ‘Sally-Anne’ task (Wimmer & Perner, 1983). In this task an object is moved from one hiding place to another by ‘Anne’, without the knowledge of ‘Sally’. Children are then asked where they believe ‘Sally’ will search for the ball. By the age of four years, children typically display an understanding of Sally’s mindset, understanding that she holds a ‘false belief’, and so can correctly identify where she will look for the ball – they have developed a ‘theory of mind’. Over ten years later, in a landmark study, Clements and Perner (1994) revolutionised the field of theory of mind research with new evidence suggesting that children displayed evidence of a much earlier emerging implicit version of theory of mind, and were able to pass false belief tasks prior to their third birthday. Since then, this field of research has transformed, with the creation of a multitude of new paradigms designed to investigate this ‘implicit’ form of mentalising. Such paradigms include violation of expectation tasks, interactive tasks, and anticipatory looking paradigms; with anticipatory looking paradigms recognised as the most prolifically used task type ([Kulke](https://royalsocietypublishing.org/doi/10.1098/rsos.190068), [Wübker & Rakoczy](https://royalsocietypublishing.org/doi/10.1098/rsos.190068), 2019).

There are multiple theories that have attempted to explain the processes underlying theory of mind processing. Nativist accounts would argue that implicit mentalising paradigms tap the earliest emerging form of theory of mind, which later develops into a fully realised mentalising system incorporating later developing explicit mentalising abilities (Carruthers, 2016). By contrast, sceptical accounts would argue that the evidence in favour of implicit mentalising could instead be accounted for by other, sub-mentalising, explanations (such as attentional processing) (Ruffman & Perner, 2005). However, one final compelling explanation lies in the dual system theory of mentalising, which proposes that theory of mind processing occurs across two distinct mentalising systems (Apperly & Butterfill, 2009). The first system is the early emerging, ‘implicit’ system; an automatic process engaged frequently throughout day-to-day life; fast, efficient and independent of cognitive resources. The second system is the later developing ‘explicit’ system; more flexible but also more cognitively demanding and under voluntary control.

The terms ‘implicit’ and ‘explicit’ can vary in how they are operationalised, therefore, prior to discussing the dual systems theory of mentalising I will first define what is meant when referring to these terms respectively. One way of operationalising these terms can be related to the instrument of measurement i.e. the type of task used in the experiment. In this case ‘implicit’ would refer to a task where a participant is unaware of the outcome measure (what the researcher is measuring), and ‘explicit’ would refer to a task where the participant is aware of the outcome measure (Petty, Fazio, & Briñol, 2009). An alternative to this view is that these terms instead refer to the underlying psychological construct to be measured, with ‘implicit’ describing unconscious mental representations and ‘explicit’ referring to conscious mental representations (Greenwald & Banaji, 1995).

In this thesis I will aim to avoid conflating these two definitions and instead seek to use the terms as defined by Gawronski and Hahn (2019) and Rosenblau, Kliemann, Heerkeren and Dziobek (2015). These authors attempt to provide a clear separation between the terms used to refer to the task and the terms used to refer to the underlying mental representations. In line with previous research, an ‘implicit’ mental representation is determined by whether a participant’s response is automatic, unintentional and independent of cognitive resources. In contrast, an ‘explicit’ mental representation is determined if the participant’s response is intentional and reliant upon cognitive resources. Therefore, throughout the thesis ‘explicit’ and ‘implicit’ will refer to the cognitive processes we are seeking to measure. Moving from this, the tasks intended to measure these processes will be referred as ‘direct’ or ‘indirect’. Drawing from Petty et al., (2009) an ‘indirect’ task, where the participant is unaware of what behaviour is being measured, will be used to record implicit responses; and a ‘direct’ task, where a participant is aware of what behaviour is being measured, will be used to record explicit responses. In summary, we will therefore measure implicit processes using an indirect task, and explicit processes using a direct task.

Traditional false belief paradigms (such as the ‘Sally-Anne’ task) are direct tasks that require a conscious, voluntary response from a participant. However, these paradigms can be adapted to become indirect tasks in which the participant is not directly asked to track the belief state of the protagonist (Clements & Perner, 1994). Instead, during these types of indirect tasks a participant’s passive viewing behaviour is recorded. This type of paradigm has revealed that participants demonstrate ‘anticipatory looking’ behaviour, whereby they will make an automatic eye movement to fixate an object, location or individual independent of a voluntary selection process. In the case of a false belief task, individuals have been shown to demonstrate anticipatory looking behaviour in line with tracking the mental state of the task protagonist, regardless of whether an explicit response is required. These types of paradigms have been used across multiple studies, and have revealed that both young children and adults can display these types of anticipatory eye movement behaviour (Senju, Southgate, White & Frith, 2009; Schneider, Slaughter, Bayliss & Dux, 2013; Sodian, Schuwerk & Kristen, 2015; Schuwerk et al., 2016).

Indirect tasks are often critiqued for being unable to provide absolute interpretations of implicit outcome measures, with an absence of standardised absolute cut-offs by which all data can be evaluated. Without such standardised cut-offs it is difficult to draw comparisons regarding implicit mentalising performance between different studies. However, recent research has concluded that it is perfectly feasible to draw conclusions about differences between groups based on a relative interpretation of scores within individual experiments (Gawronski & Hahn, 2019). In this thesis Chapters 3 and 4 utilise an indirect task, with responses recorded via eye tracking equipment. As no pre-existing standardised interpretations of implicit mentalising exist, the implicit data collected within these experiments is therefore not compared to any pre-existing absolute cut-offs. Instead, the results are discussed as a relative interpretation of differences in responding between two conditions within a specific study.

Evidence for a distinction between the implicit and explicit mentalising systems initially emerged from studies with infants. Early studies typically found that children were unable to pass traditional theory of mind tasks until 4 years of age (Wimmer & Perner, 1983). However, these studies relied upon a direct, verbal response as a measure of accuracy. By contrast, studies using non-verbal, indirect measures have found that children display evidence of mentalising from as young as 15 months of age (Onishi & Baillargeon, 2005; Buttelmann, Carpenter & Tomasello, 2009). Further, there appears to be a clear dissociation between these two processes, with younger children who are unable to pass direct tasks found to be unaware of their correct implicit responses by showing high confidence in their incorrect explicit answers (Ruffman, Garnham, Import & Connelly, 2001). Further, these two forms of mentalising having been shown to persist into adulthood and continue to be a critical component of social functioning into old age (Senju et al., 2009; van der Wel, Sebanz & Knoblich, 2014; Nijhof, Brass, Bardi & Wiersema, 2016; Edwards & Low, 2017; Grainger, Henry, Naughtin, Comino & Dux, 2018).

Further evidence for the dual systems theory of mentalising can be drawn from the extent to which each system draws upon cognitive resources, or executive functions. Executive functions (EF) describe a series of higher-order cognitive skills that allow us to plan and carry out goal-directed behaviours. Executive functions are broadly agreed to consist of three distinct yet overlapping core components; inhibitory control, working memory and cognitive flexibility (Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000). Inhibitory control is the ability to override our initial impulses or urges to instead provide a more appropriate response (Diamond, 2013). Working memory describes the ability to hold and process information in our mind (Baddeley & Hitch, 1994). Finally, cognitive flexibility incorporates aspects of both of the previous two executive functions but emerges much later in development. This final core executive function involves the ability to change perspectives and switch between different tasks with overlapping demands (Miyake et al., 2000).

Executive functions have been shown to be crucial correlates of theory of mind ability from an early age; improvements in theory of mind ability typically occur concurrently with increases in executive function ability (Carlson & Moses, 2001; Pellicano, 2007). Of note, both working memory and inhibitory control are identified as significant factors in explicit theory of mind competence in younger children (Carlson, Moses & Claxton, 2004; Diamond, 2013). This is perhaps unsurprising when reviewing the demands of a direct theory of mind task; in order to successfully complete the task a participant must suppress their own perspective in order to successfully identify the perspective of another (inhibitory control), and must actively hold and process information in mind in order to track the movements of an object and the task protagonists (working memory) (Diamond, 2013). By contrast, cognitive flexibility develops much later in childhood than either inhibitory control or working memory abilities, but has been shown to predict social understanding and perspective taking ability (Bock, Gallaway & Hund, 2015; Low, 2010; Kloo, Perner, Aichhorn & Schmidhuber, 2010), and continues to play a critical role in theory of mind ability in both older childhood and adulthood (Bock et al., 2015; Gökçen, Frederickson & Petrides, 2016).

In line with the dual systems theory of mentalising, previous research has found that executive functions are differentially related to each system. In particular, the conscious, cognitively effortful explicit system has been found to have a significant relationship with measures of executive function, whilst the involuntary, cognitively efficient implicit system does not (Schuwerk, Jarvers, Vuori & Sodian, 2016). This therefore supports the claim that the two systems draw upon separable cognitive resources, and that implicit mentalising occurs automatically without the involvement of cognitive processing. However, this relationship is far from transparent, with other research demonstrating that depletion of cognitive resources can lead to a detrimental effect on the implicit mentalising system (Schneider, Lam, Bayliss, & Dux, 2012). This suggests that the implicit system does have a relationship with executive functions and, thus, may not exist as a distinct system to the explicit system, or operate as an involuntary, unconscious process. I will therefore investigate the relationship between implicit and explicit mentalising and executive functions in Chapter 3 to a) identify if each system is differentially related to executive function, and b) to confirm that the indirect task aimed at measuring implicit mentalising provides a measure of involuntary, automatic behaviour.

# *1.4. Implicit Mentalising in Autism Spectrum Conditions*

Previous research has shown that autistic children typically display atypicalities in theory of mind (ToM) ability, as demonstrated through the use of traditional false belief tasks. For example, in a ‘Sally-Anne’ task, NT children and children with Down’s syndrome were significantly more accurate than autistic children in identifying that Sally held a ‘false belief’ about the location of the ball (Baron-Cohen, Leslie & Frith, 1985). This finding has been replicated in high functioning autistic adults (Baron-Cohen, Jolliffe, Mortimore & Robertson, 1997). Further, in an interesting study Abell, Happe & Frith (2000) found that autistic children used less mentalising descriptions then NT children and, further, that these descriptions were frequently inaccurate. Critically, this pattern of results was found even in children who had passed a traditional theory of mind task. This therefore provides further evidence that autistic individuals experience difficulties in attributing mental states to other.

The evidence from the studies discussed above suggests that individuals with a diagnosis of an ASC have difficulties in attributing mental states to others. This is, perhaps, unsurprising as the core characteristics associated with autism spectrum conditions are persistent deficits in social communication and social interaction across multiple contexts (DSM-5). However, the results found by Abell et al., (2000) raise the interesting possibility that autistic individuals can pass a false belief task, whilst still demonstrating deficits in mentalising. Further, whilst explicit theory of mind acquisition in autistic children may be delayed, many children develop the ability to pass direct tasks albeit at a later age than their neurotypical peers (Happé, 1995). One potential explanation for the disparity between these results lies in the distinction between the implicit and explicit mentalising systems.

Whilst neurotypical children and adults show clear evidence of a fast, efficient implicit mentalising system, individuals with a diagnosis of an autism spectrum condition do not show the same pattern of behaviour. When completing indirect and direct tasks, measuring either implicit or explicit mentalising, research has demonstrated that both autistic children and adults perform significantly worse than neurotypical controls on the indirect (anticipatory looking) version of the task (Senju et al., 2009; Senju et al., 2010). Further, this finding has been found to extend beyond those with a clinical diagnosis of autism, with at-risk siblings also demonstrating difficulties with indirect tasks (Gliga, Senju, Pettinato, Charman & Johnson, 2013). Critically, it has been found that the same adults who show atypicalities with implicit mentalising show similar competence to NT controls on measures of explicit mentalising, and likewise with autistic children once verbal mental age is controlled for (Senju et al., 2009; Senju et al., 2010; Schneider et al., 2013). These results therefore suggest that the existence of a domain-specific deficit in implicit theory of mind could potentially be a phenotype of autism.

The research discussed above suggests that both autistic children and adults exhibit failures in spontaneous mentalising but can demonstrate comparable explicit mentalising ability to neurotypical controls. One explanation for the disparity between these results is that autistic individuals use compensatory strategies in order to consciously pass direct theory of mind tasks. One potential such compensatory technique is the use of language to ‘hack out’ a logical solution to the task (Happé, 1995). Language has previously been shown to play an important role in ToM acquisition in neurotypical children (De Villiers & De Villiers, 2014), and appears to play a prevalent role in ToM use in autistic children. A meta-analysis on studies conducted across a five-year period revealed that autistic children display a minimum verbal mental age barrier, before which they cannot pass direct ToM tasks, and also a higher verbal mental age barrier, after which all participants can pass a direct ToM task (Happé, 1995). Further, previous research has demonstrated that whilst verbal ability is not correlated with ToM task completion for NT individuals, it is significantly correlated with task competence for autistic children (Lind & Bowler, 2009) and that whilst autistic individuals are able to pass direct tasks that rely on verbal ability (such as the ‘Sally-Anne’ task), they demonstrate difficulties with direct tasks that are not reliant on the use of language (Schuwerk et al., 2015). This suggests that autistic individuals use language as a compensatory strategy which would allow them to solve a theory of mind task, which suggests that autistic individuals are potentially capable of passing a theory of mind task without the use of mentalising.

An alternative suggestion is that autistic individuals can actively learn how to mentalise. Research has demonstrated that autistic individuals who show failures in implicit mentalising on indirect anticipatory looking paradigms, can show significant improvements in task performance if they are able to witness the consequences resulting from the false belief (Schuwerk et al., 2015). This suggests that providing a participant with an active association from which they can learn to predict actions can thereby lead to improvements in implicit ToM processes (Sodian et al., 2015). However, in contrast, other multi-trial experiments have failed to find a learning effect, with autistic individuals demonstrating consistent failures in implicit mentalising over multiple concurrent trials across the course of one hour (Schneider et al., 2013).

On balance, the evidence discussed above indicates that autistic individuals exhibit difficulties with implicit mentalising. This conclusion therefore raises an important empirical question – do these difficulties effect, or lead to problems in, other areas of the individual’s life? This idea of a ‘knock-on effect’ has resonated throughout many recent papers. It is argued that difficulties in the ability to spontaneously ‘mind-read’ can contribute to the wider ranging characteristics associated with Autism Spectrum Conditions (Happé, 2015). The ability to understand other’s belief and intentions can affect our ability to communicate efficiently with those around us, for example, distinguishing sarcasm and the pragmatics of a sentence. Likewise, this would also prevent the acquiring of key information from our social surroundings. Hanley et al., (2015) argue that failure to extract social information from eyes/faces not only leads to exclusion from the social information within our environment, but could also contribute to atypicalities in attending to eyes. Why attend to features which contain no information? However, alternative views would argue against such a ‘domain-specific’ explanation for the traits associated with autism, arguing that we should not presume that all developmental outcomes can be traced back to one underlying domain (Leekam, 2016). Although both views discussed here provide differing explanations for the atypicalities autistic individuals experience with implicit mentalising, it is very clear that the implications from mentalising research should be discussed beyond what is found in the lab. As a phenomenon, mentalising permeates our daily lives, guiding our interactions, it is therefore imperative that research should seek to investigate how mentalising likely responds in real-to-life environments.

# *1.5. The Effect of a Social Presence on Mentalising*

Of critical relevance, many theory of mind tasks are administered via an experimenter (i.e. with a social presence), it is therefore imperative that studies attempt to assess the impact of social presence on participant behaviour. However, to date, few studies have examined the effect of a social presence on mentalising behaviour. Expanding on this, at the current time there are a distinct lack of experiments investigating the effect of social presence on explicit and implicit mentalising in autistic adults. Due to the overall lack of naturalistic studies researching explicit/implicit mentalising in autistic adults, it is therefore difficult to predict how performance on theory of mind tasks would behave in a more social context. For example, whilst some researchers would argue that it is unlikely that compensatory strategies are applied outside of typical lab tasks (Lind & Bowler, 2009); others would argue that, on the contrary, autistic adults mask their deficits in ToM through the use of compensatory strategies (Senju et al., 2009).

Whilst there are few studies that have directly investigated the effect of differing social stimuli on mentalising, studies have suggested that including individuals as active participants (rather than passive observers) in direct false belief tasks can facilitate the ability to attribute mental states to others (Bialecka-Pikul, Kosno, Bialek & Szpak, 2019; Ferguson, Apperly, Ahmad, Bindemann & Cane, 2015). Further, in a key study Chevallier, Parish-Morris, Tonge, Le, Miller and Schultz (2014) examined the effect of social presence on children’s performance on a direct theory of mind task. Neurotypical and autistic children were asked to view comic strips, which were either shown on a computer screen or presented via an experimenter. They found that both the neurotypical and autistic children performed similarly on the ToM tasks presented via computer. However, when the task was administered via an experimenter the neurotypical children’s performance on the ToM tasks improved, but the autistic children’s performance did not. Furthermore, the neurotypical group performed significantly better than the autistic children in the social context. This was argued to be due to an ‘audience effect’, whereby the neurotypical group performed better in the presence of another, by comparison the autistic children showed a diminished audience effect. The findings from this study suggest that inclusion of a social presence in a direct ToM task can lead to significantly different patterns of results than tasks presented via computer. Therefore, it is necessary to gain a greater understanding of these differences to appreciate the generalisability of the results before applying them to the real world.

The inclusion of social partners is becoming an increasingly important consideration across social cognition research, and recent studies have begun to reveal the critical impact of social interactions on mentalising abilities. Of key consideration, the use of fMRI hyperscanning techniques have revealed significant differences in the activation of areas of the mentalising network during real-time ‘second-person’ social interactions, as compared to traditional ‘third-person’ observation paradigms. Critically, parts of the mentalising network have been found to engage in response to a real-time social presence, even when there are no explicit mentalising demands, but that these same areas are not engaged for the same scenario with cartoon stimuli (Redcay & Schilbach, 2019). It has been proposed that this provides evidence for continual implicit processing of our social partners (Redcay & Schilbach, 2019). Further, it is suggested that this implicit processing is what drives our understanding of our social partners and, as such, is significantly more important in real-time social interactions (Lehmann et al., 2019). However, whilst this research has begun to yield new and critical discoveries regarding the importance of social interactions in mentalising research, there is still little understanding regarding the behavioural impact of a social presence upon implicit mentalising behaviour.

Further evidence for the potential importance of naturalistic stimuli in implicit mentalising can be drawn from studies with non-human primates. Whilst studies have consistently shown evidence of *explicit* theory of mind abilities in non-human primates, until relatively recently studies had failed to find evidence of similar *implicit* mentalising abilities. However, a recent study, utilising a paradigm featuring (human) task protagonists engaged in naturalistic scenarios, found that chimpanzees can demonstrate evidence of implicit mentalising behaviour (Krupenye Kano, Hirata, Call & Tomasello, 2016). This suggests that the inclusion of naturalistic social scenarios was sufficient to generate evidence of spontaneous belief tracking in non-human primates. This effect is yet to be fully replicated, or investigated, in humans, with only one study to date demonstrating that naturalistic stimuli can lead to a numerical improvement in implicit mentalising performance, although this improvement was not statistically significant (Kulke, Wübker & Rakoczy, 2019). It is therefore critical that future research attempts to gain a greater understanding of the effects of using more ecologically valid paradigms, including the inclusion of social partners, in mentalising research.

Whilst there are no studies which have directly investigated the effect of a social presence on implicit mentalising, there are studies which have used indirect tasks that have included a real time social presence. One such study involved the use of an anticipatory looking paradigm featuring a real-time social presence with autistic children (Hanley, Riby, McCormack, Carty, Coyle, Crozier, Robinson & McPhillips, 2014). Participants were asked to watch a magician ‘practice’ magic tricks, during which an unexpected event occurred (the magician’s hand puppet was stolen), participant’s anticipatory looks back to the magician’s face were taken as a measure of spontaneous mentalising. Hanley et al., found that the autistic group showed significantly longer latencies to return their gaze to the magician’s face, as well as overall reduced attention to the eyes/face. This suggests that autistic individuals may exhibit underlying difficulties with implicit mentalising that may be apparent across both lab and more naturalistic, face-to-face tasks. Nevertheless, the primary initiative of the experiment was not to investigate the effect of social presence and therefore it lacks a control condition, which would allow a comparison for the effects of a social presence.

The suggestion that different kinds of stimuli can elicit different patterns of behaviour in mentalising tasks is a serious consideration for future research. This is of particular relevance when we consider that the method of administration of theory of mind tasks can differ considerably across different studies. Whilst one study may use static, schematic images (Baron-Cohen, Leslie & Frith, 1985; van der Wel et al., 2014), another may use naturalistic, dynamic stimuli (Schulze & Tomasello, 2015). These paradigms clearly differ in the complexity of the stimuli used, and yet the conclusions drawn from each experiment are broadly accepted as analogous (Cole et al., 2018).

A greater concern when examining the paradigms used to investigate explicit and implicit mentalising is that task demand and task complexity are generally not equivalent for direct and indirect tasks, often very different procedures are used for each respective task. Indirect tasks most often utilise variations of false belief paradigms, however, direct tasks can range from using the ‘mind in the eyes’ task, ‘smarties task’ or ‘strange stories’ task, right up to second order false belief paradigms, all of which are considered to provide a coherent measure of explicit mentalising ability (Cole et al., 2018). Specifically, previous studies tend to use highly structured direct tasks, but less structured and more dynamic indirect tasks. The use of such differing tasks therefore makes it difficult to compare and differentiate between how the two systems behave, with findings from one task ungeneralisable to the other (Rosenblau et al., 2015). Further, the deficits associated with autism are typically more apparent in unstructured dynamic environments (Klin et al., 2002), and so there is the potential that these task differences could contribute to poorer indirect task performance.

Previous research has demonstrated that the characteristics of an ASC are typically most evident in scenarios featuring complex social stimuli (Klin et al., 2002; Hanley et al., 2013). Therefore, it would not be unexpected that the use of a social presence (real or implied) could serve to exaggerate the difficulties autistic individuals demonstrate with theory of mind tasks. More recently it has been argued that the use of simplistic, non-social stimuli in direct tasks could be an underlying factor in how autistic individuals are able to demonstrate comparable performance to neurotypical individuals, thereby perpetuating the assumption of comparable explicit mentalising competence (Cole et al., 2018). In support of this claim, studies that have sought to use complex, naturalistic stimuli for direct tasks have found that autistic adults do demonstrate difficulties with explicit mentalising (Cole et al., 2018; Rosenblau et al., 2015). Further, when directly comparing performance between a simple and complex direct task within participants, it is found that autistic adults demonstrate difficulties only on the complex, naturalistic task (Ponnet, Roeyers, Buysse, De Clercq & Van Der Heyden, 2004). This therefore suggests the use of more naturalistic stimuli, such as tasks featuring a social presence, may lead to different patterns of behaviour than paradigms featuring two-dimensional, simplistic stimuli. Further, the use of naturalistic stimuli would promote the participants’ use of everyday behaviours; allowing key insights into how a person utilises their ability to mentalise outside of a lab environment (Rosenblau et al., 2015).

