Face processing in Autistic individuals

Face Processing In Autistic Individuals

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Declaration

I, Bayparvah Kaur Gehdu confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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With Maharaj ji's Kirpa- we are all beautiful strands of Oneness.

The work reported in this thesis has been published in the following papers:

Chapter 3 - Gehdu, B. K., Gray, K. L., & Cook, R. (2022). Impaired grouping of ambient facial images in autism. *Scientific Reports*, *12*(1), 6665.

Chapter 4 - Gehdu, B. K., Press, C., Gray, K. L., & Cook, R. (2024). Autistic adults have insight into their relative face recognition ability. *Scientific Reports*, *14*(1), 17802.

Chapter 5 - Gehdu, B. K., Tsantani, M., Press, C., Gray, K. L., & Cook, R. (2023). Recognition of facial expressions in autism: Effects of face masks and alexithymia. *Quarterly Journal of Experimental Psychology*, *76*(12), 2854-2864.

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During my PhD I have also contributed to the following papers:

Bunce, C., **Gehdu, B. K**., Press, C., Gray, K. L., & Cook, R. (2024). Autistic adults exhibit typical sensitivity to changes in interpersonal distance. *Autism Research*, *17*(7), 1464-1474.

Vestner, T., **Gehdu, B. K**., Gray, K. L., & Cook, R. (2024). Autistic adults exhibit a typical search advantage for facing dyads. *Autism Research*, *17*(12), 2572-2578.

Abstract

Face processing abilities vary significantly among autistic individuals, impacting their ability to recognise facial identities and interpret expressions accurately. These processes are essential for navigating our social environments and living independently. Difficulties in these areas can lead to social anxiety and undermine quality of life. This thesis explores the considerable variability in face processing abilities among autistic individuals. **Chapter 1** outlines the theoretical explanations for these difficulties alongside the current literature that motivates subsequent empirical experiments. **Chapter 2** outlines the online research processes employed, the measures administered and addresses concerns regarding gender representation in autistic samples.

To investigate whether difficulties in facial identity recognition stem from deficits in face learning or perceptual encoding, two experiments in **Chapter 3** assessed whether autistic individuals derive less benefit from facial variability when learning new identities as measured by their accuracy in grouping ambient images by facial identity. Next, to examine whether autistic individuals have insight into their face recognition abilities and if they can provide meaningful responses to self-report measures, the relationship between PI20 scores and CFMT performance was assessed in **Chapter 4**. Here, factors such as autism severity, non-verbal intelligence, alexithymia and ADHD were also considered as potential predictors of face recognition performance. **Chapter 5** investigated the influence of alexithymia on facial expression recognition by comparing autistic participants (with and without high levels of alexithymia) to non-autistic participants in their ability to categorise facial expressions under eyes-only and whole face conditions. Finally, **Chapter 6** explored the impact of face recognition difficulties on social anxiety and loneliness in autistic individuals, independently of alexithymia and ADHD, through standardised self-report measures and a short bespoke qualitative survey. **Chapter 7** summarised these empirical findings, discussing implications for understanding the variability of face processing problems in the autistic population along with potential limitations and future research directions.

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Chapter 1: Introduction

1.1 Autism and Visual Perception

1.1.1 What is Autism?

Our current working definition and diagnostic criteria of autism have been conceptualised through biomedical and psychological frameworks and continue to reflect Kanner's original 1943 clinical description (Anderson-Chavarria, 2022; Kanner, 1943). According to current diagnostic criteria, autism is characterised as a lifelong neurodevelopmental condition associated with social communication differences and/ or difficulties, together with restricted and repetitive patterns of behaviours and intensive interests (American Psychiatric Association, 2013). Autistic individuals are described as being on the autistic "spectrum" to highlight the heterogeneous nature of autism (Botha et al., 2022; Lai et al., 2013).