# *1.6. Overview of Thesis Chapters and Aims*

In summary, from the research discussed above it is clear that we need to better understand the effects of the inclusion of social partners in social cognition research. As a species humans are incredibly social, therefore it appears counterintuitive that much traditional social cognition research has been conducted in isolation. As outlined in the sections above, humans are incredibly sensitive to the presence of social partners, and this sensitivity remains regardless of whether a paradigm uses a real-time social presence or if the social presence is implied via manipulating a participant’s perspective of a stimulus. However, to date there are few studies which have aimed to directly test the effect of a social presence on cognitive tasks for autistic individuals. Further, whilst social presence has been shown to effect social attention and eye movement behaviour, it is yet to be determined the extent to which it effects other areas of social cognition, such as in theory of mind research.

Taken from the research discussed throughout this chapter it can reasonably be expected that social presence is likely to lead to behavioural differences for both neurotypical and autistic individuals on social cognition tasks. The aim of this thesis is therefore to investigate the effect of a social presence, both real and implied, on cognitive tasks in both neurotypical and autistic adults. In line with previous research it is predicted that neurotypical individuals will perform significantly better on cognitive tasks when in the presence of a real social partner. In contrast, it is predicted that autistic individuals will not show the same improvement. This thesis will aim to investigate the precise effect of a social presence on autistic individuals, in particular whether it negatively impacts task performance or whether it has no significant effect on task completion.

The aims of the thesis are addressed in the following sequence of empirical chapters: Chapter 2) Are autistic adults sensitive to social agency when interpreting patterns and forming predictions? Chapter 3) The effect of social presence and autistic traits on implicit and explicit mentalising in a first order theory of mind task; Chapter 4) The effect of social presence, autistic traits and autism spectrum conditions on implicit and explicit mentalising in a second order theory of mind task. These empirical chapters are followed by a general discussion, Chapter 5) where key findings are discussed and overarching conclusions drawn.

# **Chapter 2: Autistic adults are sensitive to social agency when interpreting patterns and forming predictions.**

# **2.1. Introduction**

The literature review in Chapter 1 revealed that humans are remarkably sensitive to the presence of social partners, and that this sensitivity can lead to changes in behaviour for neurotypical individuals. This sensitivity has been shown to extend beyond a mere awareness of the presence of other people. In particular, humans are considered to be especially attuned to patterns arising from the behaviour of social partners. This skill is thought to arise from theory of mind processing, enabling an understanding of the preferences and choices of others (Gopnik & Wellman, 2012; Hudson, Bach & Nicholson, 2018). However, as discussed in Chapter 1, individuals with a diagnosis of an ASC typically show difficulties with theory of mind processing, and are also less sensitive to detecting patterns derived from the behaviour of social partners (White et al., 2011; Schuwerk et al., 2016; Schneider et al., 2013). The aim of the current chapter was therefore to investigate whether autistic adults are sensitive to social agency and are able to accurately form predictions relating to social patterns of behaviour.

Pattern recognition enables us to learn and develop adaptive responses to the many scenarios we encounter within our daily lives (Mattson, 2014). This is of particular relevance in today’s modern society where we are exposed to numerous patterns emerging from both social and non-social sources. In our day to day life we encounter many instances of patterns generated through computer algorithms, from traffic signals telling us when to ‘stop’ or ‘go’, to those found within our electronic navigation devices and apps. We can identify patterns and form contingencies and predictions from observation of these non-social algorithms (Clark, 2013). Further, these predictions are continuously updated as a means of monitoring our environment and, once formed, a prediction is not fixed but in a constant process of revision; adjusted continually according to how probable we believe an action to be (Darriba & Waszak, 2018). Effective engagement in this pattern recognition process therefore furthers our understanding of our environment.

Patterns can arise from any number of sources within our environment, but humans are particularly adept at recognising social patterns relating to others (Hudson, Bach & Nicholson, 2018). Across development the attention we direct to the actions of our social partners becomes increasingly selective, with a narrowed focus directed to physical features capable of conveying social intentions e.g. a hand motion (Simion et al., 2008). This is thought to aid in the prediction of others’ actions and the outcomes of those actions (Loucks & Sommerville, 2013). The ability to predict social behaviours arises not only as a consequence of observation, but also as a result of higher order mental processing, which enables the attribution of preferences and beliefs to others (Bach & Schenke, 2017). This awareness is thought to be due to theory of mind processing, allowing the ability to identify the thought processes and intentions behind a given behaviour (Baron-Cohen, Leslie & Frith, 1985). For example, it has been shown that we can actively update our predictions of an action based upon our knowledge of an actor’s intentions (Hudson et al., 2018). This heightened sensitivity to the behaviour of others suggests that individuals may therefore be significantly more able to predict patterns and contingencies arising from social, as compared to non-social, entities.

In line with these expectations, the use of socially relevant stimuli has been shown to affect neurotypical participants’ performance on cognitive tasks. Recent research has shown that even simply manipulating the perception of a cue as having social agency is sufficient to drive changes in attentional orienting. Wiese et al., (2012) showed participants images of both human and robot faces. Participants were informed that the eye movements of the face could be controlled by either a human or a robot. They found that gaze cueing effects were significantly larger when participants believed the faces were controlled by a human agent- regardless of whether they viewed a human or robot face. This demonstrates that humans are sensitive to the social properties of a stimulus, displaying a social facilitation effect and better task performance when a cue is perceived to possess social agency.

Further, in a key study, Gobel et al., (2018) aimed to investigate whether it is the social appearance or the social relevance of a cue that drives the redistribution of attention. To do this they manipulated the perceived social agency of a cue, with the cue itself lacking any inherent social features. Prior to the presentation of a stimulus participants were presented with a cue (a small red dot), which they were informed either indicated where another participant had preferentially looked during the same trial, or which had been selected at random by a computer algorithm. It is important to note that the properties of the stimulus did not deviate between conditions, only the description of its nature was altered. The social manipulation was found to modulate inter-personal spatial orienting, with participants’ eye gaze aligning with the red dot significantly more when they believed the cue to have social agency. From this they concluded that attentional orienting in relation to social stimuli is not exclusively reliant on the physical properties of the stimulus. Taken together the studies conducted by Wiese et al., (2012) and Gobel et al., (2018) suggest that humans use patterns emerging from social stimuli to guide their own behaviour, and that the use of social stimuli can lead to measurable changes in task performance. Of critical relevance, Gobel et al.,’s (2017) study also suggests that we are sensitive to the behavioural patterns of others when inferring and predicting another person’s intentions.

It has been argued that autistic individuals have ‘strong systemising’ abilities, which promote heightened attention to detail and allow advanced capabilities in pattern recognition (Baron-Cohen, Ashwin, Ashwin, Tavassoli & Chakrabarti, 2009). Systemising involves the identification of associations and rules which together allow predictions to be made regarding the outcome of certain patterns of behaviour (Baron-Cohen, 2006). This heightened attention to detail has been linked to enhanced perceptual functioning in autism (Mottron, Dawson, Solieres, Hubert & Burack, 2006), with autistic individuals demonstrating superior performance to neurotypical individuals on tasks associated with pattern recognition (Caron, Mottron, Rainville & Chouinard, 2004). However, whilst individuals with a diagnosis of an ASC show strong pattern recognition abilities for non-social stimuli, research would suggest that they are less sensitive to patterns of social behaviour. For example, autistic children perform significantly worse than NT children when predictive tasks require an understanding of mental processes and intentions (Baron-Cohen et al.,1986). This is thought to arise as a result of difficulties in theory of mind abilities (Senju et al., 2009; Schuwerk et al., 2015; Schuwerk et al., 2016; Baron-Cohen et al., 1985), with difficulties in understanding and attributing intentions and motives to others leading to difficulties in predicting subsequent behaviour. Further, it has been proposed that the traits associated with an autism diagnosis (insistence on sameness; difficulties with action prediction; difficulties with theory of mind ability) can lead to overall difficulties in forming predictions for occurrences within everyday life (Sinha et al., 2014).

Previous research has demonstrated that autistic individuals experience difficulties in discriminating patterns of biological motion (Klin, Lin, Gorrindo, Ramsay & Jones, 2009; Kaiser & Shiffrar, 2012). One explanation for this finding can be drawn from the Bayesian and predictive coding framework accounts of perception. Discriminating and interpreting social stimuli relies upon higher-order perceptual processing and the ability to integrate specific, local stimulus details into a global bigger picture (Mottron, Dawson, Soulieres, Hubert & Burack, 2006). However, both the Bayesian and predictive coding framework account outline key differences in higher-order perceptual processing abilities in autistic individuals. The Bayesian account argues that NT individuals’ perceptual abilities are informed by ‘priors’ (prior contextual information) that allow us to generate specific predictions that guide our processing of perceptual stimuli (Pellicano & Burr, 2012). An autism diagnosis is argued to lead to ‘hypo-priors’ where an individual is unable to successfully integrate their prior perceptual experiences, leading to an attenuation in their ability to make successful higher-order predictions. The ‘predicting coding framework’ expands upon the Bayesian account and argues that hypo-priors often lead to a mismatch between higher-order predictions and lower-order sensory input (Van Boxtel & Lu, 2013). These errors lead to an overreliance on the exogenous attention system and a heavy reliance on lower-order processing in order to process sensory stimuli (van Boxtel & Lu, 2013). The implications of these accounts are critical, as much previous research has demonstrated that biological motion perception is dependent on higher-order global processing. Impairments in these abilities, and an overreliance on low-level, local processing, can therefore be seen as critical exponents of the difficulties autistic individuals experience in recognising patterns of behaviour from biological movements (van Boxtel & Lu, 2013).

As discussed, neurotypical participants’ attention can be altered by the belief that a cue is under the control of another human, rather than if it is believed to be under the control of a computer algorithm (Wiese et al., 2012; Gobel et al., 2017). However, based on previous research it would be expected that this would not be the case for individuals with a diagnosis of ASC (Senju et al., 2009; Schneider et al., 2013; Schuwerk et al., 2015; Schuwerk et al., 2016). The ability to discern patterns from social behaviour is a critical contributor to the ability to function as a member of a social group (Frost et al., 2013; Mattson, 2014). Therefore, if autistic individuals have difficulties interpreting patterns from social sources then this would hinder their ability to integrate information from social scenarios into an understanding of the world. However, this specific prediction has not previously been tested. The aim of this research was therefore to investigate the effect of manipulating the social agency of a cue in neurotypical and autistic adults. In particular, to investigate whether autistic adults show difficulties in their ability to accurately form predictions relating to social, as compared to non-social, patterns of behaviour.

The current study took the form of an online experiment and used an adaptation of a paradigm previously used by Foulsham and Lock (2015). In one part of that study, participants completed a preference task in which they chose which of four abstract patterns they preferred, while their eye movements were recorded. In a subsequent, “guess” task participants were then asked to watch the eye movements of another participant (represented by animations of a moving red dot) and guess which image the other participant had chosen. The findings indicated that participants were sensitive to the patterns of gaze behaviour and were able to accurately identify which design had been chosen by the previous participant, suggesting that participants were aware of the systematic patterns associated with making a choice. In the present studies, we also investigated how well naïve participants could judge preference based on the movements of a cursor – using the participant eye movement animations from Foulsham and Lock. However, unlike Foulsham and Lock’s study, the current study included a ‘non-social agency attribution’ part and a ‘social agency attribution’ part, as described below.

During the ‘non-social agency attribution’ part of the study participants were informed that they would view an animation of a red dot, which represented a computer algorithm selector, and would be asked to identify which of four designs they believe was selected by the algorithm. In the ‘social agency attribution’ part of the experiment the participants were instead informed that the red dot represented the eye movements of *another participant*, and they were then asked to choose which design that participant had selected. In addition to being asked to identify which design had been selected, participants indicated on a likert scale how easy they found completing the non-social agency attribution and social agency attribution version of the task. The main experiment used a within-subjects design, with all participants first completing the non-social part of the study, followed by the social part of the study. The order of conditions was not counterbalanced between participants the main experiment as previous research has demonstrated that once a stimulus is identified as having social agency (e.g. representing eyes) participants are unable to disregard the attribution and therefore continue to show gaze cueing effects even if the cue is subsequently labelled as being non-social (Ristic & Kingstone, 2005). However, in order to confirm that any differences observed between conditions in the main experiment could not be attributed to order effects, a second ‘control experiment’ was conducted which used a between-participants design with neurotypical participants. In the control experiment, participants completed *only* the non-social agency attribution or the social agency attribution part of the study.

In summary, this study aimed to investigate whether manipulating participants’ perception of a cue as having social agency would affect performance on a prediction task. Based upon previous research (Wiese et al., 2012; Gobel et al., 2017) it was predicted that NT adults would be significantly more accurate at identifying which design was selected in the social agency attribution, compared to the non-social agency attribution condition. Of central focus, the Bayesian account/predictive coding framework of perception (van Boxtel & Lu, 2013; Pellicano & Burr, 2012) indicates that autistic individuals demonstrate difficulties with the higher-order processing necessary to interpret biological motion, it was therefore predicted that autistic adults would not show the same improvement in accuracy as the NT controls when in the social agency condition. Further to this, it was predicted that autistic adults would find the social agency attribution condition significantly more difficult to complete than NT adults, with previous research demonstrating that the social difficulties associated with an ASC are more pronounced when increasing the social complexity of a stimulus (Klin et al., 2002; Hanley et al., 2013). In line with this prediction it was also expected that accuracy in the social agency attribution part of the study would be negatively related to the level of self-reported social difficulties, with those reporting higher levels of social difficulties being less able to identify which of the designs had been selected by the eye movements of another participant. If autistic adults do not show the same improvement as NT controls in the social agency attribution condition then this would support previous research demonstrating that people with a diagnosis of ASC are less sensitive to the presence of social others (Chevallier, Kohls, Troiani, Brodkin & Schultz, 2012; Chevallier et al., 2014), and show difficulty in detecting patterns and forming inferences from the behaviour of social partners (Abell et al., 2000; White et al., 2011; Schuwerk., 2016; Schneider., 2013; Baron-Cohen et al., 1986). However, if autistic adults do show improved performance given the knowledge that the cue presented has social agency, this would demonstrate that they do show a social facilitation effect and therefore difficulties in predicting social behaviours do not arise from a lack of sensitivity to social agency.

# **2.2. Method: Main Experiment**

# *2.2.1. Participants*

An a-priori power analysis revealed that on the basis of a medium effect size (*d* =.50), approximately 64 participants would be needed in each group to obtain statistical power at the .80 level. However, the online experiment encountered technical difficulties which led to a large loss of a data, for the main experiment this left a sample of 32 participants with a diagnosis of an Autism Spectrum Condition (ASC) (11 female, 21 male) and 32 age and gender matched Neurotypical (NT) Controls (11 female, 21 male). Participants with a diagnosis of ASC were recruited from the Sheffield Autism Research Lab (ShARL) database and received a gift voucher as a thank you for taking part. All Autistic participants had previously received a diagnosis of either ‘Aspergers’ or ‘Autism Spectrum Condition’ from a qualified clinician. The NT participants were recruited via the online crowd-sourcing platform “Prolific” and received a monetary compensation as a thank you for their time. The study was approved by the Department of Psychology Ethics Committee, and all participants gave informed consent before participating.

Three participants from the autistic group were excluded for failure to follow task instructions. A further two participants from the NT group scored more than 3 SD from the mean for task accuracy and were also removed from the analysis. All participants also completed the Social Responsiveness Scale (2nd Ed.) (SRS-2) as a measure of the level of social impairment associated with an autism diagnosis. Three NT participants scored over the threshold for clinical relevance on the SRS-2 and so were excluded from the final analysis. This left a total of 29 participants with an ASC diagnosis, and 27 neurotypical controls (Table 1). An independent samples *t*-test indicated a highly significant difference between groups on SRS-2 t-scores*, t*(37.5)=9.643*, p*<.001, *d*=3.15.

*Table 1.**Participant characteristics*

|  |  |  |
| --- | --- | --- |
|  | Autistic participants | Neurotypical participants |
| Gender (Male : Female) | 19 : 10 | 19 : 8 |
| Age |  |  |
| Mean | 35.9 | 36.7 |
| SD | 12.4 | 11.2 |
| Range | 21 – 60 | 23 – 58 |
| SRS-2 |  |  |
| Mean | 74.3\*\* | 52\*\* |
| SD | 11.5 | 4.7 |
| Range | 52 – 95 | 44-59 |

\*\* denotes significant between group difference, *p<*.001

# *2.2.2. Design*

The main experiment used a mixed-measures design with one between-subjects independent factor of ‘group’ (autistic or NT), and one within-subjects independent factor of ‘condition’ (non-social agency attribution or social agency attribution). The study paradigm was a prediction task, which required participants to correctly identify which of four designs had been selected by an animated red dot.

# *2.2.3. Materials & Apparatus*

The study was conducted online through the use of the online survey platform ‘Qualtrics’. The stimuli in each trial were animations based on data collected by Foulsham and Lock (2015). In each case, four designs from freely available collections (<http://www.nahee.com/spanky/index.html>) were displayed in a grid on a white background. These designs were colourful computer-generated artwork with no inherent meaning, ensuring that preferences for the designs were idiosyncratic. One hundred and forty-four designs were used in total and each design was randomly assigned to a group of four. Animations consisted of a red dot moving around the screen displaying the four designs. The trajectory of the red dot matched the eye movements of two representative participants (neurotypicals) from Foulsham and Lock (2015, Experiment 1) who were asked to view the four designs and indicate which of the designs they preferred. On average the duration of each clip was 4.3 seconds, and the clips were encoded as FLV files with a frame rate of 24fps.

Each participant also completed the Social Responsiveness Scale (2nd Ed.) (SRS-2), a 65-item questionnaire designed to test the severity of social impairments associated with autism spectrum conditions. A clinical cut-off of a total t-score of ≥ 60 was used to distinguish between scores associated with neurotypical performance, and those associated with an ASC diagnosis (Constantino & Gruber 2012). The SRS-2 has demonstrated a high sensitivity (>78%) to detecting social impairments associated with autism, and therefore was suitable for use in this study to confirm the range of social impairment present within the autistic group, and to control for individuals with high levels of social impairments in the NT group. Only NT participants that scored below the cut-off were included in the final sample.

# *2.2.4. Procedure*

Prior to starting the main experiment each participant completed three practice trials. Each trial consisted of a five second countdown to a short clip, featuring the red dot moving over the four designs, after which it disappeared. Following the clip the participant was then asked to indicate which of the four designs they thought had been selected by the red dot (figure 1).



5 second count- down to clip

Clip plays (~4.3 sec). Red dot moves over and across the four designs then disappears

Clip ends. Participant selects which design they believe was chosen

Figure 1. The trial procedure. Designs were presented at random in each trial.

During the practice trials the participant viewed each clip three times before being prompted to make a selection, but during the main part of the experiment the participant could only view each clip once prior to making the selection. The repetition of video clips during the practice trials allowed participants time to familiarise themselves with the presentation of the video stimuli prior to beginning the main experiment. For study Part 1 participants were informed that “the red dot represents a computer program while it was selecting an image”; the non-social agency attribution part of the study. Before starting each part of the experiment, the participant was asked to state what the red dot represented. Following completion of the non-social agency attribution trials each participant was then asked to respond to a series of questions asking how easily they were able to guess which of the patterns was selected, and what was important in helping them make their decision (i.e. what strategies they used).

During the second part of the study participants were instead informed that “the red dot represents the eye movements of another participant while they were selecting an image”; the social agency attribution part of the study. The participant was again asked to confirm what the red dot represented prior to starting the next part of the study. Upon completion of the second part of the study the participants were again asked to confirm the ease with which they could identify the chosen design, what strategies they used to aid the identification and, additionally, if they had noticed any differences between the two parts or used different strategies in each part of the study. Each part of the study included 18 trials in a randomized order, with each participant completing 36 trials in total. Importantly, due to the counterbalancing described above, the exact same clips appeared in both Part 1 (the non-social agency attribution) and Part 2 (the social agency attribution), so any differences in guesses cannot be related to differences between the clips. Following completion of the main experiment participants were asked to complete the SRS-2, before receiving a full debrief as to the aims of the experiment.

# **2.3. Results: Main Experiment**

# *2.3.1. Group Accuracy in the Social Agency Attribution and Non-Social Agency Attribution Condition*

Accuracy was determined by comparing the participant’s guess with the ground-truth choice made by the original, eye-tracked participant. The proportion of correctly identified designs was determined for each participant for each condition by calculating how many designs they correctly identified out of the total number of trials in each condition. A 2x2 mixed model ANOVA, with a within-subject factor of condition (social agency attribution/non-social agency attribution) and a between-subjects factor of group (autistic/NT) on the proportion of correctly chosen designs revealed a main effect of condition (*F*(1,54)=10.096, *p=.*002, *ηρ²*=.158), as the proportion of correct responses was greater in the social, eye movement cue, condition (M=.68, SD= .13) compared to the non-social, computer algorithm cue, condition (M=.61, SD=.12 ). There was also a main effect of group (*F*(1,54)=4.896, *p=.*031, *ηρ²*=.083), as the proportion of correct responses was greater for the NT group (M=.68, SD=.05) compared to the autistic group (M= .62, SD=.12). However, there was no condition x group interaction (*F*(1,54)=.014, *p=.*906, *ηρ²*<.001), demonstrating that both groups responded similarly to the manipulation of the perception of the stimulus as social or non-social. Paired samples t-tests confirmed that both the autistic (*t*(28)=-2.265, *p=*.031, *r=*.155) and NT (*t*(26)= -2.226, *p*=.035, *r=*.160) group were significantly more accurate at predicting which design was chosen in the social agency attribution, compared to the non-social agency attribution, condition (Figure 2).

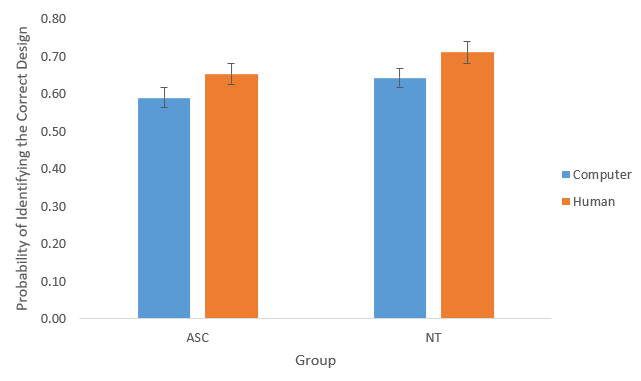


Figure 2**.** The proportion of correct responses for each group in each condition (social/non-social, ASC/NT). Error bars show +/−1 within-subject standard error of the mean (S.E.M). The dashed line indicates chance.

\*

\*

Proportion of Correct Responses

# *2.3.2. Order Effects*

In order to determine that the improvement between the first and second part of the study was not likely explained by order effects, we compared performance between the first half of the trials and the second half of the trials for each part of the study. Paired samples t-tests revealed that in the computer condition there was no significant difference in accuracy between the first half of the trials (M=0.62, SD=0.19) and the second half of the trials (M=0.63, SD=0.18; t(55)=-.149, *p=*.882, *r=*.02). Further, there was also no significant difference in accuracy in the eye movement condition between the first half of the trials (M=0.68, SD=0.17) and the second half of the trials (M=0.68, SD=0.17; t(55)= .112, *p=* .911, *r=*.02). This analysis suggests that the significant improvement in accuracy between the non-social agency attribution and social agency attribution conditions is not explained by order effects (Figure 3). However, in order to confirm that the effect found in this main study was definitely due to the manipulation of the cue, we conducted a follow up control study which tested whether participants who only believed a cue to represent the eye movements of another participant were significantly more accurate at the task than participants who only believed the cue to represent a computer algorithm (see control study below).

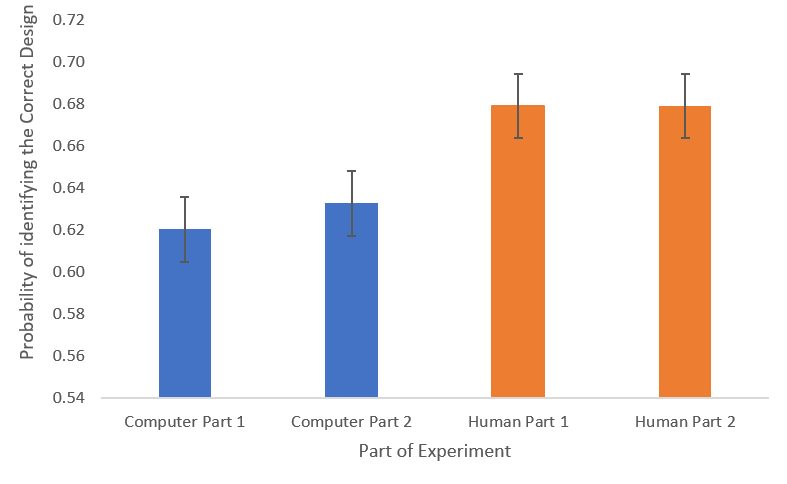


Figure 3. The proportion of correct responses for the first and second half of trials in each condition. Error bars show +/−1 within-subject standard error of the mean (S.E.M).

Proportion of Correct Responses

# *2.3.3. Ease of Completion*

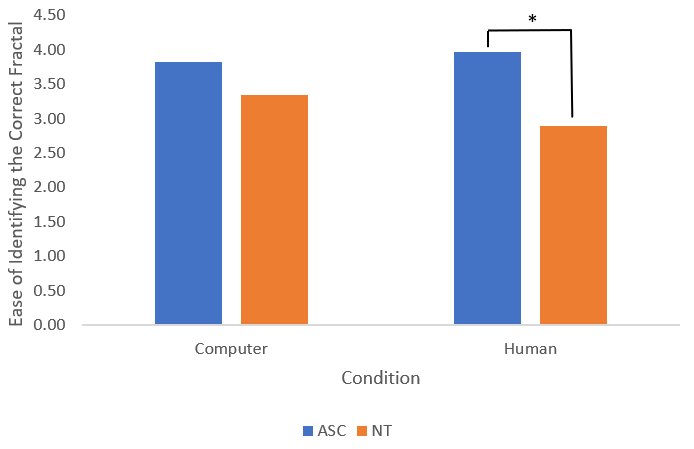
At the end of each part of the study participants were asked to rate on a Likert scale ‘How easy did you find it to guess which of the patterns was selected?’ The scale ranged from 1 – ‘Very Difficult’ to 7 – ‘Very Easy’. Planned comparisons investigated whether the NT and autistic groups differed in the ease with which they reported completing the task in the social agency attribution or non-social agency attribution conditions. The Likert scale data was ordinal; therefore Mann-Whitney U tests were used. The results revealed that in the social agency attribution condition autistic participants (Med=2.00) reported finding it significantly more difficult to identify the chosen design then the NT participants (Med=4.00; U=-2.604, *p=.*009, *r*=.35). In contrast, in the non-social agency attribution condition participants did not display this effect and there was no difference in reported difficulty between the autistic (Med=3.00) and NT groups (Med=3.00; U=-1.263, *p=.*207, *r*=.17*).* Therefore, despite the fact that the only change made to the stimuli was the way in which they were described (eye movements vs computer algorithm), the groups differed in their estimates of difficulty (Figure 4). Whilst The NT participants reported finding the second block easier, which is in line with their improved performance. Autistic participants showed a different pattern, reporting that the social agency attribution condition was more difficult (when, in fact, they were also better at accurately predicting which design had been selected in the eye-movement condition than in the computer algorithm condition).

Figure 4. The ease of identifying the correct design in each condition for each group (social/non-social, autistic/NT). Error bars show +/−1 within-subject standard error of the mean (S.E.M).

In order to test whether individual perceptions of difficulty were related to how well each person performed on the task, Spearman’s Rho correlations were conducted between the self-rating of task difficulty and actual task performance. The results revealed that ease of completion did not correlate with task accuracy in the social agency attribution condition for either the NT (r=.024, *p=.*906) or autistic (r=.154, *p=.*425) group. Likewise, there was also no correlation between ease of completion and task accuracy in the non-social agency attribution condition for either the NT (r=-.146, *p=.*467) or autistic (r=.194, *p=.*314) group. This suggests that individual differences in perceived task difficulty did not reflect the NT or autistic groups’ accuracy in either the social agency attribution or non-social agency attribution condition.

# *2.3.4. Strategy Use in the Social Agency Attribution and Non-Social Agency Attribution Condition*

Next, we aimed to test whether the autistic and NT groups used different strategies in order to identify the chosen design. Upon completion of each condition participants were asked to identify the strategies they used in order to select the chosen design; they were asked to identify as many strategies as applied. The total number of respondents for each strategy in each condition is shown below (Table 2):

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Control** | | | **Autistic** | | |
| **Part 1 Question / Part 2 Question** | **Non-Social (%)** | **Social (%)** | | **Non-Social (%)** | **Social (%)** | |
| **What I thought was the best item** | 4 | | 4 | 3 | | 3 |
| **Where the dot moved/Where the person looked** | 44 | | 41 | 62 | | 52 |
| **How long or how much the dot selected a pattern/they looked** | 26 | | 37 | 31 | | 48 |
| **Where the dot moved first/ What they looked at first** | 4 | | 7 | 0 | | 3 |
| **Where the dot moved last/ What they looked at last** | 89 | | 85 | 79 | | 62 |
| **Where the dot didn't move/ What they didn't look at** | 11 | | 15 | 7 | | 7 |
| **My previous knowledge about computers/ about people** | 7 | | 0 | 14 | | 3 |
| **I guessed** | 7 | | 7 | 10 | | 10 |
| **Other** | 0 | | 4 | 0 | | 0 |

Table 2. Percentage of participants in the autistic and NT groups who used each strategy to identify the chosen design in the social and non-social condition.

Visual inspection of the strategy-use percentages indicated that each group used similar strategies, with the three most commonly used strategies in both the autistic and NT group being ‘where the dot moved/where the person looked’; ‘how long or how much the dot selected a pattern/they looked’; and ‘where the dot moved last/where they looked last’.

# *2.3.5. Social Responsiveness Scale Scores*

To investigate whether task accuracy was related to the level of self-reported social difficulties, Pearson’s correlations were used to assess the relationship between task performance and SRS-2 t-scores. SRS-2 t-scores were not significantly correlated with performance for NT participants in either the first part (r=.264, *p=*.184) or second part (r=.273, *p=*.168) of the study. Further, SRS-2 t-scores were also not significantly correlated with performance for autistic participants in either the first part (r=.029, *p=*.883) or second part (r=.089, *p=*.645) of the study. Therefore, sensitivity to the social agency of the cue was not related to the level of social impairment shown by either autistic or NT participants.

# **2.4. Method: Control Experiment – Order Effects Check**

# *2.4.1. Participants*

An a priori power analysis revealed that on the basis of the effect size observed in the main experiment (*d*=0.87), 36 participants would be needed in each group in order to obtain statistical power at the .80 level. Therefore, the control experiment recruited 38 neurotypical participants for the non-social agency attribution group (30 Female, M=30.76, SD=9.64, Range=18-60), and recruited 37 age and gender matched participants for the social agency attribution group (30 Female, M=30.41, SD=9.42, Range=19-57). Participants were recruited via the online crowd-sourcing platform “Prolific” and received a monetary compensation as a thank you for their time. The study was approved by the Department of Psychology Ethics Committee, and all participants gave informed consent before participating.

Five participants were excluded who had either received a previous diagnosis of an autism spectrum condition, or who were awaiting an official diagnosis. A further 4 participants were excluded for failing to follow the task instructions (n=3), or having prior knowledge of the task (n=1). For the non-social agency attribution group this left a final sample of 35 participants (28 Female, M=30.77, SD=9.96, Range=18-60); for the social agency attribution group this left a final sample of 31 participants (25 Female, M=30.26, SD=9.62, Range=19-57). Due to the time frame available for participant recruitment, the final sample was slightly less than that indicated by the power analysis.

# *2.4.2. Design*

The control experiment used a between-participants design, with one independent factor of ‘group’ (non-social agency attribution or social agency attribution). The control experiment used the same design and apparatus as outlined for the main experiment.

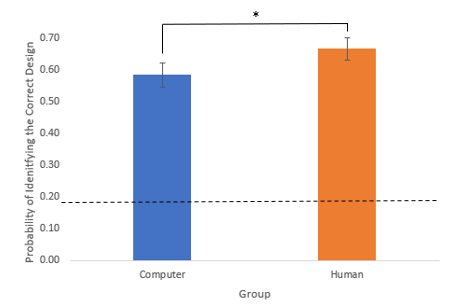
# *2.4.3. Procedure*

The control experiment used a similar procedure to the main experiment. However, for the control experiment, each participant completed *only* the non-social agency attribution or social agency attribution part of the experiment, completing 18 trials in total. As in the main experiment, upon completion of the 18 experimental trials the participants were asked to confirm the ease with which they could identify the chosen design, and what strategies they used to aid the identification of the chosen design.

# **2.5. Results: Control Experiment – Order Effects Check**

The aim of the control experiment was to determine that the improvement between the first and second part of the main experiment was not likely explained by order effects, and that the difference in accuracy between the conditions was due to the experimental manipulation. A Shapiro-Wilk test for normality showed that the data was not normally distributed (*p*<.05); Mann-Whitney U tests revealed a significant difference in accuracy between the non-social agency attribution group (med=.58) and social agency attribution group (med=.67; U=2.262, *p=.*024, *r=*.28), with participants in the social, eye movement, group significantly more accurate at predicting which design was chosen (Figure 5). This therefore confirms that participants performed significantly more accurately when they believed a cue to possess social agency, and that the significant improvement in task accuracy between the non-social agency attribution and social agency attribution condition in the main experiment is not explained by order effects.[[1]](#footnote-1)

Figure 5. The proportion of correct responses for each group (non-social/social). Error bars show +/−1 within-subject standard error of the mean (S.E.M). The dashed line indicates chance.



Proportion of Correct Responses

Average Preferential Looking Score

# **2.6. Discussion**

This study investigated whether manipulating participants’ perception of a cue as having social agency would affect autistic adults’ performance on a prediction task. Neurotypical participants were significantly better than autistic participants at identifying which design had been chosen, however all participants scored well above chance (25%) in both the non-social agency attribution and social agency attribution condition. This demonstrates that even in the non-social agency attribution condition, where participants believe the *cue* they viewed was controlled by a computer algorithm, all of the participants were still able to accurately judge which design had been selected. As predicted, NT participants were significantly better at identifying the correct design when they believed that the cue represented the eye movements of another participant. In contrast to the study hypotheses the results clearly demonstrated that autistic participants also showed a significant improvement when they believed a cue to have social agency, even though they reported finding the social agency attribution condition significantly more difficult to complete then did the NT participants. Further, prediction accuracy was not related to individual differences in social impairment, as indicated by the SRS-2. This therefore provides evidence that autistic adults show the same social facilitation effect as neurotypical adults and can more accurately predict another’s choices given the knowledge that a cue has social agency. This demonstrates that whilst autistic adults may show difficulties in interpreting patterns of social behaviour this does not necessarily arise from a lack of sensitivity to social agency, or from an inability to form predictions of social behaviour on the basis of social agency.

In line with the study hypotheses, NT participants were significantly more accurate at predicting which design would be chosen in the social agency attribution condition when they believed that the dot represented eye movements. This supports a number of previous studies. Firstly, it supports those studies which demonstrate that a cue does not need to display social characteristics in order for participants to show behavioural differences. Instead it appears that simply believing a cue to possess social agency is sufficient to generate top-down processing (Wiese et al., 2012; Foulsham and Lock, 2015; Gobel et al., 2017). Secondly, as this improvement does not rely upon the physical properties of the stimulus this study therefore lends support to research suggesting that these changes occur as a result of the engagement of theory of mind processes (Mattson, 2014; Bach & Schenke, 2017; Hudson et al., 2018), which allow inferences into the mental state of a social partner and promote increased accuracy on the prediction task.

This study shows that autistic adults were significantly more accurate at predicting which design would be chosen when they believed a cue to have social agency, demonstrating a similar sensitivity to the social properties of a stimulus as neurotypical individuals. Further, task performance was found to be unrelated to the level of social impairment associated with an autism spectrum condition (as measured by the SRS-2). This contrasts with previous research which argues that autistic people have difficulty identifying patterns and predicting behaviours which rely upon the integration of social information and theory of mind processes. Of key interest, previous research has argued that autistic individuals show difficulties in their implicit mentalising abilities (Senju et al., 2009; Schneider et al., 2013; Schuwerk et al., 2016), from which we would expect that participants would not be able to make predictions based on mental states. However, this study provides evidence that participants with a diagnosis of ASC inferred the mental state of another participant, which significantly improved the accuracy with which they could identify the chosen design. This suggests that difficulties in implicit mentalising abilities are not universal in autism spectrum conditions.

The finding that autistic adults did spontaneously take account of cue social agency when forming predictions also contrasts with the social motivation theory of autism. The social motivation theory of autism purports that autistic individuals have less interest in social phenomena then neurotypical individuals (Chevallier et al., 2012). For example, Chevallier et al., (2014) found that NT children’s performance on a ToM task improved significantly when the task was administered by an experimenter rather than a computer, in comparison they found that autistic children did not show the same social facilitation effect. The social motivation theory proposes that a lack of social interest may actually be a causal factor of the social difficulties associated with autism, rather than a side effect. However, in contrast to this theory the findings from our study suggest that autistic adults do show comparable social facilitation effects to NT adults, clearly demonstrating that the perception of the cue as being social significantly improved prediction accuracy in both groups.

One potential explanation for improved performance when provided with the critical information that the cue had social agency could arise from the study’s use of a disembodied stimulus. The use of the red dot allowed for the control of extraneous variables arising from the physical characteristics of typical social cues. The social difficulties associated with an ASC are more pronounced when using increasingly complex social stimuli, for example, moving from the use of a photograph to a dynamic video (Klin et al., 2002; Hanley et al., 2013), and individuals with a diagnosis of ASC display gaze avoidance behaviour, which is thought to affect their ability to process social cues (Freeth & Bugembe, 2018; Hanley et al., 2014). Therefore, the use of a disembodied stimulus may have served to remove a potential area of conflict; thereby allowing autistic participants to process the social information provided in the second part of the study without the distraction of the physical properties of the stimuli. This is important as it suggests that behaviours associated with autism can present differently as a consequence of the stimuli used within a given paradigm, in cases this may therefore exaggerate the extent of a difficulty by masking preserved underlying abilities.

Whilst autistic participants’ task performance was improved by the perception of the cue as social, they performed significantly worse than the NT participants in both the non-social and social condition. One explanation for this finding can be drawn from the Bayesian account and the predictive coding framework of perception (Pellicano & Burr, 2012; van Boxtel & Lu, 2013). These accounts argue that an overreliance on lower-order (local) processing due to a decrease in higher-order (global) processing leads to difficulties in identifying the ‘bigger picture’. In addition to the dynamic red dot cue, each trial also featured four background patterns displaying abstract visual details. To successfully complete each trial the participant therefore had to rely on global processing in order to integrate the specific details of the scene to form a ‘big picture’ that allowed the recognition of the pattern chosen by the red dot. If autistic individuals focus more on local, specific details, and experience difficulties in global processing then it is likely that this affected their ability to integrate all of the information available in the scene. This therefore would have made it harder to recognise the preference of the cue in either the social or non-social condition, leading to the autistic participants being less accurate then the NT participants in both conditions.

A further finding arising from this study relates to the ease with which participants reported being able to complete each part of the experiment. Whilst there were no-significant differences between each group with the ease with which they reported completing the non-social agency attribution part of the study, there was a significant difference between each group for the ease with which they reported completing the social agency attribution part of the study. Specifically, the autistic group reported finding the social agency attribution condition significantly more difficult to complete than did the NT group. However, one question which arises from this finding is whether the participants with a diagnosis of ASC actually did find the social agency attribution part of the task harder to complete than the NT participants, or whether they just perceived it to be so. Self-ratings of task difficulty did not correlate with task performance for either the autistic or NT group, suggesting that an individual’s perception of the difficulty of the task did not reflect their actual performance. An explanation for this finding could stem from the presence of demand characteristics (Orne, 1962; Nichols & Maner, 2008). There is a general awareness that autism spectrum conditions are typically associated with difficulties in social cue use and ToM tasks. This awareness may therefore have led to the autistic participants forming expectations regarding their own abilities, and thus to the generation of demand characteristics when rating the difficulty of the social agency attribution task, whereas in reality knowledge that the cue had social agency actually improved performance and the size of this effect was similar for both NT and autistic participants.

In summary, the results of this chapter reveal that the implied presence of a social partner was sufficient to drive changes in participants’ behaviour, positively affecting their performance on the prediction task. Both NT and autistic adults were sensitive to the social agency of a cue, and successfully engaged in theory of mind processing in order to predict the preferences of a social partner. However, as previously discussed, the paradigm used a simplistic cue; disembodied and without the physical characteristics associated with the social cues we would typically see within our everyday lives. Whilst the use of this cue type revealed that autistic adults may have preserved underlying abilities relating to social sensitivity and theory of mind use, it does not allow us an insight into how such abilities fare in more naturalistic environments.

There is now a keen focus within the literature to increase the ecological validity of social cognition paradigms (Reader & Holmes, 2016; Risko et al., 2012), and research has demonstrated that participants display different patterns of behaviour depending on whether or not real people are present (Foulsham et al., 2011; Freeth et al., 2013). Further, this chapter has exposed the significant impact of an *implied* social presence on social cognition, in particular on the engagement of theory of mind processes. Therefore, this highlights the critical need to investigate the impact of a *real* social presence on social cognition. The following chapters will therefore aim to investigate whether the presence of real, physical social partners affects social cognition in both neurotypical and autistic adults.

# *2.6.1. Conclusion*

This study investigated whether manipulating the perception of a cue as being socially relevant would affect autistic adults’ performance on a prediction task. Our results clearly demonstrate that both autistic and neurotypical adults were significantly more accurate when they believed a cue to have social agency. This study therefore demonstrates that autistic participants showed a social facilitation effect despite the visual stimulus remaining exactly the same and, further, could successfully interpret the social information available from a cue in order to form predictions relating to others’ choices. This chapter highlights the significant impact of an implied social presence on social cognition in both NT and autistic adults, and the following chapters will investigate whether this finding extends to the presence of real social partners.

# **Chapter 3: Social Presence, Mentalising and Autistic Traits**

# **3.1 Introduction**

The findings of Chapter 2 demonstrate that both neurotypical and autistic individuals are highly attuned to social agency, and that the belief that a cue or stimulus possesses social agency can lead to significant changes in social cognition. If an *implied* social presence can have such a significant effect on task completion, it is therefore critical to investigate what implications a *real* social presence has for other areas of social cognition, such as theory of mind paradigms. This is the focus of the current chapter.

# *3.1.1. Social Presence Metholodology*

Evidence suggests that there are two discrete forms of mentalising; an involuntary, cognitively efficient ‘implicit’ system, and a conscious, cognitively effortful ‘explicit’ system (Apperly & Butterfill, 2009). However, our understanding of these two systems has largely emerged from studies using differing methodologies to assess implicit and explicit mentalising, in which the individuals whose mental states are to be tracked are not physically present. It is yet to be determined whether the mechanisms of implicit and explicit mentalising hold when mentalising is performed in situations where those whose mental states are being tracked are present as a real-time social presence.

There are reasons to think that cognitive mechanisms relating to social phenomena, such as mentalising, may differ depending on whether or not a social partner is presented in real-time. It has been shown that social presence categorically alters the nature of social attention (Foulsham, Walker & Kingstone, 2011; Freeth et al., 2013; Laidlaw et al., 2011), with a critical factor being whether or not there is the potential for reciprocity (Elekes, Varga & Király, 2016). It has been argued that studies without the potential for reciprocal social interaction can unnaturally constrain behaviour, and that the mechanisms of interest may be altered by such paradigms. This highlights the importance of including the potential for social interactions within investigations (Reader & Holmes, 2016; Risko et al., 2012).

One possible explanation for why behavioural differences arise in relation to a social presence is that our eyes both receive *and* convey social information. When others are present, there is the potential for them to receive information from us. In contrast, this is not possible when the “social partner” in an experiment is not perceived as a conscious social entity e.g. in the case of photographs or cartoons (Gobel et al., 2015; Risko et al., 2016). In such contexts, social norms dictating our behaviour are much less relevant (Foulsham et al., 2011). Taken together, this body of research raises the very real possibility that studies without the potential for social interaction – particularly where stimuli are presented via pre-recorded stimuli on a computer – cannot be considered a suitable analogue for real-world social scenarios. It is therefore critical to investigate the role that social presence may play in mentalising research, in particular, whether participants demonstrate different patterns of mentalising behaviour in response to a real-time social partner.

Mentalising has typically been studied using ‘false-belief’ tasks. However, the method of administration of false-belief tasks tends to vary across studies, ranging from animated computer presentations (Baron-Cohen, Leslie & Frith, 1985; van der Wel et al., 2014) to experimenter-enacted tasks (Schulze & Tomasello, 2015), with researchers drawing general conclusions about the mechanisms of mentalising from a composite of both types of methodology. Of key interest, when children at around 10 years of age complete direct false-belief tasks, their performance tends to significantly improve if instructions are given verbally by an experimenter, rather than if they are read by participants themselves on a computer screen. However, this effect is not present for children with a diagnosis of an ASC (Chevallier et al., 2014). This suggests that there are alterations to the mechanisms of mentalising when required to do so in the presence of a social partner, and that these alterations are subject to individual differences, such as those associated with autism spectrum conditions. This is important to consider in relation to understanding mentalising as a cognitive process.