In addition to these core characteristics, co-occurring psychiatric conditions (such as anxiety and depression), neurological conditions (such as epilepsy), and neurodevelopmental conditions (such as intellectual disabilities, motor conditions, and attention-deficit hyperactivity disorder (ADHD)) are common in autistic individuals (Happé & Frith, 2020; Lai et al., 2019; Lord et al., 2020).

Twin and family studies consistently demonstrate that autism may have a significant genetic component, with heritability estimates ranging from approximately 40% to 90% (Cross-Disorder Group of the Psychiatric Genomics Consortium et al., 2013; Gaugler et al., 2014; Lord et al., 2020). Environmental factors such as increased parental age, birth complications, and pregnancy-related factors (e.g., maternal obesity, maternal diabetes) are thought to increase the likelihood of autism however, these findings are heavily debated (Modabbernia et al., 2017). One of the most extensive studies to date, which used population data from 5 countries, suggested that around 80% of the variation in autism

prevalence rates is due to inherited genetic factors rather than maternal and environmental effects (Bai et al., 2019).

It is estimated that approximately 1 in 100 children globally are autistic (Zeidan et al., 2022). Historically, it has been suggested that autism is more prevalent in males than females, with an estimated ratio of 3:1 (Loomes et al., 2017). However, many have argued that this sex ratio is inaccurate and more likely to reflect biases in the current diagnostic criteria, which is considered to poorly capture the autistic female presentation rather than reflect the true prevalence rates of autism between the sexes (Rubenstein et al., 2015). Furthermore, autistic individuals are more likely to identify as gender diverse/ expansive (e.g., non-binary, gender fluid, transgender) than non-autistic individuals (Strang et al., 2018; Warrier et al., 2020).

A recent UK population-based cohort study examined the time trends in autism diagnoses between 1998 and 2018 (G. Russell et al., 2022). Researchers found that the overall rise in autism diagnoses aligned with other studies from the United States (Boyle et al., 2011; Maenner & Durkin, 2010) and Europe (Parner et al., 2008; Smeeth et al., 2004), and that these increases were greater in adults and females due to societal awareness of autism in both these groups rather than a clear etiological explanation. It is important to note that we do not have a comprehensive overview of how autism presents across different demographic (non-White) groups and across a variety of identity intersections in the UK.

1.1.2 Differences in Visual Perception in Autism

Research literature has demonstrated differences in low-level vision between autistic and non-autistic individuals. For example, studies have reported variations in contrast sensitivity, contour integration, depth perception and motion perception (see review by Simmons et al., 2009). In line with the current version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013) many autistic individuals describe experiencing a heightened sensory sensitivity and sensory overload to everyday

stimuli (Grandin, 2005). In research with infants, differences in visual perception are thought to predict subsequent diagnoses of autism (Gliga et al., 2015). Therefore, suggesting that perceptual differences may interact with social difficulties (Chung & Son, 2020; Dellapiazza et al., 2020; Robertson & Baron-Cohen, 2017). For many autistic individuals, this heightened sensory sensitivity has been demonstrated through superior performance across various visual search tasks. Autistic individuals tend to outperform matched non-autistic peers on the Embedded figures task (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983) and on Block design tasks (Caron, 2006; Shah & Frith, 1983; Simmons et al., 2009).

Plaisted, O'Riordan and Baron-Cohen (1998) have suggested that autistic individuals show this superior performance due to their enhanced capacity for perceptual discrimination on visual search tasks. In their study, they compared the performance of autistic and non-autistic children across two visual search tasks: feature and conjunctive search tasks. Examples of these two kinds of tasks are presented in **Figure 1.1**. For example, in the feature search task (see the left box in Figure 1.1), participants are asked to search for the red S target letter among red T and green X distractors. Here, the target letter only shares one dimension (the colour red) with one set of distractors (red Ts) and is unique in another dimension (such as form, green Xs). In the conjunctive search task (see the right box in Figure 1.1), the target letter (red X) shares dimensions across both sets of distractors, for example, the same colour (red Ts) and shape (green Xs). Here, the conjunctive target is defined by a combination of two dimensions. Plaisted et al. (1998) found that compared to non-autistic children who were slower on the conjunctive search task than the feature task, autistic children performed equally well across both tasks, with fast performance on the conjunctive task compared to the non-autistic children. This pattern has since been replicated in autistic adults (O'riordan, 2004) and also with superior performance on complex triple conjunction search tasks (O'Riordan & Plaisted, 2001).