# *3.1.2. Executive Functions*

Previous research has demonstrated the importance of executive functioning to theory of mind development during childhood (Carlson & Moses, 2001), and this link has been shown to continue along a developmental trajectory into middle childhood and adulthood (Bock et al., 2015; Brown-Schmidt, 2009). The implicit and explicit mentalising systems are generally thought to differ in the extent to which they draw upon executive functions. Previous research has highlighted a robust relationship between executive functions and the explicit mentalising system, with strong links between explicit mentalising, inhibitory control (Carlson et al., 2002; Carlson et al., 2004) and working memory (Mutter, Alcorn & Welsh, 2006). In later development, cognitive flexibility has been shown to predict critical aspects of ToM functioning, such as social understanding in children (Bock et al., 2015), and the ability to take the perspectives of others (Kloo et al., 2010; Kloo & Perner, 2003; Diamond, 2013). However, whilst EF are strongly linked to the explicit mentalising system, they are not believed to play an active role in the automatic, cognitively efficient implicit mentalising system (Apperly & Butterfill, 2009), with recent research demonstrating that EF tasks are related to explicit, but not implicit, task performance (Schuwerk et al., 2016). The differing cognitive demands between implicit and explicit mentalising suggests that mentalising should be studied as two discrete systems, with each drawing upon differing cognitive resources. Therefore, as part of the current study I will aim to investigate the extent to which either mentalising system is related to executive functioning.

# *3.1.3. Autistic Traits*

Individuals with an autism spectrum diagnosis have consistently been shown to demonstrate difficulties with both ToM processing and executive functioning (Pellicano, 2007). Of note, difficulties with ToM processing in autistic individuals tend to relate specifically to the implicit mentalising system, with the intact explicit system serving to compensate for (and mask) difficulties with implicit processing (Senju et al., 2009; Schuwerk et al., 2015; Schneider et al., 2013; Schuwerk et al., 2016). Critically for this study, as a spectrum condition, individuals without an ASC diagnosis can also display traits associated with the broad autism phenotype. In particular, individuals who are sub-clinical yet still demonstrate high levels of autistic traits have been found to perform significantly worse on perspective taking and mentalising tasks than participants with low levels of autistic traits (Gökçen, Petrides, Hudry, Frederickson & Smilie, 2014; Lockwood, Bird, Bridge & Viding, 2013; Gökçen, Frederickson & Petrides, 2016). This therefore suggests that autistic traits have a significant influence on neurotypical individuals’ mentalising abilities. Therefore, this study will aim to investigate whether performance on tasks designed to measure explicit and implicit mentalising is related to the level of autistic traits in neurotypical individuals.

# *3.1.4. The Current Study*

The purpose of this chapter was therefore to investigate: First, whether the presence or absence of task protagonists leads to different patterns of implicit and explicit mentalising behaviour. Second, whether the explicit and implicit mentalising systems draw upon differing cognitive resources, and finally, whether task differences due to social presence are related to autistic traits. This study tested neurotypical adults using a first-order theory of mind task. There were two versions of the task, an indirect version designed to measure implicit mentalising ability, and a direct version designed to measure explicit mentalising ability. The tasks were completed in one of two conditions: “live”, where the task protagonists were physically present acting out the task trials, or “recorded”, where the task protagonists were depicted in a video recording. In all other respects, the two conditions were identical. Participants were also asked to complete a battery of executive function tasks, and the participants’ self-reported levels of autistic traits were recorded.

Given the reported effects of social presence on behaviour observed in relation to direct tasks (Chevallier et al., 2014), it was predicted that participants would show better explicit mentalising in the live condition compared to the recorded condition. Further, with the use of a first-order of theory of mind task it was expected that participants would show a high level of accuracy in each condition. However, no previous studies have compared performance on indirect tasks between live and recorded conditions, hence I was interested to discover whether implicit mentalising ability would be enhanced by the live presence of protagonists compared to the recorded condition of the task. If there are differences in performance between the live and recorded conditions – for the direct task or the indirect task – this would suggest that the context in which mentalising is observed has important implications for the engagement of the mentalising systems. This would demonstrate that social presence is a crucial factor that must be taken into account when creating paradigms designed to investigate social cognition.

Next, the study aimed to investigate whether there would be functional differences between the implicit and explicit mentalising systems. Participants were asked to complete a battery of EF tasks, aimed at measuring inhibitory control, working memory and cognitive flexibility. Based upon previous research (Carlson et al., 2002; Carlson et al., 2004; Mutter et al., 2006; Bock et al., 2015; Schuwerk et al., 2016). I predicted that the cognitively effortful explicit mentalising system would be related to EF task performance, but that involuntary, automatic implicit mentalising performance would not be related to EF task performance. If it were found that these two systems are differentially related to EF then it would provide further evidence for a divergence between the implicit and explicit mentalising system.

Finally, the study investigated whether performance on the indirect task and direct task was related to autistic traits, and whether task differences due to social presence were related to autistic traits. Previous research has demonstrated that individuals with ASC can successfully explicitly mentalise, but show deficits in their ability to implicitly mentalise (Senju et al., 2009; Schuwerk et al., 2015; Schneider et al., 2013; Schuwerk et al., 2016). Therefore, it would be predicted that participants with higher levels of autistic traits would perform significantly worse on the indirect task then participants with lower levels of autistic traits. Further it would be expected that participants with higher levels of autistic traits would not show the same task improvement as participants with lower levels of autistic traits when the tasks are completed with a real-time social presence (Chevallier et al., 2014).

A first-order theory of mind task was considered appropriate as our aim was to capture unconscious looking behaviour. The study therefore sought to avoid a cognitively demanding task in order to reduce cognitive load and avoid the recruitment of conscious cognitive processing. Further, this type of false-belief task has been commonly used within implicit mentalising paradigms, and has previously been shown to elicit anticipatory looking behaviour. This study aimed to replicate the sample size of a previous research study that investigated explicit and implicit mentalising behaviour across multiple trials (Schneider, Bayliss, Becker & Dux, 2012), and therefore aimed to recruit approximately 36 participants.

# **3.2. Methods**

# *3.2.1. Participants*

The length of time that the undergraduate volunteers were available to act as confederates placed limitations on the available recruitment time and meant that the final sample size was smaller than that recruited in Schneider et al.,’s study. Thirty-one participants (19 female) took part in the study. Undergraduate Psychology students received credit from the University of Sheffield Department of Psychology Online Research Participation Scheme for taking part. The study was approved by the Department of Psychology Ethics Committee, and all participants gave informed consent before participating. All participants had normal, or corrected to normal, vision. Of the 31 participants tested, 8 were excluded from the final analysis: two for failure to complete the task and six for indicating that they had consciously engaged in strategies to process the actor’s mindset in the indirect task, as indicated by responses to the funnelled debrief. This left a sample of 23 participants (12 females) (Table 3).

*Table 3.**Participant characteristics*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | Executive Function Tasks | | |
|  | Age | BAPQ | Cognitive Flexibility Task | Inhibitory Control Task | Working Memory Task |
|  |  |  |  |  |  |
| Mean | 22 | 93.74 | 234.66 | 37.75 | 46.83 |
| Range | 19-25 | 62-130 | -121 - 870 | 0.45 - 98 | 17 - 72 |
| SD | 2.65 | 16.47 | 230.09 | 38.66 | 16.63 |
|  |  |  |  |  |  |

# *3.2.2. Design and Data Handling*

The study used a within-subjects design with two independent variables: condition (live or recorded) and task type (indirect or direct). Each participant therefore completed four versions of the tasks: 1. live-indirect; 2. live-direct; 3. recorded-indirect; 4. recorded-direct. The order in which the live and recorded conditions were presented was counterbalanced between participants, but the indirect task was always completed before the associated direct task. The study paradigm was a non-verbal first-order theory of mind task which required participants to track the knowledge state of two protagonists. In the live conditions, a sequence was acted out in real time in front of the participant; in the recorded conditions, the participant was shown a video of the same sequence.

In each version of the task, the participant watched as two protagonists (the “hider” and the “seeker”) acted out a role-play in which the hider hid a ball and the seeker tried to find the ball (Figure 6). On each trial the seeker would leave the scene, and the hider would then manipulate two visually identical boxes – either swapping their positions, or picking them up and replacing them in the same positions. On a number of trials, the seeker would peek back and watch the scene, meaning that on those trials they could accurately track the ball’s location. On other trials, the seeker did not watch the hider’s actions, and thus could not reliably track the location of the ball. Participants were told in advance that the hider would not know whether the seeker peeked on each trial, and that the seeker would not know whether the hider would swap the boxes. To ensure that the conditions were as closely matched as possible, the videos used in the recorded condition were created from recordings of the live condition, the actors in the recording were the same people who enacted the live display. The sole difference between each condition was the live or recorded nature of the scene. Additionally, the actors in the live condition avoided any form of socially engaging behaviour, maintaining neutral facial expressions and looking straight ahead rather than at the participant during each trial.



a.

b.

c) 1.

2..



4.

3.



d.



e.

**Figure 6.** The experimental procedure. The trial type is labelled based on the SEEKER’s belief. (A) The HIDER hides the ball, watched by the SEEKER. (B) The seeker leaves. (C). 1) True-belief trial: the hider lifts the boxes and replaces them in their original positions; the seeker remains hidden. 2) True-belief trial: the hider lifts the boxes and replaces them in their original positions; the seeker watches. 3) True-belief trial: the hider swaps the boxes, the seeker watches. 4) First-order false-belief trial: the hider swaps the boxes, the seeker remains hidden. (D) The seeker emerges to search for the ball. (E) The seeker remains standing behind the table. During the explicit trials the participant provides a response.

For the indirect task, participants were instructed simply to watch the role-plays; during these tasks, participants’ eye movements were recorded. The indirect trials measured whether participants spontaneously tracked the seeker’s false belief; this was measured both via the participants’ anticipatory gaze behaviour and their overall pattern of preferential looking. Attending to the box congruent with the seeker’s false belief (i.e. where the seeker would search based on their knowledge of what they had seen happen) was considered as the “correct” response. The anticipatory gaze data indicated which box the participant first fixated; if the participant’s first fixation was to the correct box, then the fixation was labelled as a correct response. To allow comparison with previous literature, a second indirect measure was also calculated. In order to assess the participants’ preferential looking patterns, a preferential looking score was calculated for each trial. This was computed by taking the total duration of fixations on the correct box and then dividing this by the total duration of fixations on all boxes. Trials in which the participant did not direct any fixations towards the four boxes were removed prior to analysis. The preferential looking score for each trial was then averaged across the total number of trials to give an overall score for each participant. This measure therefore gave an index of whether participants preferentially looked towards the correct location over the course of the experiment. In order to determine if participants demonstrated a systematic bias to attend to the correct box, both the preferential looking data and the first fixation data were analysed to confirm that performance on at least one measure was significantly greater than would be expected from a random allocation of attention. The threshold used to identify systematic attendance to the correct box was determined to be 25%, based on the potential for participants to randomly allocate their gaze to any of the four boxes used in the paradigm. To establish whether participants preferentially attended more to the correct box than any of the other three boxes, I calculated the proportion of time participants spend looking at each of the four boxes on each trial, and then compared the value of the correct box against the threshold of 0.25 (25%). For the first fixation data, performance was based on which box, out of the four boxes, was first fixated.

To check that participants were engaging in implicit mentalising processes to complete the task, each participant completed a funnelled debriefing procedure at the end of the testing period (see Appendix A). This procedure was adapted from that used by Schneider et al., (2013), which was in turn adapted from a procedure designed to test higher implicit processes by Bargh and Chartrand (2000). The debriefing procedure consisted of a series of questions, which probed the participants’ understanding of the task and confirmed that they had not engaged conscious belief processing for the indirect version of the task.

The direct task followed the same procedure as the indirect task, however, at the end of each trial participants were asked to indicate which box they thought the seeker would look in. Responses were recorded via a finger point (for the live condition) or by a button press (for the recorded condition). In the live condition, the finger point was captured via the cameras on a mobile eye tracker; these were replayed by the experimenter and manually coded for accuracy. For the indirect trials in the recorded condition, the button press was recorded as either correct or incorrect for each trial during the experiment.

# *3.2.3. Apparatus*

*Broad Autism Phenotype Questionnaire*

Participants completed the Broad Autism Phenotype Questionnaire (BAPQ). This questionnaire was chosen for use as it is designed to be sensitive to the broader autism phenotypes present within neurotypical populations (Hurley, Losh, Parlier, Reznick and Piven, 2007). The questionnaire features a cut-off point of 108 (with those scoring above this cut-off classified as having a broad autism phenotype) and 3 additional subscales of measurement (Aloof, Rigid and Pragmatic Language). The BAPQ has demonstrated a high sensitivity (>70%) to detecting these phenotypes, and therefore was suitable for use in this study as a measure of the number of autistic traits present in the neurotypical participants who took part in the study.

*Executive Function Tasks*

A Go/No-Go task (Redick, Calvo, Gay & Engle, 2011) was used to assess participants’ inhibitory control abilities. The task consisted of 20 practice trials and 200 experimental trials. During each trial a letter was displayed in the centre of the screen for 300ms, followed by a black screen which remained for 700ms before moving onto the next trial. During the task participants were asked to press a button (‘n’) on their keyboard every time a letter appeared on the computer screen; a ‘Go’ trial. However, participants were asked to inhibit this response and not press the button if the letter displayed was ‘c’; a ‘No-Go’ trial. In total there were 160 ‘Go’ trials, and 40 ‘No-Go’ trials. The task aimed to measure the proportion of no-go trials for which the participant successfully inhibited the button press.

A task-switching paradigm based on a task used by Yeung and Monsell (2003) was used to measure cognitive flexibility. This task also consisted of 20 practice trials and 200 experimental trials. Each trial began with a blank screen displayed for 300ms, after which the stimuli would appear. The stimuli consisted of a letter displayed at the top of the screen and a number displayed at the bottom; in the middle of the screen would be displayed either the word ‘LETTERS’ or the word ‘NUMBERS’. Based on this word the participants would know to attend to either to the top or the bottom of the screen. If participants were directed to the letter at the top of the screen they were then required to press ‘B’ if the letter was a consonant, or press ‘N’ if the letter was a vowel. Alternatively, if the participants were directed to the number at the bottom of the screen they were then required to press ‘B’ if the number was even, or ‘N’ if the number was odd. Participants could either complete ‘No-switch’ trials, where they responded to the same stimulus (letters or numbers) as that from the previous trial; or ‘Switch’ trials where they would respond to a different stimulus to that from the previous trial (swapping from letters to numbers, or vice versa). This task aimed to measure the mean difference in reaction times between ‘No-switch’ and ‘Switch’ trials, in order to assess the effect of switching between the letters and numbers tasks.

An automated version of the Operation Span task (OSPAN; Unsworth, Heitz, Schrock & Engle, 2005) was used to assess working memory ability. The task commenced with three rounds of practice trials. During the first, participants were presented with a series of letters on screen with each letter presented in isolation for 800msecs. Participants then viewed a 4x3 matrix of letters from which they were asked to select letters in the order in which they were presented. This section of the task was untimed. In the second round of practice trials participants were asked to solve a series of simple maths problems as quickly and as accurately as possible. Participants were asked to click the mouse in order to move to the next screen once they had solved the equation. On the following display a number was displayed on screen and participants were asked to select from the options ‘true’ or ‘false’ as to whether it was the correct answer to the equation. During these trials each participant’s reaction time was recorded. This allowed the system to generate an average time for how long each participant took on the maths problems, and this value (+/- 2.5SD) was then used as a time limit for the maths sections of the experimental trials. The third and final practice round combined the letter and number tasks as would follow in the experimental trials.

On completion of the practice trials each participant completed three blocks of experimental trials. During these trials the letter recall and maths problems were interleaved such that participants completed a maths problem, then viewed a letter to memorise. The maths-letter pairings were presented in sets of three to seven pairs e.g. three maths problems paired with three letters to be recalled. Following each set participants were asked to recall the letters in the order they had been presented throughout the set. Within each block, set size (3-7) was randomised and each set was presented once, therefore participants completed 25 maths problems and recalled 25 letters within each block. Task performance was measured through the generation of a partial score, which was calculated by summing the number of letters correctly recalled in the correct order across all three blocks.

*Eye Trackers*

Participants’ eye movements were recorded during each experimental condition. SMI (Senso Motoric Instruments) mobile eye-tracking glasses were used during the live condition, and a desktop-mounted EyeLink1000 was used during the recorded condition. The mobile eye-tracking glasses were calibrated using a one-point calibration, which required participants to focus on a point within their visual field (in this case, the tip of the experimenter’s extended finger), at a distance within the range that the main trial action took place. Accuracy of the calibration was monitored in real time during the experiment, through observation of the participants’ gaze location in context of the visual field recording. The cursor representing the participants’ gaze was checked to ensure that it matched up with points of interest (such as the blue ball or the red clue; see figure 6) as each trial unfolded. The glasses had an eye-tracking range of 80° horizontal, 60° vertical with a binocular 30 Hz temporal and up to 0.1° spatial resolution combined with 24 Hz front-view camera with a field of view 60° horizontal and 46° vertical. The desktop EyeLink1000 had an eye-tracking range of 32° horizontal, 25° vertical with a monocular 1000 Hz temporal and up to 0.01° spatial resolution. The EyeLink1000 was calibrated using a 9-point calibration. The calibration was monitored and corrected between each trial via an additional drift correction to ensure an optimal calibration.

In order to determine scores for trial accuracy in each version of the indirect task, eye-movement data were analysed offline using BeGaze (mobile eye tracker) and DataViewer (desktop eye tracker) software. Prior to analysis, each participant’s data were checked to ensure an accurate calibration; when offset corrections were required they were implemented by measuring eye gaze against a frequently fixated object of interest (the blue ball). The mobile eye-tracking data represented a participant’s eye movements via a cursor overlaid on the video recording. The eye-movement data were analysed based on a 3000msec interest period. This began from the moment the seeker emerged from behind the screen (Figure 7a) and ended when the seeker was positioned behind the table (Figure 7b). Data were manually coded to indicate the location of the participant’s gaze based on eight areas of interest (AOI). These were: the four boxes, the seeker’s face, the seeker’s body; the hider’s face and the hider’s body (Figure 7).

**Figure 7.**The areas of interest for the anticipatory gaze data analysis. (A) At the start of the interest period, as the seeker emerges from behind the screen. (B) At the end of interest period, whilst the seeker remains behind the table.

**A.**

**B.**



# *3.2.4. Procedure*

Both the indirect task and the direct task featured 12 trials in total: 6 false-belief experimental trials, and 6 true-belief baseline trials. True-belief trials were included, firstly, to discourage the use of rule-based strategies (for example, always indicating the box that contained the ball), and secondly to act as a test of participants’ understanding of the task. This meant that any poor performance on the false-belief trials could be ascribed to difficulties with mentalising (i.e. tracking the seeker’s knowledge), rather than to any misunderstanding of the task.

The two conditions (live and recorded) followed an identical procedure. Task instructions were given directly by an experimenter for each condition to rule out the possibility that improvements in task performance in the live condition could be due to participant interaction with the experimenter. In each condition, participants first watched four practice trials, then completed the indirect task, then completed the direct task. The indirect task practice trials were structured to introduce the participant to the task, introducing a new concept with each phase. The concepts were not verbally stated, but were introduced as part of each role-play; first, the seeker will always search for the ball; second, the hider may lift and replace the boxes when the seeker leaves; third, the hider may swap the boxes when the seeker leaves; fourth, the seeker would sometimes peek back and observe the boxes being swapped. During these practice trials the seeker actively searched for the ball, emphasising her role for the following trials. For the indirect task, participants completed 6 experimental trials presented in a random order (3 true-belief trials, where the seeker knew where the ball really was and 3 false-belief trials, where the seeker held a false belief about where the ball really was), were then offered a break, and then completed another 6 experimental trials (3 true-belief trials and 3 false-belief trials). During the experimental trials the seeker did not actually search for the ball; instead the trial ended just before the search phase would have begun. For the direct task, participants completed 3 practice trials. Participants were asked “Where will the seeker search for the ball?”. These trials could be either true-belief or false-belief trials, and were included to allow the participant to practice the button press/finger point response. They then completed 6 experimental trials, before being offered a break. They then completed another 6 experimental trials. As participants did not receive feedback on where the seeker would search during the experimental trials, they were therefore unaware whether their responses on each trial were correct or incorrect.

Following the completion of the mentalising tasks in the first condition, participants were then asked to complete the BAPQ and the three executive function tasks. The procedure for the mentalising tasks was then repeated for the remaining condition. Therefore, in total each participant completed 48 experimental trials (6 x live-indirect false-belief; 6 x live-indirect true-belief; 6 x live-direct false-belief; 6 x live-direct true-belief; 6 x recorded-indirect false-belief; 6 x recorded-indirect true-belief; 6 x recorded-direct false-belief; 6 x recorded-direct true-belief). Finally, participants were guided through the funnelled debriefing procedure to check that they had engaged in implicit mentalising behaviour.

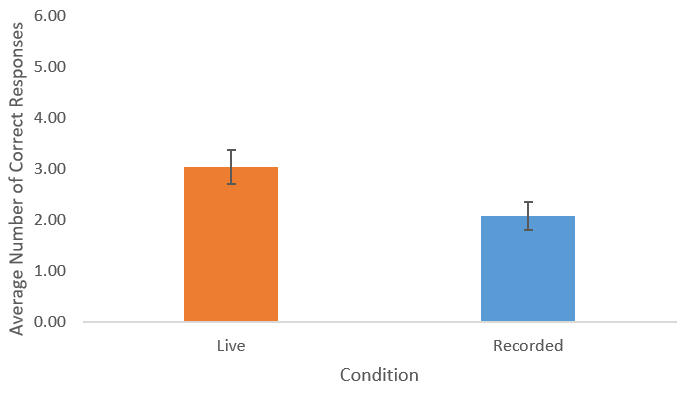
# **3.3. Results and Discussion**

Due to the use of a within-subjects design, the order of presentation of the live and recorded conditions was counterbalanced between participants; preliminary analyses confirmed that there were no order effects present within the data as a result of this manipulation.[[2]](#footnote-2)

# *3.3.1. Implicit Mentalising*

# *First Fixation Analysis*

For the indirect task, the critical analyses focussed on whether participants performed differently on the indirect task depending on whether it was completed in the live or recorded condition. First, statistical analyses aimed to investigate whether there were differences between the live and recorded conditions for the area of interest first fixated. Paired samples *t*-tests revealed a significant difference in accuracy between the conditions, *t*(22) = 2.36, *p*=.028, *d=*0.66. In line with the study hypotheses, participants were more accurate on the indirect task when they completed it in the live condition than when they completed it in the recorded condition (Figure 8).

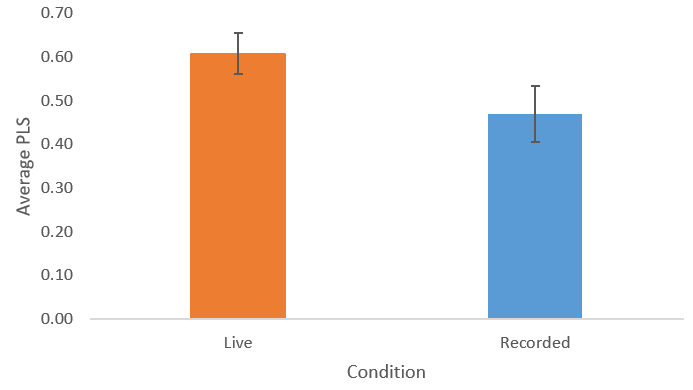


\*

**Figure 8***.* Average number of indirect-task correct first fixation responses in the recorded and live conditions. Error bars show +/−1 within-subject standard error of the mean (S.E.M)[[3]](#footnote-3)

# *Preferential Looking Score*

To further investigate differences in eye-movement behaviour between the live and recorded conditions for the indirect task, the preferential looking score was calculated for each participant to determine which box the participants preferentially looked towards over the course of the experimental trials. Preferentially attending to the box congruent with the seeker’s false belief was considered as the “correct” response. A paired samples *t*-test revealed that there was no significant difference in preferential looking behaviour between the live and recorded conditions (t(22)=1.766, *p*=.091, *d=*0.37); however, there was a trend for participants to preferentially attend more to the correct box in the live (Mean proportion correct=.61) compared to the recorded (Mean proportion correct=.47) condition. (Figure 9).



**Figure 9***.* Average preferential looking score in the recorded and live conditions. Error bars show +/−1 within-subject standard error of the mean (S.E.M).[[4]](#footnote-4)

It is important to note that whilst a preferential looking score allows an overall analysis of which AOI participants preferentially attended to, the longer time window for analysis introduces the potential to capture artefacts of conscious looking behaviour. The first fixation analysis is therefore arguably a better measure of implicit mentalising, with the short onset time reflecting a participant’s immediate reaction to each trial.

The results revealed that participants’ first fixations were significantly more likely to be directed towards the correct box in the live condition when the task was completed in the presence of social others. Participants also preferentially attended more to the correct box in the live condition than in the recorded condition. Taken together, these findings therefore demonstrate that implicit mentalising happens differently depending upon the context in which it takes place. In particular it reveals that participants are more likely to engage in implicit mentalising behaviour when in the presence of social partners.

# *3.3.2. Implicit Mentalising Error Analysis*

# *First Fixation Errors*

In order to investigate the nature of the errors made when participants’ first fixation was not to the correct box, the location of these incorrect fixations were analysed to determine where the participants directed their gaze instead. Fixations were coded based on the AOIs indicated in Figure 7. The percentage of first fixations to each AOI are listed in Table 4.

|  |  |  |
| --- | --- | --- |
| **Area Of Interest** | **Live (%)** | **Recorded (%)** |
|  |  |  |
| **Correct Box** | 54.35 | 44.20 |
| **Box Containing the Ball** | 7.97 | 10.14 |
| **Other Box** | 1.45 | 4.35 |
| **Hider** | 2.17 | 7.97 |
| **Background** | 12.32 | 10.87 |
| **Seeker** | 21.74 | 22.46 |

**Table 4.** Percentage of errors to each AOI in the indirect task.

It can be seen from the data presented in Table 3 that similar errors were made in each condition, with the three most commonly fixated AOIs on incorrect trials being the Seeker, the background, and the box containing the ball. Wilcoxon signed-rank tests were performed to check for differences in the types of errors made between the live and recorded conditions. The only significant difference found between conditions was that participants would look to the hider significantly less often in the live condition compared to the recorded condition (*Z=*2.828, *p=*.005, *r*=.590). Similarity in the areas looked at between the live and recorded trials therefore suggests that participants displayed similar levels of attention to each AOI in both conditions. This suggests that worse performance on implicit mentalising in the recorded condition compared to the live condition was not due to lack of task engagement in the recorded condition.

# *Preferential Looking Errors*

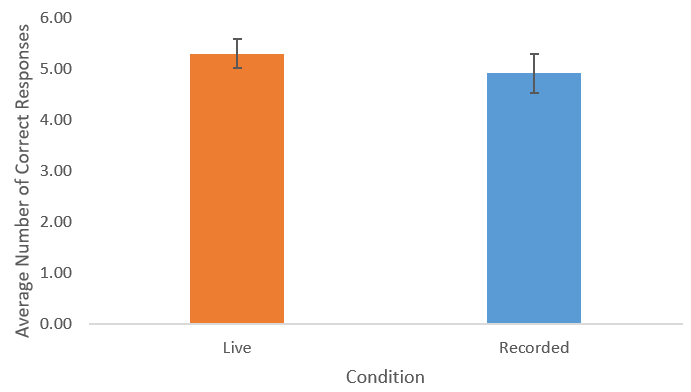
To investigate the nature of the errors made when participants preferentially attended to the incorrect location, the preferential looking data for incorrect trials were inspected, and the AOI with the greatest gaze duration was noted. The trials where each AOI category had been preferentially gazed at were then summed and the percentage of participants preferentially attending to each AOI was calculated (Table 5).

|  |  |  |
| --- | --- | --- |
| **Area Of Interest** | **Live (%)** | **Recorded (%)** |
|  |  |  |
| **Correct Box** | 59.42 | 37.68 |
| **Box Containing the Ball** | 16.67 | 28.99 |
| **Other Box** | 0.72 | 0.72 |
| **Hider** | 0.00 | 3.62 |
| **Background** | 6.52 | 6.52 |
| **Seeker** | 16.67 | 21.01 |

**Table 5.** Percentage of participants preferentially attending to each AOI for the indirect task.

Consistent with the first fixation error analysis, it was found that similar errors were made in each condition, with the three most commonly fixated AOIs being the box containing the ball, the seeker and the background. Wilcoxon signed-rank tests confirmed that there were no significant differences between the live and recorded condition for which AOI was preferentially attended to. Again, this confirms that participants found both conditions equally engaging, with errors arising from comparable sources across both contexts. In combination with the first fixation error analysis, it is clear that participants demonstrated a preference to attend to the box containing the ball and to the seeker. Participants were therefore more likely to attend to the AOIs that were directly related to the narrative of each trial, rather than to randomly distribute their attention to alternate areas of the scene. This demonstrates that participants continued to show task-contingent eye-movement behaviour even on incorrect trials and, consequently, that when errors occurred they were not related to a lack of task engagement.

# *3.3.3. Explicit Mentalising*

For the direct task, the critical analyses focussed on whether participants performed differently depending on whether the task was completed in the live condition or the recorded condition. Data for the direct task were not normally distributed, therefore Wilcoxon signed-rank tests were used to investigate whether participants performed differently on the direct tasks in the live and recorded conditions. There was no difference in accuracy between the conditions, Z = -.823, *p*=.410, *r*=.172. This indicates that participants did not perform differently on the direct task in the live and recorded conditions. However, it was not possible to draw definitive conclusions as to the effect of a social presence on explicit mentalising due to the participants’ high level of accuracy on the direct task (Figure 10).

**Figure 10**. Average number of direct-task correct responses in the recorded and live conditions. Error bars show +/−1 within-subject standard error of the mean (S.E.M).

# *3.3.4. Autistic Traits and Executive Functions*

Due to the ceiling effects found on the direct-task, and the small sample size for the study in general, it would be inappropriate to run correlations to investigate the relationship between a) performance on the executive function tasks and the mentalising tasks and, b) the number of self-reported autistic traits and performance on the mentalising tasks. Study 3 will therefore seek to recruit a larger sample of participants and utilise a more challenging version of a false belief task.

# **3.4. Discussion**

The current chapter investigated the effect of a social presence on participants’ implicit and explicit mentalising behaviour. The study found that implicit mentalising was affected by a social presence, with participants performing significantly better when a real person was present. In contrast, explicit mentalising was found to be unaffected by a social presence, with no difference in performance whether the task was viewed live or recorded, although this result was likely confounded by the ceiling effects found for the direct task. Taken together, these results demonstrate that the implicit mentalising system is especially sensitive to a real-time social presence and provide evidence of a separation between the implicit and explicit mentalising systems.

This study is the first to look at the effect of a social presence on explicit and implicit mentalising, and the results suggest that beliefs and intentions of others are tracked much more effectively when presented via a real-time social presence. This represents an important extension of previous studies that report different patterns of social attention according to whether or not a task includes a social presence (Chevallier et al., 2014; Elekes et al., 2016; Freeth et al., 2013; Laidlaw et al., 2011). There are a range of implications resulting from this finding, of which the most important is that research paradigms lacking a social presence may not, after all, serve as suitable analogues for real world social interactions. This suggests that social presence does not merely affect how we observe a scene (Risko et al., 2016; Reader & Holmes, 2016; Risko et al., 2012), but that it alters the way in which we engage with and process mental states in other people. Studies that attempt to draw conclusions about mentalising ability without real-time protagonists are likely to miss out on crucial aspects of this ability.

There are several plausible explanations for why participants perform differently in response to real-time vs pre-recorded stimuli, with one potentially important contributor to these differences being the potential for reciprocity (Risko et al., 2012). Whilst pre-recorded video-based stimuli present realistic depictions of the situations they display, they inevitably remain unaffected by the participants’ behaviour and are, plainly, unable to respond to social overtures. Social attention has most likely evolved as a two-way interaction (Risko et al., 2012) – indeed, human eyes have a dual function whereby we can both receive and transmit information with our gaze (Risko et al., 2016; Gobel et al., 2015). Tasks without a social presence remove the potential to engage with a social partner, suggesting that contexts lacking the potential for this type of reciprocal interaction may fail to engage the processes which would be involved in social interactions in everyday life.

In contrast to the study hypotheses autistic traits were not found to be related to task performance for the indirect or direct task, in either the live or recorded condition. This conflicts with previous research which has found that autistic individuals lack sensitivity to social presence and typically show difficulties in their implicit mentalising abilities (Chevallier et al., 2014; Senju et al., 2009; Schneider, Bayliss, Becker & Dux, 2012a; Schuwerk et al., 2016;). However, this finding supports other studies with neurotypical adults which have found no relationship between autistic traits and explicit and implicit mentalising (Nijhof et al., 2016) or social attention (Freeth et al., 2013; Laidlaw et al., 2011). One potential explanation for this finding stems from the fact that this experiment tested a neurotypical population, without a clinical diagnosis of an autism spectrum condition. Therefore, whilst participants presented a differing number of autistic traits, it is possible that this was not analogous with the mentalising behaviour that would have been shown by autistic adults. In Chapter 4, I will therefore aim to investigate whether participants with a clinical diagnosis of autism also show improved implicit mentalising in the presence of others, or if previously reported difficulties in implicit mentalising generalise to situations where real people are present.

There are two further methodological considerations relating to this chapter which will be addressed in Chapter 4. First, the sample size in the previous study (N = 23) may have played a role in limiting the significance of some of the statistical comparisons conducted. Further, the sample size prevented the use of statistical analyses on the executive functioning data. A post hoc power analysis revealed that on the basis of the mean effect size observed for the effect of social presence on implicit and explicit mentalising in this chapter (d =.40), approximately 51 participants would be needed to obtain statistical power at the .80 level. Therefore, in Chapter 4, study 3a will recruit a larger sample of participants. The second consideration relates to the ceiling effects observed for the direct task. Out of the 23 participants tested, 19 scored at ceiling level on the direct task in the live condition, and 17 scored at ceiling level in the recorded condition. Whilst this demonstrates that participants were able to clearly comprehend and engage with the task, the very narrow range of scores prevented the identification of any potential differences in task performance between the live and recorded condition. Therefore, a more challenging second-order theory of mind task was used in Chapter 4 in an attempt to achieve a greater range of scores for the direct task.

# *3.4.1. Conclusion*

This study investigated whether implicit and explicit mentalising happens in a different manner when social others are physically present. The results show that implicit mentalising is sensitive to the presence of real people, with participants performing better when the protagonists were physically present than when they were not, however, it remains unclear whether explicit mentalising is sensitive to social presence in this way. Further, this study clearly demonstrates the importance of acknowledging social presence as a crucial factor in our understanding of the mentalising process.

# **Chapter 4: Social Presence, Mentalising and Autism Spectrum Conditions**

# **4.1. Introduction**

As discussed in Chapter 3, implicit mentalising was found to be sensitive to a social presence, and improvements in task performance were evident regardless of the level of self-reported autistic traits in neurotypical individuals. However, the paradigm used in Study 2 likely confounded the results of the direct task; most participants performed at ceiling level leading to difficulties in interpreting how social presence affected explicit mentalising. The studies within this chapter will therefore aim to use a more challenging second-order theory of mind task in order to elicit a greater range of results. Further, it is yet to be determined whether individuals with a diagnosis of an autism spectrum condition demonstrate similar improvements in implicit mentalising ability when in the presence of real people. The primary aim of this chapter is therefore to investigate the effect of a social presence on mentalising behaviour in both neurotypical and autistic individuals.

The implicit and explicit mentalising systems are generally thought to develop along different time-courses. Children can demonstrate implicit mentalising from as young as 15 months of age (Onishi & Baillargeon, 2005; Ruffman, Garnham, Import & Connelly, 2001; Southgate & Vernetti, 2014), with neurotypical children demonstrating explicit mentalising capabilities by 4 years of age (Wimmer & Perner, 1983). The divergence between explicit and implicit mentalising is of particular relevance in the case of autism spectrum conditions. In the literature, autism has long been associated with delays in the development of theory of mind processes (Baron-Cohen et al. 1985), with autistic children showing delays in their ability to pass direct theory of mind tasks when compared to neurotypical peers (Happé, 1995). However, whilst older autistic children and adults can develop the ability to pass direct theory of mind tasks, difficulties with implicit mentalising have been shown to persist into adulthood (Senju et al., 2009; Schuwerk et al., 2015; Schneider et al., 2013; Schuwerk et al., 2016).

As discussed in Chapter 3 (Section 3.1.1.), the method by which mentalising tasks are presented can vary considerably *between* individual studies, ranging from static cartoon depictions to experimenter presented tasks. However, a further critical issue is that the tasks used to measure implicit or explicit mentalising can typically differ *within* the same study, with different task types used to measure each mentalising system. The difficulties autistic individuals experience with social stimuli are most evident when studied using complex, naturalistic stimuli (Klin et al., 2002), therefore results drawn from differing paradigms may not give equivalent conclusions. For example, whilst tasks used to measure explicit mentalising typically rely upon relatively simplistic stimuli, such as still images or cartoon strips, tasks used to study implicit mentalising typically use more complex stimuli, such as videos (Senju et al., 2009; Schuwerk et al., 2015). It is therefore possible that the use of such differing stimuli can influence the reported results. Indeed, studies that have attempted to study implicit and explicit mentalising using comparable, naturalistic tasks have found evidence of difficulties in explicit mentalising in autistic adults (Rosenblau et al., 2015; Cole et al., 2018). The implications of this research are therefore two-fold; first, deficits in mentalising behaviour may be masked via the use of simplistic, non-naturalistic study paradigms. Second, when studying the two mentalising systems comparable tasks should be used if comparisons are to be drawn.

To my knowledge there are only two previous studies which have attempted to study both implicit *and* explicit mentalising in autistic adults using complex naturalistic stimuli (Rosenblau et al., 2015; Cole et al., 2018). However, these studies relied on the use of videos - thereby ameliorating the effect of the presence of a real-time social partner. This study will therefore be the first to investigate the effect that the presence of a social partner has upon implicit and explicit mentalising behaviour in adults with and without a diagnosis of an autism spectrum condition. Following the findings of Chapter 3, both studies 3a and 3b used a non-verbal second-order theory of mind task (adapted from Apperly, Samson, Carroll, Hussain & Humphreys, 2006) to prevent the ceiling effects which would likely be obtained from the use of a first-order direct theory of mind task. A second-order task requires participants to understand that a protagonist holds a false belief about another person’s belief. As in Chapter 3, there was both a direct and an indirect version of the task, and each task was completed in a live (task protagonists were physically present) and recorded (task protagonists depicted in a video recording) condition. Study 3a recruited neurotypical adults, whereas study 3b tested adults with a diagnosis of an autism spectrum condition and age, gender and non-verbal IQ matched neurotypical controls.

Both studies 3a and 3b aimed to investigate the effect of social presence on explicit and implicit mentalising, and whether task differences due to social presence were related to either autistic traits or an autism spectrum diagnosis. Following the findings of Chapter 3, it was expected that the NT participants in study 3a and study 3b would demonstrate significantly enhanced patterns of implicit mentalising when completing the indirect task in the live condition compared to the recorded condition. Further, based on previous research (Foulsham et al., 2011; Freeth et al. 2013; Laidlaw et al., 2011; Chevallier et al., 2014) it was predicted that explicit mentalising performance would also be enhanced by the presence of social others, compared to the recorded condition of the task.

With reference to the effect of an ASC, it was predicted that there would be no difference in task performance between the autistic participants and NT participants for the direct task in the recorded condition. This follows research demonstrating comparable performance for direct tasks (Senju et al., 2009). By comparison, it was predicted that there would be a significant difference in task performance between the autistic participants and NT participants on the indirect task in the recorded condition, with previous research demonstrating pervasive difficulties in implicit mentalising abilities for individuals with a diagnosis of an ASC (Senju et al., 2009; Schuwerk et al., 2016; Schneider et al., 2015).

Further, it was predicted that the autistic participants in study 3b would not show the same improvement for the direct task in the live condition as the NT controls (Chevallier et al., 2014). However, no previous studies have investigated the effect of a social presence on implicit mentalising in autistic adults, therefore a key aim of these studies was to investigate the effect of a social presence on task performance for the indirect task. If both NT and autistic participants display different patterns of mentalising behaviour for either the indirect or direct task in the live compared to the recorded condition then this would suggest that the mechanisms underlying mentalising are differentially engaged if real people are present. If this is found to be the case then this would have implications for our understanding of the nature of the implicit and explicit mentalising systems, as we likely use them in everyday life.

# **4.2. Study 3a: Method**

# *4.2.1. Participants*

Fifty adults (21 female & 26 male) participated in Study 3a. Participants were recruited via opportunity sampling through a university-wide volunteers list and received a £10 gift voucher as a thank you for taking part. All participants completed the Broad Autism Phenotype Questionnaire.

Of the 50 participants tested, 5 were excluded from the final analysis: 1 participant was excluded due to failure to complete the task, 2 were excluded due to poor eye-tracking calibrations, 1 participant scored fewer than 6 out of 12 correct responses on the direct true-belief trials, and 1 participant was excluded for misunderstanding the task instructions. This left a final sample of 45 participants (Table 6). Due to prior commitments, the undergraduate volunteers who acted as confederates were unavailable for further participant recruitment. This resulted in a final sample size slightly less than that indicated by the power analysis.

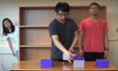
*Table 6.**Participant characteristics*

|  |  |
| --- | --- |
|  | **Demographics** |
| Gender (Male : Female) | 23 : 22 |
| Age  Mean (Range)  SD | 35 (18 – 66)  13.19 |
| BAPQ |  |
| Mean (Range)  SD | 97.72 (50 – 148)  20.64 |
|  |  |

# *4.2.2. Design*

Study 3a used an identical design to the study presented in Chapter 3, namely a within-subjects design with two independent variables: condition (live or recorded) and task type (indirect or direct). The key difference from the study presented in Chapter 3 was that instead of a first-order task, a non-verbal second-order theory of mind task was used. This task required participants to track the knowledge state of three protagonists.

The introduction of a third protagonist altered the procedure of the role-play from that used in the study in Chapter 3. During the second-order task, the participant watched as three protagonists (the “hider”, the “seeker”, and the “helper”) acted out a role-play in which the hider hid a ball, the seeker tried to find the ball, and the helper tried to assist with the seeker’s search (Figure 11). The participant was told that the helper would always try to help the seeker (by placing a small red marker on the box they believed contained the ball). On each trial, the helper would leave the scene, and the hider would then manipulate two visually identical boxes – either swapping their positions, or picking them up and replacing them in the same positions. On a number of trials, the helper would peek back and watch the scene, meaning that on those trials they could accurately track the ball’s location. Participants were told in advance that the seeker would not know whether the helper peeked on each trial.



a.

b.

c.

d. 1.

2.

3.

4.

e.

f.

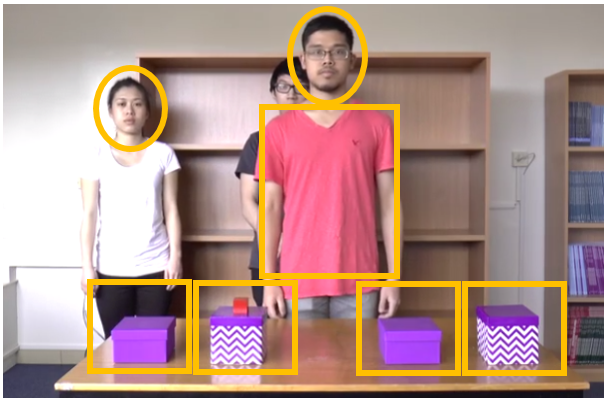
g.

**Figure 11.** The experimental procedure. The trial type is labelled based on the SEEKER’s belief. (A) The HIDER hides the ball, watched by the HELPER. (B) The seeker appears; he is aware that the ball has been hidden and that the helper knows where it is. (C) The helper leaves. (D) 1) True-belief trial: the hider lifts the boxes and replaces them in their original positions; the helper remains hidden. 2) True-belief trial: the hider lifts the boxes and replaces them in their original positions; the helper watches; the seeker is not aware the helper has peeked. 3) Second-order true-belief trial: the hider swaps the boxes, the helper remains hidden. 4) Second-order false-belief trial: the hider swaps the boxes, the helper watches; the seeker is not aware the helper has peeked. (E) he helper places the clue (red cube). (F) The seeker steps forward to search for the ball. (G) The seeker remains standing behind the table. During the direct trials the participant provides a response at this point.

# *4.2.3. Apparatus and Procedure*

Study 3a used the same apparatus and procedure as detailed in Chapter 3 (Sections 3.2.3 & 3.2.4). However, the areas of interest used to code the eye tracking data were updated to reflect the change in task. In study 3a the data were manually coded to indicate the location of the participant’s gaze based on eight areas of interest (AOI). These were: the four boxes, the seeker’s face, the seeker’s body; the helper’s face and the helper’s body (Figure 12).