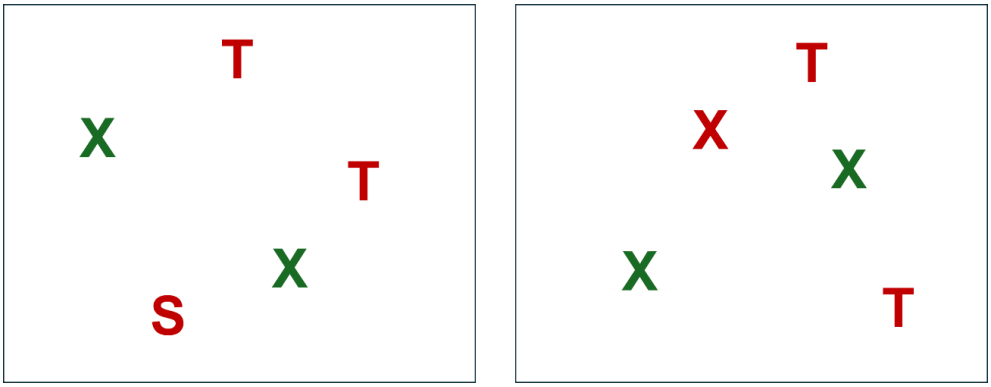

Figure 1.1 An illustration of the type of feature (left) and conjunctive (right) search tasks described by Plaisted et al. (1998) in 'Enhanced visual search for a conjunctive target in autism: a research note'. Original illustration created by Bayparvah Kaur Gehdu, inspired by content licensed under John Wiley & Sons, obtained via RightsLink. © 1998 John Wiley & Sons. Licence number: 5832580212771.

Taken together, these findings are supported by neuroimaging evidence showing higher activation in occipital brain regions of autistic individuals during visual detection tasks (Damarla et al., 2010; Kana et al., 2013; Lee et al., 2007; Ring et al., 1999) suggesting that autistic individuals have an enhanced capacity for perceptual discrimination compared to non-autistic individuals (O'Riordan et al., 2001; Simmons et al., 2009). This perceptual advantage has been considered to have many real-world benefits in daily life and in many workplace decisions where accurate monitoring and screening (e.g., detecting dangerous items at airport security, detecting abnormalities during health screenings) requires sustained detection for long time periods (Gonzalez et al., 2013).

1.1.3 Difficulties in Social Perception in Autism

Some autistic individuals have enhanced perceptual discrimination skills compared to non-autistic individuals, which can be advantageous in tasks requiring precise monitoring and screening. However, these perceptual differences in autism have been linked to difficulties in social perception, such as the processing of human faces (Chung & Son, 2020). A wide range of face recognition abilities has been described in this population. Some individuals – around 25% (Hedley et al., 2011) perform poorly enough to qualify for a comorbid diagnosis of developmental prosopagnosia (DP), a separate neurodevelopmental condition

characterised by difficulties in recognising and discriminating faces (Behrmann & Avidan, 2005). However, many others perform comfortably within the typical range, and some exceed typical levels of performance (Weigelt et al., 2012). A similar picture is seen for facial expression recognition. Here again, a subset of individuals appear to be significantly impaired, while others seem to perform typically (R. Cook et al., 2013; Loth et al., 2018; Uljarevic & Hamilton, 2013). The ability to recognise faces and interpret facial expressions helps us to navigate our social environment successfully. Being able to recognise others and determine their intention are key skills needed to live independently. Where observed, difficulties recognising faces and expressions can therefore lead to social anxiety and undermine an individual's quality of life (Yardley et al., 2008).