**Figure 12.**The areas of interest for the anticipatory gaze data analysis. (A) At the start of the interest period, as the seeker steps forward from the bookcase. (B) At the end of interest period, whilst the seeker remains behind the table.



**A.**

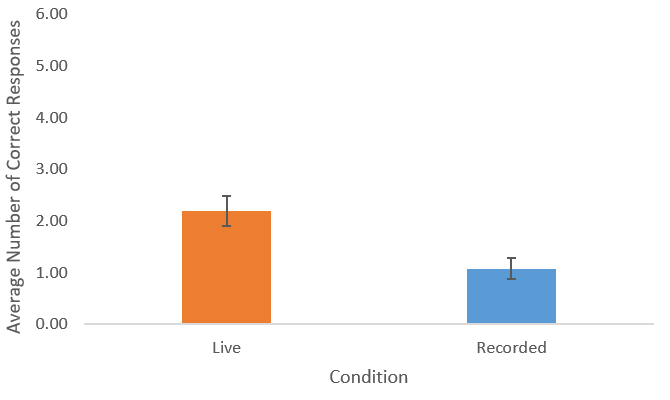
**B.**

# **4.3. Study 3a: Results**

# *4.3.1. Implicit Mentalising*

# *First Fixation Analysis*

First, the data was analysed to investigate whether the AOI that participants first fixated differed depending on whether the task was completed in the live or recorded condition. A Shapiro-Wilk test for normality showed that the data was not normally distributed (*p*<.05); a Wilcoxon signed-rank test revealed that participants were significantly more accurate on the indirect task in the live condition compared to the recorded condition, Z=-3.262, *p*=.001, *r*=.486 (Figure 13).

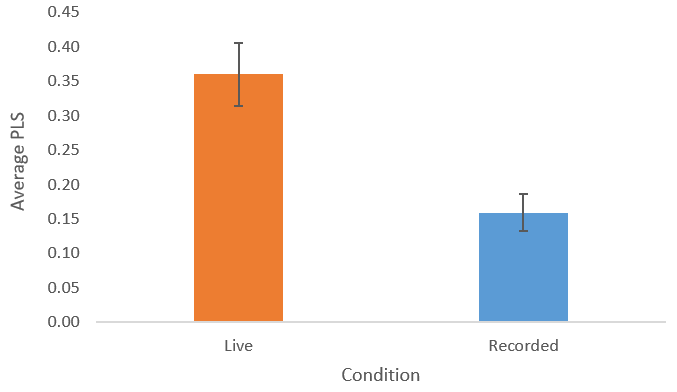


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**Figure 13***.* Average Number of indirect-task correct first fixation responses in the recorded and live conditions. Error bars show +/−1 within subject standard error of the mean (S.E.M).[[5]](#footnote-5)

# *Preferential Looking Score*

To investigate differences in eye-movement behaviour between the live and recorded condition for the indirect task, the preferential looking score was calculated to test whether participants preferentially looked towards the correct box over the course of the experimental trials. A Wilcoxon signed-rank test revealed a significant difference in preferential looking behaviour between the live and recorded conditions (Z=-3.677, *p*<.001, *r=.*548), with participants preferentially attending more to the correct box in the live condition than in the recorded condition (Figure 14).

****

\*

**Figure 14***.* Average preferential looking score in the recorded and live conditions.[[6]](#footnote-6) Error bars show +/−1 within subject standard error of the mean (S.E.M).

In line with the study hypotheses, participants were significantly more accurate at the indirect task when it was completed in the presence of real people, as confirmed by the participants’ first fixation data and preferential looking score.

# *4.3.2. Implicit Data Error Analysis*

# *Implicit Mentalising First Fixation Error Analysis*

|  |  |  |
| --- | --- | --- |
| **Area Of Interest** | **Live**  **(%)** | **Recorded (%)** |
|  |  |  |
| **Correct Box** | 35.56 | 18.43 |
| **Box Containing the Ball** | 27.41 | 35.29 |
| **Other Boxes** | 3.33 | 10.2 |
| **Helper** | 2.59 | 5.49 |
| **Hider** | 0.00 | 0.39 |
| **Background** | 4.44 | 8.63 |
| **Seeker** | 26.67 | 21.57 |

Table 7. Percentage of neurotypical and autistic participants who first fixated each AOI on the incorrect trials for the indirect task in the live and recorded condition in Study 3a.

To investigate the nature of the errors made on the incorrect trials for the indirect task, the eye-movement data from the trials where participants had responded incorrectly were analysed (Table 7). Errors were analysed based on the AOIs indicated in Figure 6. Data were analysed using Wilcoxon signed-rank tests to check for differences in the types of errors made between the live and recorded conditions. Of note, the analysis revealed that participants were significantly more likely to first fixate one of the “other boxes”, i.e. boxes that had never contained the ball, in the recorded condition compared to the live condition (Z=-2.812, *p=*.005, *r=*.419). The use of a second-order theory of mind task made it substantially harder for participants to track the mental state of the seeker, and this analysis reveals that participants were significantly less able to track the narrative of the trial in the recorded condition. The “other boxes” were not directly relevant to the narrative of each trial, and did not play an active role in enabling the participant to track the mental state of the Seeker. In the live condition, the participant was more likely to successfully track the narrative of each trial and attend to the two boxes relevant to the mental state of the seeker. In line with the study hypotheses, this suggests that the presence of real social partners influenced implicit mentalising behaviour, leading to changes in the types of errors made between each condition.

# *Preferential Looking Errors*

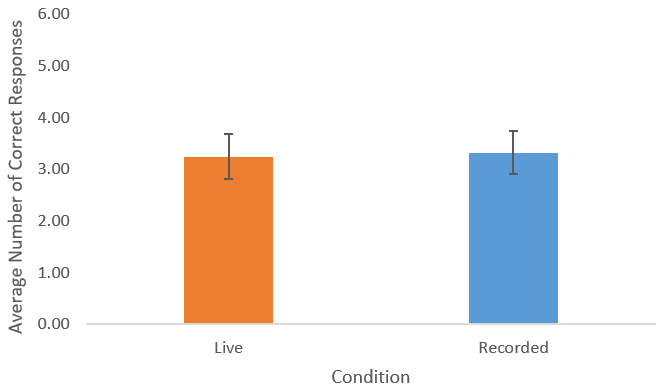
To investigate the nature of the errors made when participants preferentially attended to the incorrect location, the preferential looking data for incorrect trials were inspected. The proportion of overall looking time directed to each AOI was calculated for each participant (Table 8).

|  |  |  |
| --- | --- | --- |
| **Area Of Interest** | **Live**  **(%)** | **Recorded**  **(%)** |
|  |  |  |
| **Correct Box** | 45.70 | 21.67 |
| **Box Containing the Ball** | 27.73 | 32.08 |
| **Other Boxes** | 3.13 | 5.00 |
| **Helper** | 0.79 | 1.25 |
| **Hider** | 0.00 | 0.42 |
| **Background** | 1.56 | 2.08 |
| **Seeker** | 21.09 | 37.50 |

Table 8. Percentage of participants preferentially attending to each AOI for the error trials for the indirect task.

It was found that participants made similar errors across each condition, most commonly attending to the AOIs directly related to the narrative of each trial, i.e. either the seeker or the box containing the ball. The data was then further analysed using Wilcoxon signed-rank tests. Participants were significantly more likely to preferentially attend to the seeker in the recorded condition compared to the live condition (*Z=*2.017, *p=*.044, *r=*.300). In combination with the first fixation analysis, this confirms that errors in the recorded condition are likely a result of a failure to follow the narrative of each trial, rather than due to a lack of engagement with the task. This provides further evidence that the types of errors made on the indirect task were affected by the presence of real social partners.

# *4.3.3. Explicit Mentalising*

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**Figure 15.**Average number of direct-task correct responses in the recorded and live conditions in Study 3a. Error bars show +/−1 within subject standard error of the mean (S.E.M).

Regarding the direct task, the critical analysis focussed on whether participants performed differently on the direct task depending on whether it was completed in the live or recorded condition. Histograms revealed that the data for the direct task in Study 3a for both conditions appeared bimodal (Figure 15). A Shapiro-Wilk test for normality showed that the data was not normally distributed (*p*<.05), therefore a Wilcoxon signed-rank test was run to determine whether there was a difference in the number of accurate responses given in the live and recorded conditions. Participants did not perform differently on the direct task in the live compared to the recorded condition, Z=.286, *p*=.775, *r*=.04. This is in contrast to the study hypotheses, and differs from the findings of the indirect task, where implicit mentalising was clearly affected (and facilitated) by the task being conducted live rather than being presented via a recording.

# *4.3.4. Autistic Traits*

The final analyses aimed to test whether performance on the indirect and direct tasks was related to the number of autistic traits reported by an individual. Spearman’s Rho correlations revealed that task accuracy was not related to autistic traits for the indirect task for either the participants’ first fixations (Live r=.019, *p=*.901; Recorded *r=*.134, *p=.*381) or preferential looking score (Live *r=.*077, *p=.*616; Recorded *r=.*228, *p=*.132). Spearman’s Rho correlations revealed that task accuracy was also not related to autistic traits for the direct task in either the Live (*r=-.*048, *p=.*754) or recorded condition (*r=-.*048, *p=.*753). Replicating the results of Study 2, the results reveal that neither the indirect or direct version of the task was influenced by the number of self-reported autistic traits in neurotypical individuals in either the live or recorded condition. Therefore, Study 3b will aim to recruit both neurotypical controls and participants with a clinical diagnosis of an autism spectrum condition.

# **4.4. Study 3b: Method**

# *4.4.1. Participants*

A post-hoc power analysis revealed that on the basis of the mean effect size observed for the effect of social presence on implicit and explicit mentalising in Study 2 (*d* =.40), approximately 60 participants would be needed in each group to obtain statistical power at the .80 level. However, due to the challenges associated with recruitment in autistic populations (Chapter 5, Section 5.3) and the availability of the task confederates, only twenty-one autistic adults (13 male, 8 female) took part in study 3b. Of the fifty neurotypical participants recruited for Study 3a, 18 participants were identified as age, gender and non-verbal IQ matched controls (12 male, 6 female) for Study 3b. Participants with a diagnosis of an ASC were recruited from the Autism Research Lab database and neurotypical participants were recruited via opportunity sampling through a university-wide volunteers list. All participants received a gift voucher as a thank you for taking part.

Neurotypical participants completed the Broad Autism Phenotype Questionnaire and all participants in the ASD group had previously received a clinical diagnosis of Asperger’s or Autism Spectrum Disorder. Additionally, all autistic participants were asked to complete the Autism Diagnostic Observation Schedule (ADOS-2) to provide an indication of their current level of autistic traits. All participants also completed the Matrix Reasoning section of the Wechsler Abbreviated Scale of Intelligence (WASI) as a measure of non-verbal reasoning. An independent samples *t*-test indicated no difference between the two groups on the matrix reasoning task(*t*(34)=-1.064*, p*=.295, *d*=0.36), indicating the two groups were evenly matched on non-verbal reasoning ability. Three autistic participants were excluded from the final sample due to technical difficulties calibrating the eye trackers. This left a total sample of 18 participants with an ASC diagnosis, and 18 neurotypical controls (Table 9).

*Table 9.**Participant characteristics*

|  |  |  |
| --- | --- | --- |
|  | Autistic participants | Neurotypical participants |
| Gender (Male : Female) | 13 : 5 | 12 : 6 |
| Age  Mean (Range)  SD | 42.11 (21 – 60)  15.03 | 36.7 (23 – 58)  15.49 |
| ADOS  Mean (Range)  SD  BAPQ  Mean (Range)  SD | 7 (2 – 14)  3.07  -  - | -  -  92.67 (68 – 107)  13.03 |
| Matrix Reasoning  Mean (Range)  SD | 59.56 (50 – 72)  6.08 | 57.50 (49 – 69)  5.50 |

# *4.4.2. Design*

Study 3b used a mixed model design, with two within-participant variables, condition (live or recorded) and task type (indirect or direct), and one between-participants variable ‘group’ (ASC or NT). The study used the same design outlined in Study 3a (Section 4.2.2).

# *4.4.3. Apparatus and Procedure*

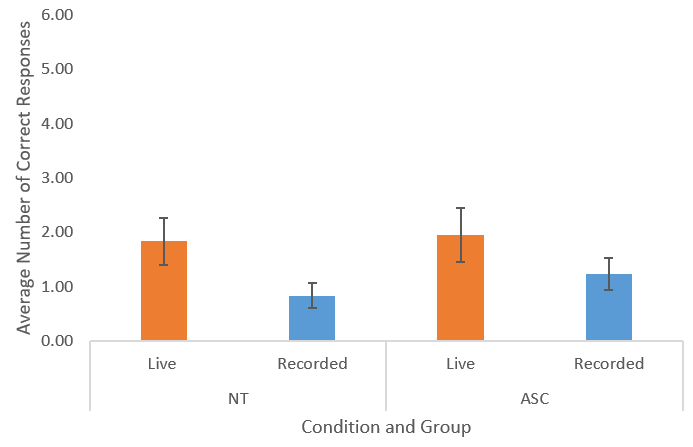
Both the neurotypical and autistic participants in Study 3b were required to complete the Matrix Reasoning section of the Wechsler Abbreviated Scale of Intelligence (WASI). In this subtest participants view incomplete matrices and are required to select a response option that completes the matrix. The Matrix Reasoning is designed to test non-verbal reasoning, and was used to ensure that the autistic group and NT group were matched within three IQ points for non-verbal reasoning ability.

# **4.5. Study 3b: Results**

# *4.5.1. Implicit Mentalising*

# *First Fixation Analysis*

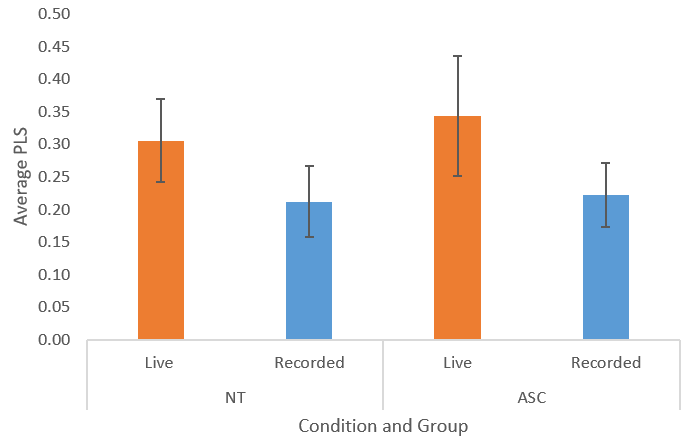
First, analyses were conducted to investigate whether the AOI that participants first fixated differed depending on whether the task was completed in the live or recorded condition. A Shapiro-Wilk test for normality revealed that the data was not normally distributed (*p*<.05), however ANOVAs are considered robust to violations of normality if there are equal numbers of participants in each group. A 2x2 mixed measures ANOVA, with a within-subject factor of condition (live/recorded) and a between-subjects factor of group (autistic/NT) revealed a main effect of condition (*F*(1,34)=6.967, *p=.*012, *ηρ²*=.170), as the number of correct responses was greater in the live condition (M=.1.83, SD= 1.91) compared to the recorded condition (M=1.00, SD=1.10). There was no main effect of group (*F*(1,34)=.156, *p=.*695, *ηρ²*=.005) and no condition x group interaction (*F*(1,34)=.279, *p=.*601, *ηρ²*=.008), demonstrating that both groups responded similarly to the presence of social others in the live condition (Figure 16).



**Figure 16***.* Average number of indirect-task correct first fixation responses in the recorded and live conditions for the neurotypical and ASC group. [[7]](#footnote-7) Error bars show +/−1 within subject standard error of the mean (S.E.M).

Consistent with the results of Studies 2 and 3a, participants were more accurate on the indirect task when they completed it in the live condition than when they completed it in the recorded condition. Further, this result was found to extend beyond neurotypical participants, with autistic participants also performing significantly more accurately in the live condition.

# *Preferential Looking Score*

The preferential looking score was calculated to test whether participants preferentially looked towards the correct box over the course of the experimental trials. A 2x2 ANOVA revealed a main effect of condition (*F*(1,34)=4.269, *p=.*047, *ηρ²*=.112), as the number of correct responses was greater in the live condition (M=.315, SD=.323) compared to the recorded condition (M=.211, SD=.215) (Figure 17). There was no main effect of group (*F*(1,34)=.011, *p=.*918, *ηρ²*<.001) and no condition x group interaction (*F*(1,34)=.046, *p=.*831, *ηρ²*=.001), revealing that both groups showed the same improvement in accuracy when in the presence of real social partners.

**Figure 17***.* Average preferential looking score in the recorded and live conditions for neurotypical and ASC group.[[8]](#footnote-8) Error bars show +/−1 within subject standard error of the mean (S.E.M).

All participants were significantly more accurate at the indirect task when it was completed in the live condition. This provides evidence that implicit mentalising processes are substantially enhanced when in the presence of a social partner, with the implicit mentalising system much more engaged when subjected to a social presence.

# *4.5.2. Implicit Data Error Analysis*

# *Implicit Mentalising First Fixation Error Analysis*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **NT** | | **ASC** | |
| **Area Of Interest** | **Live**  **(%)** | **Recorded (%)** | **Live**  **(%)** | **Recorded**  **(%)** |
|  |  |  |  |  |
| **Correct Box** | 27.62 | 14.85 | 30.56 | 25.93 |
| **Box Containing the Ball** | 25.71 | 33.66 | 25.93 | 38.27 |
| **Other Boxes** | 0.95 | 2.97 | 0.93 | 2.47 |
| **Helper** | 3.81 | 8.91 | 5.56 | 6.17 |
| **Hider** | 0.00 | 0.99 | 0.00 | 4.94 |
| **Background** | 10.48 | 2.97 | 12.96 | 9.88 |
| **Seeker** | 44.76 | 21.78 | 24.07 | 12.35 |

Table 10. Percentage of neurotypical and autistic participants who first fixated each AOI on the incorrect trials for the indirect task in the live and recorded condition.

An exploratory analysis investigated the nature of the errors made on the incorrect trials for the indirect task (Table 10). Data were analysed to check for differences in the types of errors made between the live and recorded conditions. Of note, Wilcoxon signed-rank tests revealed that both the autistic participants (Z=-2.179, *p=*.029, *r=*.514) and NT participants (Z=-2.390, *p=*.017, *r=*.563) were significantly more likely to first fixate the seeker in the live condition as compared to the recorded condition. This demonstrates that in the live condition, participants were more likely to first attend to the AOIs relevant to the narrative of each trial, in this case, the Seeker. This provides further evidence that the types of errors made on the indirect task were affected by the presence of real social partners.

# *Preferential Looking Errors*

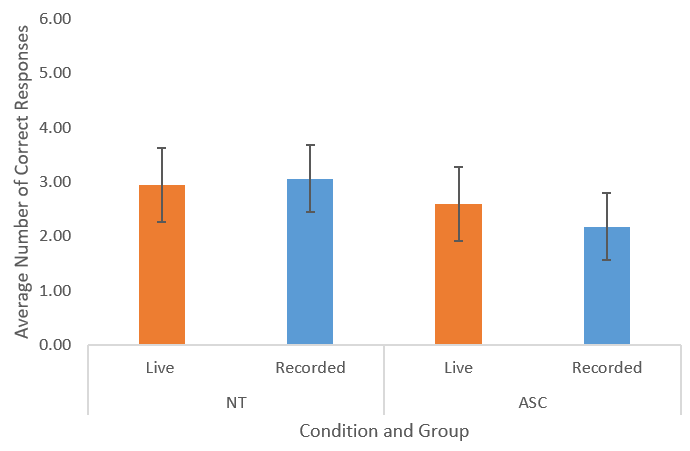
To investigate the nature of the errors made when participants preferentially attended to the incorrect location, the preferential looking data for incorrect trials were inspected. The proportion of overall looking time directed to each AOI was calculated for each participant (Table 11).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **NT** | | **ASC** | | |
| **Area Of Interest** | **Live (%)** | **Recorded (%)** | | **Live (%)** | **Recorded (%)** | |
|  |  |  | |  |  | |
| **Correct Box** | 41.51 | 18.81 | | 35.40 | 21.49 | |
| **Box Containing the Ball** | 37.74 | 34.65 | | 39.82 | 36.36 | |
| **Other Boxes** | 2.83 | 0.00 | | 4.42 | 10.74 | |
| **Helper** | 0.94 | 1.98 | | 0.00 | 0.00 | |
| **Hider** | 0.00 | 0.99 | | 0.00 | 6.61 | |
| **Background** | 0.94 | 4.95 | | 5.31 | 8.26 | |
| **Seeker** | 16.04 | 38.61 | | 15.04 | 16.53 | |

Table 11. Percentage of participants preferentially attending to each AOI for the error trials for the indirect task.

In line with Studies 2 and 3a, participants were found to make similar errors across each condition, most commonly attending to the AOIs directly related to the narrative of each trial. The data was then further analysed using Wilcoxon signed-rank tests. There were no significant differences between the error types for the live and recorded conditions for the autistic participants, however, mirroring the results of Study 3a, the neurotypical participants were significantly more likely to preferentially attend to the seeker in the recorded condition compared to the live condition (*Z=-*2.693, *p=*.007, *r=*.635). This confirms that participants remained engaged with the task across both conditions and attended to the AOIs directly relevant to the narrative of the trial, providing further evidence that errors in the recorded condition were not due to a lack of engagement with the task.

# *4.5.3. Explicit Mentalising*

In line with the study hypotheses, analyses aimed to investigate whether participants performed differently on the direct task depending on whether it was completed in the live or recorded condition. A 2x2 mixed model ANOVA revealed no main effect of either group (F(1,34)=.787, *p=*.381, *ηρ²*=.023) or condition (F(1,34)=.227, *p=*.637, *ηρ²*=.007) and no condition\*group interaction (F(1,34)=.735, *p=*.397, *ηρ²*=.021), demonstrating that neither group completed the direct task differently in either condition (Figure 18). These results therefore provide further evidence that explicit mentalising is unaffected by the presence of live task protagonists, and that implicit and explicit mentalising are differentially affected by whether a task is performed live or presented via a recording.

**Figure 18***.* Average number of direct-task correct responses in the recorded and live conditions for the Neurotypical and ASC groups. Error bars show +/−1 within subject standard error of the mean (S.E.M).

These results therefore provide further evidence that explicit mentalising is unaffected by the presence of live task protagonists, and that implicit and explicit mentalising are differentially affected by whether a task is performed live or presented via a recording

# **4.6. Discussion**

The current chapter investigated whether autistic and neurotypical individuals track the beliefs of others in an enhanced manner when those “others” are physically present in the room – in other words, whether either group’s mentalising behaviour would be affected by a real social presence. In combination with the results presented in Chapter 3 the answer was a very clear “yes”: it was found that both autistic and neurotypical participants’ implicit mentalising behaviour was affected by a social presence, with participants performing significantly better when a real person was present. In contrast, explicit mentalising was found to be unaffected by a social presence, with no difference in performance depending on whether or not real people were present.

In line with the study hypotheses, the neurotypical adults in Studies 3a and 3b were significantly more accurate on the indirect task when it was completed in the presence of real people. Further, autistic participants were also found to be significantly more accurate in the live condition. Previous research which has focussed on the effect of a social presence has found that the inclusion of real-time social partners can lead to comparable performance between participants with high and low amounts of autistic traits. This has led to the suggestion that in face-to-face situations social cues are potentially so strong that they can overcome the atypicalities associated with autism (Freeth et al., 2013). This raises the possibility that the deficits in implicit mentalising reported in participants with autism may, wholly or in part, be a function of the experimental paradigm used. If individuals with a diagnosis of an ASC, or neurotypical individuals high in autistic traits, display different patterns of behaviour in social scenarios, as compared to lab-based paradigms, then this raises important implications for the generalisability of social cognition research conducted without a social presence.

Further to this, autistic participants demonstrated comparable performance to neurotypical controls on the indirect task in both conditions. Previous research has demonstrated that autistic participants consistently show difficulties on indirect tasks requiring implicit mentalising abilities (Senju et al., 2009; Schneider et al., 2013; Schuwerk et al., 2016), however, in both the current studies and Study 2, task performance was not related to either the level of self-reported autistic traits or to a diagnosis of an autism spectrum condition. One potential explanation for this finding can be drawn from the heterogenous nature of autism spectrum conditions. Autism is now broadly recognised as consisting of multiple aetiologies, dimensions and trajectories, with each individual displaying differing profiles of relative strengths or difficulties (Masi, DeMayo, Glozier & Guastella, 2017). Of note, ToM competency has been found to be directly related to the overall severity of an individual’s autism diagnosis, with low functioning individuals shown to demonstrate greater difficulties with ToM processing (Yoshida, Dziobek, Kliemann, Keekeren, Friston & Dolan, 2010). The autistic adults who participated in Study 3b had received previous diagnoses of either Asperger’s syndrome or high functioning autism, it is therefore unlikely that this sample was representative of the full range of abilities across the autism spectrum.

An alternative explanation for this finding is related to the demographics of the participants recruited across Chapters 3 and 4, both of which engaged adult samples. Studies that have recruited infants and older children have consistently found difficulties in implicit mentalising abilities in autistic individuals (Senju et al., 2009; Schneider et al., 2013; Schuwerk et al., 2016), however, evidence from studies using adult populations is more ambiguous in relation to implicit mentalising competencies (Cole et al., 2019; Rosenblau et al., 2015). Adults have a wealth of life experience, including exposure to situations involving differing theory of mind demands. Previous research has demonstrated that exposure and feedback relating to theory of mind scenarios can lead to improvements in subsequent task performance (Schuwerk et al., 2015). This improvement is argued to result from a ‘perception-action contingency’ (Sodian et al., 2015), whereby observing the result of an action enables the ability to predict the outcome of a similar scenario. With increased exposure to situations eliciting mentalising behaviour, adults may therefore have learned and developed an association with the typical outcomes of such scenarios, contributing to an increase in mentalising ability.

Similar to implicit mentalising, the autistic and neurotypical adults showed comparable explicit mentalising ability. The use of a second-order theory of mind task did allow a greater range of scores than recorded in Chapter 3, although the data presented primarily as bimodal, with participants either passing or failing the task. The bimodal pattern of data most likely resulted from the lack of feedback given to participants at the end of each trial. As participants were not informed whether their responses were correct or incorrect, they could continue to perseverate with whichever strategy they had initially identified. The lack of feedback on task performance was necessary in order to prevent advanced knowledge of the task affecting the results in the next stage of the study, as well as allowing a clearer insight into a participant’s ability to form a conscious understanding of another person’s mental state. The results clearly demonstrate that performance on the direct task was not influenced by the presence of social others, with participants maintaining the same pattern of responding whether in the live or recorded condition.

In contrast to implicit mentalising, it is clear that explicit mentalising behaviour was unaffected by the context in which it occurred for both neurotypical and autistic participants. It is crucial to note that in the live condition, participants had no form of interaction with the actors, who maintained neutral facial expressions and avoided eye contact (or other socially engaging behaviour) throughout. Additionally, the recorded condition followed the exact experimental procedure of the live condition, and task instructions were given verbally by the experimenter in both conditions. However, there was a significant improvement in implicit mentalising ability only, and no improvement in explicit mentalising, therefore providing evidence that social presence has a differential impact on each mentalising system. Taken with the results from Chapter 3 regarding the differing role of executive functions in explicit and implicit mentalising, this provides strong evidence that mentalising exists as two discrete systems (Apperly & Butterfill, 2009).

# *4.6.1. Conclusion*

The results from Study 3a and Study 3b show that implicit mentalising is sensitive to the real-time presence of a social partner, with both neurotypical and autistic participants performing significantly better when the task protagonists were physically present. In contrast, explicit mentalising does not appear to be sensitive to social presence in this way. Further, the results revealed that the autistic participants performed comparably to neurotypical controls on both mentalising tasks, suggesting that difficulties with implicit mentalising may not be as pervasive as previously assumed in autistic adults. This study therefore highlights the need to use ecologically valid tasks when studying social phenomena in both clinical and subclinical populations – and the need to ensure that those tasks do not directly constrain and affect the very behaviour that they are aiming to study.

# **Chapter 5: General Discussion**

The aim of this PhD thesis was to investigate the effect of a social presence, both real and implied, on cognitive tasks in both neurotypical and autistic adults. The literature review in Chapter 1 highlighted that the use of progressively social stimuli can lead to quantifiable changes in both neurotypical and autistic participants’ behaviour (Reader & Holmes, 2016; Cole et al., 2016; Risko et al., 2016). However, these findings have typically arisen in the context of social attention research paradigms and there are few studies addressing how a social presence could affect other areas of social cognition. Further, whilst previous research suggests that the characteristics of ASC are most prevalent in complex social scenarios (Klin et al., 2002; Hanley et al., 2013), surprisingly little research has investigated the impact of social agency and social presence on social cognition in autistic adults. This thesis therefore aimed to investigate how the perceived presence of social partners can affect neurotypical and autistic adults’ performance on social cognition tasks. Across the four studies conducted in this thesis, both neurotypical and autistic participants were found to display significantly better task performance when they perceived a stimulus to possess social agency. Further, this effect occurred for both an implied social presence (Study 1) and a real-time social presence (Study 2, 3a & 3b). The following chapter will aim to discuss the findings of this thesis including: The implications leading from these findings, the methodological considerations relating to each of the studies in this thesis, current issues in implicit mentalising research and, finally, finish by discussing potential future directions of research.

# **5.1. Summary of Findings**

Humans are remarkably sensitive to the behaviour of social partners. This allows an understanding of the preferences of others and is thought to arise from theory-of-mind (ToM) processing (Hudson et al., 2018). However, individuals with an autism spectrum diagnosis typically show difficulties in ToM processing and are less sensitive to detecting patterns of social behaviour (White et al., 2011; Schuwerk et al., 2016; Schneider et al., 2013), therefore it may be that autistic adults demonstrate difficulties predicting a social partner’s behaviour and preferences. The first study (Chapter 2) therefore investigated whether autistic adults are sensitive to social agency when completing a prediction task. The study used an adaptation of a paradigm previously used by Foulsham and Lock (2015) and recruited both autistic and neurotypical adults. In this paradigm participants were asked to infer the selection preferences of an animated cue. The agency of the cue was manipulated across two parts of the study where the cue was either described as representing the selection process of a computer algorithm or the selection process of eye movements of another participant. Both neurotypical and autistic participants were found to be significantly more accurate when they believed the cue represented the eye movements of another participant. SRS-2 t-scores, a measure of autistic traits, were not significantly correlated with performance in either the first or second part of the study, therefore, sensitivity to the social agency of the cue was not related to the level of social impairment shown by either autistic or NT participants. This study demonstrates the significant impact of an implied social presence on social cognition in both NT and autistic adults. Further, it provides evidence that autistic participants showed a social facilitation effect and could successfully interpret the social information available from a cue, suggesting that the difficulties autistic people have in interpreting patterns of social behaviour do not arise from a lack of sensitivity to social agency.

Our behaviour is frequently influenced by those around us. However, most social cognition research is conducted using paradigms without the presence of social others. The second study (Chapter 3) therefore aimed to extend the findings of Study 1 by investigating whether the use of a real-time social presence influences the ability to track intentions during a mentalising task. Study 2 used a first-order theory of mind task aimed to test implicit and explicit mentalising behaviour across two conditions: live, where the task protagonists were physically present acting out the task, or recorded, where the same task protagonists demonstrated the task in a pre-recorded video. The study recruited neurotypical adults, and autistic traits were measured using the BAPQ. Task performance was unrelated to the self-reported number of autistic traits, but it was found that implicit and explicit mentalising were differentially affected by a real-time social presence. Implicit mentalising was found to be sensitive to a social presence, with participants performing significantly better when the task protagonists were a real-time social presence, whereas explicit mentalising was not affected by the presence of others. Further, each mentalising system was found to draw upon different cognitive resources, with a significant relationship between explicit mentalising and cognitive flexibility; but no relationship between implicit mentalising and any of the other executive function measures. This therefore supports previous research claiming that mentalising exists as two discrete systems which each reliant upon different cognitive resources (Apperly & Butterfill, 2009; Schuwerk et al., 2016). Further, it provides evidence that the indirect task used in Study 2 provided a reliable measure of an involuntary, automatic process. The results from this study demonstrated that implicit mentalising is highly sensitive to the real-time presence of others, suggesting that social presence may be a crucial factor in our understanding of the mentalising process. However, this study also raised key methodological concerns, first, surrounding the ease with which participants completed the direct task, and second, the need to recruit participants with a clinical diagnosis of an autism spectrum condition.

Studies 3a and 3b (Chapter 4) therefore introduced the use of a more complex second-order theory of mind task (Study 3a & 3b) and recruited autistic participants (Study 3b). Replicating the results of Study 2; Study 3a and Study 3b found that participants were significantly more accurate on the indirect task aimed at measuring implicit mentalising when the task was completed with a real-time social presence, but that the direct task did not display the same sensitivity and there was no difference in task performance between the two conditions. Further, task performance was found to be unrelated to the number of autistic traits reported by neurotypical participants, and there were no between group differences for the neurotypical or autistic groups on either the indirect or direct task. Taken together, these studies provide evidence that the presence of a real-time social partner significantly alters the nature of social cognition in both neurotypical and autistic individuals and demonstrates that studies without the potential for social interaction should not be assumed to be functional analogues to real-world social scenarios.

# **5.2. Implications**

# *5.2.1 The Importance of a Social Presence*

The findings from this thesis present cumulative evidence demonstrating the importance of social partners in understanding social cognition in both neurotypical and autistic individuals. Chapter 2 (Study 1) provided compelling evidence that both NT and autistic adults are sensitive to social agency: the belief that a cue represented the eye movements of another person was found to produce a social facilitation effect, with participants significantly more able to accurately predict the selection preferences of the cue when they believed it to represent a human. First and foremost, this finding supports previous research indicating that minimal changes in the perception of the social agency of a stimulus can lead to alterations in participant behaviour (Wiese et al., 2012; Gobel et al., 2017). Further, this finding was revealed to extend beyond a mere sensitivity to the agency of a cue, with participants using the social information available from the cue in order to form predictions relating to the preferences of another individual. These results therefore lend support to studies demonstrating that even such simplistic cues are capable of engaging theory of mind processing in order to infer the mental state of another person (Foulsham & Lock, 2015). Study 1 thereby demonstrates the important influence of social context in these types of paradigms. Further, these findings illustrate key considerations for the types of stimuli used within computer-based paradigms, with participants demonstrating different patterns of behaviour when believing a cue to possess social agency.

The facilitation effect found in Study 1 is yet more compelling when considering the underlying experimental manipulation that generated these results. As previously stated, there were minimal changes to the cue, physically it remained unaltered; all that differed was the participants’ perception of what the cue represented. Moreover, the cue did not possess any inherently social physical properties, and the paradigm used a stimulus and task format that participants were unlikely to encounter within their daily lives, thereby removing the potential to employ any previously learned strategies. It is therefore striking that such significant behavioural changes were observed purely on the basis that participants believed the cue to represent another person. Consequently, this raises key concerns about social cognition paradigms that lack any form of social presence: If such minimal changes as were made in Study 1 are capable of eliciting significant behavioural differences, then studies conducted in full social isolation (such as those using static or cartoon stimuli) are unlikely to reflect how social cognition behaves in truly social environments.

Chapters 3 and 4 (Studies 2, 3a & 3b) sought to extend the findings of Study 1 and further investigate the importance of a social presence in social cognition research. Specifically, the studies within these chapters investigated the effect of a social presence on mentalising processes. A current focus within social cognition literature is the importance of developing naturalistic, ecologically valid paradigms and stimuli (Reader & Holmes, 2016; Risko et al., 2016). Study 1 revealed the critical impact of an *implied* social presence; however, the study utilised a 2-dimensional stimulus, lacking ecological validity. Studies 2, 3a and 3b therefore sought to investigate the impact of more naturalistic stimuli with the inclusion of both pre-recorded videos and a real-time social presence in the form of physical task protagonists. Results revealed that a real-time social presence had a significant impact upon both neurotypical and autistic participants’ implicit mentalising abilities, with significantly improved task performance when participants completed the indirect task with live task protagonists, as compared to pre-recorded videos. Much previous research has investigated the impact of naturalistic stimuli in social attention paradigms (Risko et al., 2012; Foulsham et al., 2011; Laidlaw et al., 2011), however these studies are the first to offer tangible evidence that implicit theory of mind processes are also significantly affected by a social presence.

Of key relevance, theorists have hypothesised that the inclusion of naturalistic stimuli in mentalising paradigms could lead to improvements in implicit mentalising (Kulke et al., 2019), and neuroimaging studies have theorised that online implicit monitoring is a continuous process in real-time social interactions (Schilbach, 2016; Lehmann et al., 2019). The findings of Chapters 3 and 4 accordingly offer critical support for these arguments, demonstrating that implicit mentalising processes were significantly more engaged when in the presence of real people. Importantly, these findings have far reaching implications for social cognition paradigms lacking a real-time social presence and suggest that paradigms conducted in social isolation cannot be considered analogous to real life behaviour. Therefore, the inclusion of a social presence should be a consideration across social cognition paradigms.

The results of the studies presented in this thesis offer several implications for the different kinds of paradigms used in social cognition research. First, in computer-based lab paradigms participants display different patterns of behaviour when they believe a cue to possess social agency. Second, participants demonstrate further changes in behaviour when presented with a real-time social presence, such as real, physical task protagonists. The implications of such findings are that if participants demonstrate quantifiable behavioural changes to an implied social presence, and further quantifiable changes to a real-time social presence, than social cognition paradigms conducted in social isolation are unlikely to reflect how cognitive processes behave in real life environments. This research therefore supports previous studies which argue that social interaction is inherent to understanding social cognition (De Jaegher et al., 2010; Gobel et al., 2015). The results from the studies in this thesis suggest that social presence does not simply modify how we direct our attention to a scene (Risko et al., 2016; Reader & Holmes, 2016; Risko et al., 2012), but can affect the way in which we engage our cognitive processes. These studies consequently provide key evidence for the need to use ecologically valid tasks in social cognition research. Further, these findings raise key concerns regarding the generalisability of paradigms that are conducted without a social presence.

# *5.2.2 Social Stimuli and Autism*

Based on the literature discussed in Chapter 1 (Section 1.2 & 1.4) it was predicted that autistic individuals, and neurotypical individuals high in autistic traits, would be less sensitive to the presence of other people. This prediction was drawn from research demonstrating that an autism diagnosis, and autistic traits, are associated with atypical attention to social stimuli and a marked preference for non-social stimuli (Chita-Tegmark, 2016; Dawson et al., 1998), particularly when using complex social stimuli (Klin et al., 2002; Speer et al., 2007; Hanley et al., 2013). However, in contrast to previous literature, the findings in this thesis revealed that autistic adults showed a social facilitation effect and performed significantly more accurately on both a prediction task (Study 1) and an indirect version of a false belief task (Study 3b) when the tasks featured a social presence. Additionally, autistic traits were found to be unrelated to task performance in neurotypical participants (Studies 1, 2, 3a & 3b). The findings of this thesis therefore do not provide support for the social motivation hypothesis of autism (Chevallier et al., 2012). The social motivation hypothesis posits that the social difficulties associated with an autism spectrum diagnosis are due to a lack of motivation to engage with social stimuli. However, evidence from Study 1 suggests that autistic individuals *are* sensitive to social others and *do* attend to cues arising from social behaviour. This is furthered by the results found in Studies 2, 3a and 3b which found significantly improved implicit mentalising abilities in the presence of real-time social partners. This suggests that the social difficulties associated with autism spectrum conditions are not due to a lack of social motivation, as the studies in this thesis provide evidence that autistic adults attend to and interpret cues arising from a social partner’s behaviour.

The finding that autistic adults are sensitive to a social partner’s behaviour therefore lends support to research critiquing the social motivation hypothesis. Such studies argue that social motivation is not confined to an individual but should be viewed as an active interaction. As in the case of social cognition research, it is argued that social motivation is a two-way interaction and cannot be viewed in isolation. Likewise, it is proposed that such forms of social behaviour ought to be investigated within a social environment in order to gain a clear understanding of how these processes work within real world interactions (Jaswal & Akhtar, 2019). Evidence for the necessity of viewing social motivation as a two-way interaction can be taken from research investigating the double empathy problem (Milton, 2012). Previous research has demonstrated that neurotypical individuals are often ineffective at interpreting the behaviour of autistic individuals (Sheppard, Pillai, Wong, Ropar & Mitchell, 2016). As such this raises an interesting conundrum, if a social partner fails to interpret your social overtures, then does this necessarily mean that you are failing to show social motivation? This is a critical consideration as the assumption that an autism spectrum diagnosis leads to a lack of interest in the social world can lead to many negative assumptions and misinterpretations of an autistic individual’s behaviour (Jaswal & Akhtar, 2019), and the results of Study 1 suggest that autistic adults do engage with the behaviour of their social partners.

Interestingly, previous research has indicated that autistic individuals display atypical attention to the eyes in a face (Freeth & Bugembe, 2019; Chita-Tegmark, 2016; Hanley et al., 2015), however, it is unknown whether this arises from an inability to process social information from a gaze, or instead arises from an aversion to the physical properties of the eyes. The eyes hold a wealth of information signalling our emotions, intentions and facilitating our participation within social interactions (Gobel et al., 2015; Risko et al., 2016). Atypical gaze use and interpretation can therefore have a lasting impact upon an individual’s ability to process crucial social information and engage in social situations (Jones, Carr, & Klin, 2008; Hanley et al., 2014). On the one hand it is argued that autistic individuals attend less to the gaze of others as eyes do not hold the same information as they do for neurotypical individuals (Hanley et al., 2015). Increased attention to the mouth regions of a face could therefore be interpreted as directing attention towards facial features that are able to communicate unambiguous information, such as through speech (Hanley et al., 2015). On the other hand, it is alternately argued that autistic individuals have an aversion to the physical properties of an eye, which leads to atypical attention to this area. Evidence for this theory can be drawn from studies demonstrating that autistic individuals fail to habituate to the effects of a direct gaze by showing a continually elevated heart rate (Helminen, Leppänen, Eriksson, Luoma, Hietanen & Kylliäinen, 2017) and show higher levels of galvanic skin response than neurotypical individuals to a direct gaze (Kylliäinen & Hietanen, 2006).

Study 1 offered a unique insight into the debate of whether gaze atypicalities in autism arise from difficulties interpreting gaze information, or from an aversion to the physical characteristics of the eyes. The cue used in Study 1 revealed the eye movements of another participant, but without any of the physical characteristics of the eyes. The traits associated with an autism diagnosis are most evident when using complex social stimuli (Klin et al., 2002; Hanley et al., 2013), therefore, the use of a disembodied stimulus may have removed a potential source of distraction; thereby allowing autistic participants to process the social information available from the cue without the interference of the physical properties of a gaze. The results of Study 1 revealed that autistic participants were significantly more able to predict the preferences of the cue when they believed it represented another person’s eye movements. This therefore suggests that autistic adults were able to extract and use the social information available from a person’s gaze. This consequently lends support to the proposition that atypical attention to the eyes in autism is not due to an inability to infer social information from a gaze.

Further, previous research suggests that ASC and autistic traits are associated with difficulties in implicit mentalising (Senju et al., 2009; Schneider et al., 2013; Schuwerk et al., 2016; Gliga et al., 2013). However, Studies 2, 3a and 3b, revealed that autistic adults and neurotypical participants high in autistic traits performed comparably to NT controls and individuals low in autistic traits on both the indirect and direct tasks used across these three studies. The results from these studies therefore provide support for research which has found no relationship between autistic traits and explicit and implicit mentalising (Nijhof et al., 2016) or social attention (Freeth et al., 2013; Laidlaw et al., 2011). Further, it supports studies with autistic adults where participants have displayed intact implicit mentalising abilities (Cole et al., 2018). The results of these studies therefore contradict the Theory-of-Mind hypothesis of autism (Baron-Cohen, Leslie & Frith, 1985). When first proposed, the Theory-of-Mind account of autism was highly influential, with the proposal that the social and communicative deficits associated with autism could be explained via deficits in the ability to develop a theory of mind (Baron-Cohen et al., 1985). However, this account has now been widely criticised as, amongst other critiques, it provides only a partial explanation for the diversity present within autism spectrum conditions (Tager-Flusberg, 2007). The findings from this thesis demonstrate that the deficits in mentalising (both explicit and implicit) typically associated with an autism spectrum diagnosis are not universal, and therefore provide additional evidence that the Theory-of-Mind hypothesis cannot adequately explain the characteristics of autism for all autistic individuals.

As discussed in Chapter 4 (Section 4.6) there are several plausible explanations for why studies with autistic adults can produce equivocal findings, with the first relating to the heterogeneity of autism spectrum conditions. Due to the diverse nature of autism spectrum conditions, each individual can demonstrate a differing profile of relative strengths or difficulties (Masi et al., 2017). The autistic participants recruited in Studies 1 and 3b all identified as high functioning; therefore, they may have displayed significantly different patterns of task behaviour compared to other individuals lower on the spectrum. Alternatively, other explanations can be drawn from the demographics of the studies in this thesis. Through recruiting adult samples these studies recruit individuals with a significant amount of life experience, including exposure to scenarios requiring mentalising abilities. Such experience could therefore potentially lead to improvements in theory of mind ability via practice (Schuwerk et al., 2015). A final, and compelling, explanation for why autistic adults may display competency on theory of mind tasks relates to the types of stimuli used in these paradigms, for example, the use of action stimuli. Action stimuli require participants to infer intentions from another’s actions, as compared to inferring intentions from facial expressions or eye gaze. Previous research has demonstrated that, whilst autistic individuals may demonstrate difficulties inferring mental states from static stimuli, they are able to infer mental states from another’s actions (Cole et al., 2018). Therefore, the use of action stimuli across each of the studies in this thesis may have assisted autistic participants in understanding the mental state of the task protagonists. This could potentially be due to such stimuli representing a closer depiction of how we interpret mental states within our day-to-day lives (Reader & Holmes, 2016). This consequently provides further evidence for the need to use increasingly naturalistic stimuli in order to truly understand how social cognition in autism behaves in the real world.

# *5.2.3 Executive Functions and the Dual System Theory of Mentalising*

Study 2 aimed to investigate the relationship between mentalising and executive functioning, although the sample size for this study limited the exploration of this relationship. Previous research has indicated the importance of inhibitory control and working memory in explicit mentalising ability in younger children (Carlson et al., 2002; Carlson et al., 2004; Mutter et al., 2006), and further research has suggested that cognitive flexibility becomes increasingly important throughout development, with cognitive flexibility found to be a critical correlate of ToM processes in older children (Bock et al., 2015) and adults (Gökçen et al., 2016). As discussed in Chapter 3 (Section 3.4) one potential explanation for this finding is that cognitive flexibility contains features of both inhibitory control and working memory (Bock et al., 2015; Diamond et al., 2005), and it is this combination that allows adults to flexibly infer the mental states of others in their day-to-day lives (Bock et al., 2015). However, there are limited studies assessing the developmental trajectory of executive functions and their relationship to explicit theory of mind abilities. It is therefore key that future research attempts to better understand how this relationship develops into and throughout adulthood.

The findings from this thesis are not consistent with single system or multiple system theories of mentalising. Multiple system theories argue that it is more plausible that the efficiency of early mentalising is achieved through shared cognitive burden across many (rather than dual) specialised systems (Christensen & Michael, 2016). In contrast, single system theories would instead argue that mentalising stems from one underlying system. This system would develop through a continuous process of transition, with additional learning and schema leading to greater complexity, and drawing upon both top-down endogenous processing and bottom-up exogenous processing (Carruthers, 2016; Westra, 2016). However, the results found in this thesis provide evidence for a distinction between two discrete mentalising systems. The implicit and explicit mentalising systems were found to respond differently to a social presence, with the implicit system clearly affected and facilitated by the inclusion of real-time social partners, but the explicit system not showing the same effect. These studies are the first to examine the effect of a social presence on both explicit and implicit mentalising, therefore this demonstrates a new area in which the systems respond in a measurably different way. Further, the results found in Chapters 3 and 4 are unlikely to be explained by sceptical accounts; such low-level accounts would argue that anticipatory looking behaviour can instead be explained by an abstract-rule-based explanation. For example, such as the rule that people generally look for items in the last place they were seen (Ruffman & Perner, 2005; Krupenye et al., 2016). The inclusion of true belief trials and second-order true belief trials (Chapter 4, Figure 11) ensured that this rule could not be applied in order to successfully predict where the task protagonists would investigate. Therefore, whilst the two-systems distinction is not universally accepted (Westra, 2016; Carruthers, 2016; Christensen & Michael, 2016), there is a broad range of research providing evidence for the dual systems theory of mentalising (Apperly & Butterfill, 2009), and the results of the studies in this thesis support the existence of two distinct systems.

# **5.3. Methodological Considerations**

A key area of discussion relating to the methods used in this thesis concerns the difference in setup between the live and recorded conditions in Chapters 3 and 4. The eye trackers used in these studies were selected based on which would be the most appropriate, and yield the most accurate measure of behaviour, for each condition. In the 2-dimensional recorded condition participants were asked to view stimuli on a computer screen, therefore the most appropriate eye tracker to accurately capture participants eye movement behaviour was a desktop eye-tracker, e.g. the Eyelink1000. Our recorded condition therefore follows the procedure used in traditional types of lab-based experiments. Conversely, in the 3-dimensional live condition the more appropriate eye tracker for use was a mobile eye-tracking system, due to the visual stimulus being a live array rather than being presented on a screen. SMI mobile eye tracking glasses were used for this purpose. Critically, we attempted to control for any extraneous variables arising from differences in experimental set up that could have influenced the study conclusions. The procedure remained the same across conditions, the confederates remained the same and the pre-recorded video stimuli depicted the same visual scene as the participants viewed in the live condition. Therefore, any differences arising in behaviour were unlikely to arise from differences in visual saliency or from differences in the task stimuli. However, one consideration that does arise from the use of such a paradigm relates to the type of eye tracker used in each condition.

An evident difference between these two eye trackers relates to the temporal and spatial resolution of each respective eye tracker. Whilst the SMI mobile glasses record at 30 Hz and have a spatial resolution of up to 0.1°, the desktop EyeLink1000 records at 1000 Hz, with a spatial resolution of up to 0.01°. The desktop eye tracker is therefore capable of detecting a far greater range of eye movements, including microsaccades. Whilst it would be inappropriate to compare saccadic behaviour recorded from each respective eye tracker, the eye movements analysed within this thesis were principally concerned with fixation behaviour, an area which is considered relatively robust to fluctuations in sampling rate, with high correlations found between fixation data collected from eye trackers with differing sampling rates (Dalmaijer, 2014; Titz, Scholz & Sedlmeier, 2018). Both eye trackers were therefore considered sufficient to answer the research question. Additionally, in order to ensure comparability between the data collected with each eye tracker, reports were generated for the raw data in order to prevent any differences in data reporting that could arise from the different algorithms used in each software analysis package. Finally, in order to counter any differences in fixation accuracy that may exist between the two eye trackers generous areas of interest were used to counter any minor differences in accuracy of recordings of a participant’s gaze location. Eye fixations tend to be task-based, which makes this generous use of AOIs appropriate.

A further difference between the two types of eye trackers is that the mobile eye tracker has a greater viewing range of 80° horizontal, 60° vertical, whereas the desktop EyeLink1000 has an eye-tracking range of 32° horizontal, 25° vertical. However, previous research has shown that when comparing data recorded via desktop or mobile eye trackers participants’ eye movements naturally align with the vertical midline of a viewing scene i.e. aligning our covert attention to scenarios occurring within our central field of vision (Foulsham et al., 2011). This would mean that the participants in Chapters 3 and 4 would be naturally inclined to align their attention to the spatial location of the false belief task, rather than attend to areas at the periphery of the scene, so the additional visual angle of one tracker compared to the other would not likely have affected the results as few fixations would be expected to land in these areas. Additionally, individuals do not view a scene randomly, but instead direct their attention to relevant stimuli within their environment, for example, neurotypical adults direct their attention to the social stimuli within a scene (Fletcher-Watson et al., 2008). This is supported by the analysis of the incorrect trials in Chapter 3 (Section 3.3.2) and Chapter 4 (Section 4.3.2); whilst participants may not have made eye movements consistent with false belief understanding, they still directed their attention to task relevant stimuli over and above other areas of the scene (coded as the ‘background’). In light of these considerations I am therefore confident that the data recorded from each experimental condition was capable of providing a coherent comparison of participants’ eye movement behaviour.

An additional methodological consideration relates to the structure of the tasks used in each Chapter in this thesis. Previous research has demonstrated that although difficulties on explicit ToM tasks may be evident in early childhood, older children and adults can demonstrate comparable performance to neurotypical children and adults (Happe, 1995). Indeed, it has been suggested that explicit mentalising abilities serve to compensate for underlying difficulties with implicit mentalising (Senju et al., 2009). However, more recently it has been claimed that autistic adults may still demonstrate difficulties in explicit mentalising, but that these difficulties may be masked through the use of simplistic stimuli or through the structured format of the testing paradigm (Cole et al., 2018). Whilst the tasks used in Studies 2, 3a and 3b sought to increase the social validity of a typical direct false-belief task, they still provided a structured framework in which to complete the task, which may have aided with task completion. Further, the tasks used in these studies only required the participant to track a singular mental state, however previous research has found that autistic adults demonstrate difficulties holding more than one mental state in mind (Bradford, Hukker, Smith & Ferguson, 2018). Therefore, it may be that the difficulties autistic adults demonstrate with theory of mind processing may be most evident within the chaotic, fast-moving situations encountered within everyday life. Consequently, it is likely necessary for future research to focus upon the development of more ecologically valid paradigms featuring approximations of such scenarios in order to gain clearer insights into how theory of mind processes engage in the day-to-day lives of autistic participants.

One final methodological consideration relates to the relatively small sample sizes recruited for the studies in this thesis. In particular, the small sample sizes may have masked any between group differences between the neurotypical groups and the autistic groups, or any effects related to the number of autistic traits present in the neurotypical participants. The small sample sizes in this thesis are a reflection of an issue prevalent throughout research with autistic populations. It is widely recognised that despite autism affecting 1% of the population, and despite autistic individuals being keen to take part in research, recruitment for studies can be challenging (Warnell, George, McConachie, Johnson, Hardy & Parr, 2015). Challenges can arise due to the location of the study, the ability of the individual to complete the paradigm used in the study and also exclusionary criteria relevant to the study (Warnell et al., 2015). These challenges can lead to the small sample sizes prevalent throughout autism research, an issue which has been particularly relevant to research investigating implicit mentalising (e.g. Schuwerk et al., 2016; Schneider et al., 2013; Schneider et al., 2012a). However, it is important to note that across three studies, and 68 neurotypical participants, no relationship was found between autistic traits, task performance or the condition in which the task was completed. Further, autistic adults were significantly affected by the real-time presence of a social partner and showed significantly improved implicit mentalising abilities when in the presence of real people. Additionally, Study 1 (Chapter 2) demonstrated that autistic adults are sensitive to social agency and demonstrate social facilitation effects. This demonstrates that not all autistic adults demonstrate difficulties with social stimuli and in understanding the mental states of their social partners.

# **5.4. Current Issues in Implicit Mentalising Research**

Research providing evidence of implicit mentalising revolutionised the field of theory of mind research. Prior to this finding, theory of mind research was dedicated towards investigating explicit mentalising ability using direct, mainly verbal, tasks. Therefore, the discovery of an early emerging, cognitively efficient system transformed this area of research, spurring important theoretical considerations, new paradigms, and new hypotheses and conclusions (Kulke et al., 2019). However, although highly influential, there are now serious concerns arising regarding the robustness and reliability of implicit mentalising paradigms. Of particular concern, many replication attempts have found that a broad range of indirect tasks fail to replicate and do not provide robust evidence for the existence of implicit mentalising (Burnside, Ruel, Azar & Poulin-Dubois, 2018; Kulke, von Duhn, Schneider & Rakoczy, 2018; Schuwerk, Priewasser, Sodian & Perner, 2018; Kulke et al., 2019). Further, when certain paradigms have replicated, the identification and removal of confounds within the experiment have then led to non-replication (Kulke et al., 2018). This issue is furthered by the lack of universal agreement on a paradigm, or standardised form of data analysis to be used when researching this area (Schuwerk et al., 2018).

Attempts to explain how previous studies have found evidence of implicit belief tracking suggest that such patterns of behaviour could instead be attributable to the visual saliency of the stimuli (Kulke et al., 2018), the timings of each paradigm (Schuwerk et al., 2018) or the phrasing of the task instructions (Burnside et al., 2018). A critical finding that has emerged from reviews of previous indirect paradigms is that even in studies that provide evidence of implicit mentalising, participants’ performance often fails to rise to significantly above chance levels (Thoermer, Sodian, Vuori, Perst & Kristen, 2016). Replications of these paradigms have also found that participants’ performance on indirect tasks failed to rise above chance (Burnside et al., 2018), and this finding continues to emerge even when between group differences are apparent. For example, whilst significant between group differences may emerge for autistic and NT participants, in many cases the (more accurate) NT group task performance still fails to rise much above chance levels (Schuwerk et al., 2016). Further, this finding extends beyond child or autistic samples; NT adults also show the same variance, with samples either being barely above chance, or not at all (Schuwerk et al., 2018; Wang & Leslie, 2016). A final concern raised by replication attempts is that the main paradigms used to assess implicit theory of mind competence fail to show convergent validity, and therefore arguably do not provide a coherent measure of implicit mentalising ability (Kulke et al., 2018). The findings from such non-replications thus lend support to claims that theory of mind exists as one system, rather than two discrete systems (Westra, 2016; Carruthers, 2016) and contrast with the findings of this thesis.

However, whilst the current replication crisis within the implicit theory of mind literature is certainly a serious and important area of concern, it is worth noting that there are replication studies which have provided either partial or full replications of some of the indirect tasks used in implicit mentalising research (Schuwerk et al., 2018; Powell, Hobbs, Bardis, Carey & Saxe, 2018). It has been argued that rather than not existing, implicit mentalising may instead be a ‘fragile’ construct, which is difficult to capture and measure in a consistent fashion (Kulke et al., 2018; Kulke et al., 2019). Of particular relevance to this thesis, a new argument emerging from such replication studies is that a potentially important factor in eliciting implicit mentalising behaviour may be the inclusion of naturalistic stimuli. It is suggested that it may only be through the use of more engaging, naturalistic stimuli that we will be able to capture empirical evidence of such an involuntary, seemingly innate system (Krupenye et al., 2016; Kulke et al., 2018; Kulke et al., 2019). This suggestion is clearly supported by the findings from Chapters 3 and 4 in this thesis, whereby the inclusion of real-time social partners facilitated participants’ implicit mentalising abilities.

Evidence for the importance of ecological validity can be drawn from research demonstrating that chimpanzees only show evidence of spontaneous belief tracking when using ecologically valid, naturalistic stimuli (Krupenye et al., 2016). This argument provides a clear explanation for the pattern of results discovered in Chapter 4 (Study 3a) in this thesis; participants’ first fixation and preferential looking scores were only significantly above chance in the live condition. Conversely, in Chapter 3 (Study 2) it was found that participants’ first fixation and preferential looking scores were significantly above chance in both the live and the recorded condition, however, as previously discussed, Study 2 utilised a simpler task than Study 3a which served to improve participants’ task accuracy, and thus led to increased accuracy in the recorded condition (Section 3.4.). One clear implication of the use of the chosen paradigm in both studies 2, 3a and 3b was that participants were aware that the task featured real task protagonists, and that they would encounter these task protagonists ‘in-the-flesh’ in one of the task conditions. Chapter 1 (Section 1.1) highlighted research demonstrating that the potential for a social interaction is enough to lead to quantifiable behavioural changes on social cognition tasks, even if the participant is aware that no form of social interaction will occur (Gregory et al., 2015). I thereby tentatively suggest that the use of more naturalistic, engaging stimuli with the potential for a social interaction may have contributed to the finding of eye movements consistent with tracking the belief state of the task protagonists in the studies in this thesis. Considering the current debate within the implicit theory of mind literature, this is a critical finding and clearly has crucial implications for future implicit mentalising paradigms.

# **5.5. Future Directions**

This section will discuss future directions of research, both as an extension of the results found in this thesis, and as areas of consideration generated from the topics covered within this thesis. First, the studies presented in this thesis provide critical evidence that a social presence can significantly affect both autistic and neurotypical participants’ behaviour in areas of social cognition outside of social attention, in this case, mentalising research. The consequences of these studies are clear; however, this area requires much further research in order to fully understand the implications of this finding. Specifically, the studies in this thesis focussed on the use of one precise type of mentalising paradigm: an anticipatory looking paradigm (Studies 2, 3a & 3b). Whilst the evidence from Chapters 3 and 4 firmly suggest that implicit mentalising behaviour is facilitated by a social presence, future research is needed to determine if this effect extrapolates to other measures of implicit mentalising behaviour, for example, interactive behavioural tasks, such as helping paradigms (Buttelmann, Carpenter & Tomasello, 2009). This is of key importance in light of the current replication crisis in implicit mentalising research. Currently there is a clear and necessary movement within the mentalising literature urging the inclusion of naturalistic stimuli more reflective of our daily social interactions, in the theory that such stimuli may encourage the engagement of implicit mentalising processes. However, the studies within this thesis are the first (to my knowledge) to provide evidence that the use of such stimuli can indeed foster implicit mentalising behaviour. Therefore, if this effect is found to generalise beyond anticipatory looking paradigms then it has clear implications for the future of implicit mentalising research, both in confirming the existence of implicit mentalising as a tangible cognitive process, and in informing the development of new measures for this phenomenon.

A further consideration for future research concerns the demographics of the autistic participants recruited within Study 1 and Study 3b. As previously discussed in Chapter 4 (Section 4.6) theory of mind abilities have been found to be related to the severity of an individual’s autism diagnosis. Autism is a spectrum condition meaning that individuals can display differing levels of autistic traits, at one end of the spectrum are those typically classed as high functioning (including those approaching the cut off for a clinical diagnosis), and at the other end are those typically classed as low functioning. Autism is characterised by difficulties in social communication and interaction, therefore individuals classed as low functioning are anticipated to show significantly greater levels of social impairment than individuals classified as high functioning. It would therefore be expected that low functioning individuals would exhibit greater difficulties inferring mental states and intentions from the behaviour of their social partners. Of significant relevance low functioning individuals have been found to demonstrate poorer performance on theory of mind tasks (Yoshida, et al., 2010). This is a key consideration for Studies 1 and 3b, which both recruited individuals who had previously received a diagnosis of high functioning autism. Therefore, although these studies provide critical evidence that atypicalities using social information and in mentalising behaviour are not all pervasive in autism, these results are unlikely to generalise to the full autism spectrum. Of note, it is likely that individuals with low functioning autism may have shown a significantly different pattern of results to the autistic participants tested in this thesis, including difficulties with mentalising. Further, it may be that low functioning individuals lack the sensitivity to social partners displayed by high functioning individuals and would not show the same social facilitation effects. It is therefore imperative that future research aims to recruit a more representative sample of individuals across the autism spectrum in order to gain a greater understanding of the relationship between autism and the effect of a social presence on mentalising behaviour.

Finally, a further consideration for future research concerns the paradigm used within Chapters 3 and 4. Whilst these studies included naturalistic stimuli, they are still only an approximation of how we observe individuals within our daily lives. Evidence from neuroimaging studies reveals that involving the participant as a real social partner in a social interaction can lead to quantifiable differences in brain activity, compared to observation of similar interactions (Schilbach et al., 2016: Lehmann et al., 2019). Additionally, as discussed throughout this thesis it is increasingly recognised that social cognition should be studied within scenarios in which it typically occurs in order to gain a true understanding of how such processes truly function (De Jaegher et al., 2010; Reader & Holmes, 2016). The results from this thesis support the importance of improving upon traditional, socially isolated paradigms. With improvements in both eye tracking and imaging technologies it is therefore critical that future research aims to improve upon past paradigms, including the paradigms in this thesis, and measure social cognition in scenarios more closely approximating how processing occurs ‘in the wild’. It is likely only through the development of such paradigms that we will come to truly understand how social cognition functions within our daily lives.

# **5.6. Conclusion**

In summary, this thesis has provided two main novel conclusions. Firstly, social presence effects both autistic and neurotypical participants’ performance on social cognition paradigms, and these studies reveal a new area in which the implicit and explicit mentalising systems are shown to function differently. Secondly, the studies conducted have provided consistent evidence that both neurotypical and autistic adults are sensitive to a social presence, and that this sensitivity is apparent regardless of whether social presence is implied via manipulation of the study stimuli (Chapter 2) or via a real physical social presence (Chapters 3 & 4). Taken together, the results of this thesis therefore highlight the critical importance of understanding the effect of a social presence in social cognition research for both neurotypical individuals and individuals with a neurodevelopmental disorder. Further, this thesis raises the very real concern that paradigms lacking a social presence may not provide suitable analogues for real life behaviour.

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**Appendix A. Funnelled debriefing procedure (adapted from Schneider, Slaughter, Bayliss & Dux, 2013)**

1. What do you think the purpose of the experiment was?

2. What do you think this experiment was trying to study?

3. Did you think that any of the tasks you did were related in any way?

(If ‘yes’) in what way were they related?

4. Did anything you did on one task affect what you did on any other task?

(If ‘yes’) How exactly did it affect you?

5. Did you notice anything unusual about the movies/roleplays?

6. Did you notice any particular patterns or themes?

7. What were you trying to do while watching the movies/roleplays? Did you have any particular goal or strategy?

8. If thinking about the four boxes on the desk, which box do you think you spent the most time on?

10. Did you notice that the actor sometimes had a true belief about the ball location and sometimes had a false belief about the ball location when coming back into the room?

(If participant is unsure ask: Did you notice that the actor was sometimes tricked about the ball location when coming back into the room?)

(If ‘yes’) How did those beliefs become true or false/how

1. Mann-Whitney U tests revealed no difference between the non-social agency attribution group (Med=5.00) and social group (Med=4.00) for the ease with which participants reported completing the task (U=-.726, *p=*.468, *r=.*09). This confirms that there were no differences in task completion between the two groups, and, therefore, that any differences in task performance were related to participants’ perception of the social agency of the cue. [↑](#footnote-ref-1)
2. Wilcoxon Signed-Rank tests revealed no differences between the first and second iterations of either the indirect first fixation data or direct data (First Fixation *p* =.412; Direct *p* =.503). Paired Samples *t* tests revealed no differences in accuracy scores between the first and second iterations of the indirect preferential looking data (*p* =.068). This confirms that completion of the first task did not significantly influence performance on the second task. [↑](#footnote-ref-2)
3. Participants were significantly more likely to look at the correct box first in both the live (*p<*.001) and recorded (*p<*.05) condition than would be expected if there were no systematic bias to attend to the correct box. [↑](#footnote-ref-3)
4. Participants looked at the correct box in both the live (*p<*.001) and recorded (*p<*.05) condition for significantly longer than would be expected if there were no systematic preference to attend to the correct box. [↑](#footnote-ref-4)
5. Participants were significantly more likely to look at the correct box first than would be expected if there was no systematic looking behaviour in the live condition (*p=*.030), and displayed a systematic bias to attend to one of the incorrect boxes in the recorded condition (*p=*.021). [↑](#footnote-ref-5)
6. Participants looked at the correct box in the live (*p=.*033) condition for significantly longer than would be expected if there was no preferential looking behaviour, and displayed a systematic preference to attend to one of the incorrect boxes in the recorded condition (*p=*.021). [↑](#footnote-ref-6)
7. Participants did not show a systematic preference to attend to the correct box in the live (*p=.*305) condition, and displayed a systematic bias to attend to one of the incorrect boxes in the recorded condition (*p=*.010). [↑](#footnote-ref-7)
8. Participants did not show a systematic preference to attend to the correct box in either the live (*p=.*235) or recorded condition (*p=*.281). [↑](#footnote-ref-8)