The next two sections will discuss differences in facial identity and expression processing between autistic and non-autistic individuals.

1.2 Differences in Facial Identity Processing

Langdell (1978) conducted one of the first systematic investigations into face processing differences in autistic individuals. He compared the ability of older (M_{age}= 14.10 years) and younger (M_{age} = 9.80 years) autistic children, along with matched non-autistic children and children with intellectual disabilities, to recognise photographs of faces of peers from their school. These photographs included faces that were inverted or had facial features masked (i.e., apart from the nose or eyes, the upper or lower halves were masked). The findings revealed that older autistic children made fewer errors in identifying the inverted faces compared to younger autistic children and children across both comparison groups. Furthermore, younger autistic children made fewer errors when only the lower part of the face was visible, but this pattern was not observed in older children. The group differences observed in this face recognition task (i.e., in the autistic group, the lack of an expected inversion effect and more errors made in identifying upper regions of the face) gave rise to the idea that autistic individuals may process faces in a different manner to non-autistic individuals.

Since then, differences in processing facial identity between autistic and non-autistic individuals have also been revealed through performance variation on standardised tests. For example, in the Glasgow Face Matching Test (GFMT; Burton et al., 2010), participants view pairs of faces of either the same individual (match trials) or different individuals (mismatch trials) for an unlimited amount of time and are asked to determine if they show the same person or different people (see **Figure 1.2**). The short form of the test includes 20 match and 20 mismatch trials, presented in a random order. Although autistic individuals have performed poorly in comparison to non-autistic control participants (Stantić et al., 2021) on this task, it could be argued that poor performance may be due to difficulties in face perception, face matching (i.e., using sub-optimal decision criteria when deciding whether two facial images are of the same individual) or both (Stantić et al., 2023).

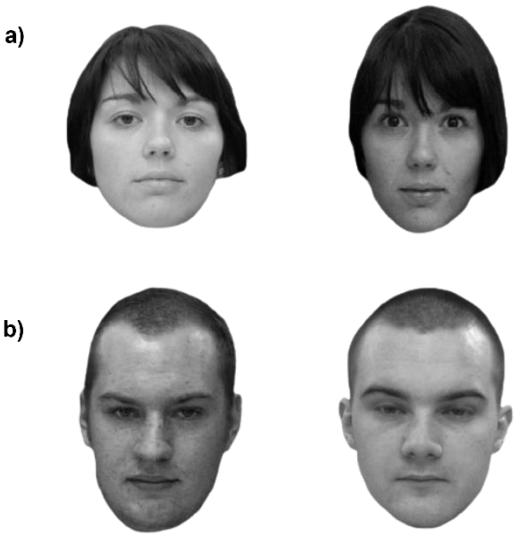

Figure 1.2 Example trial images from the Glasgow Face Matching Test (GFMT; Burton et al., 2010). **a)** matching pair (images of the same person) and **b)** mismatching pair (images of different people). Figure adapted from Robertson et al. (2016) in 'Face recognition by metropolitan police super-recognisers'. PLOS ONE, 2016, used under the Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0/).

The Oxford Face Matching Test (OFMT; Stantic et al., 2021) has been specifically designed to offer an unbiased test of face perception for groups outside the 'typical' population, including super-recognisers. The test presents face-matching trials where participants must

decide if two face images are of the same person (see **Figure 1.3**). The difficulty of this test is determined using facial recognition algorithms, allowing a full range of difficulty levels that do not favour the processing strategies of any particular group (Stantic et al., 2021). Unlike the GFMT, the OFMT is designed so that across match and mismatch trials, the faces have overlapping similarity distributions. This means that two images of the same person can look very different, while images of two different people can look quite similar. Researchers suggest that this design helps to dissociate face perception skills from matching decision-making skills. In recent work with autistic individuals, researchers found that autistic individuals exhibited poor face perception ability in the presence of intact face matching, suggesting that face processing difficulties in autism occur due to perceptual differences rather than underlying difficulties in decision processes (Stantić et al., 2023).

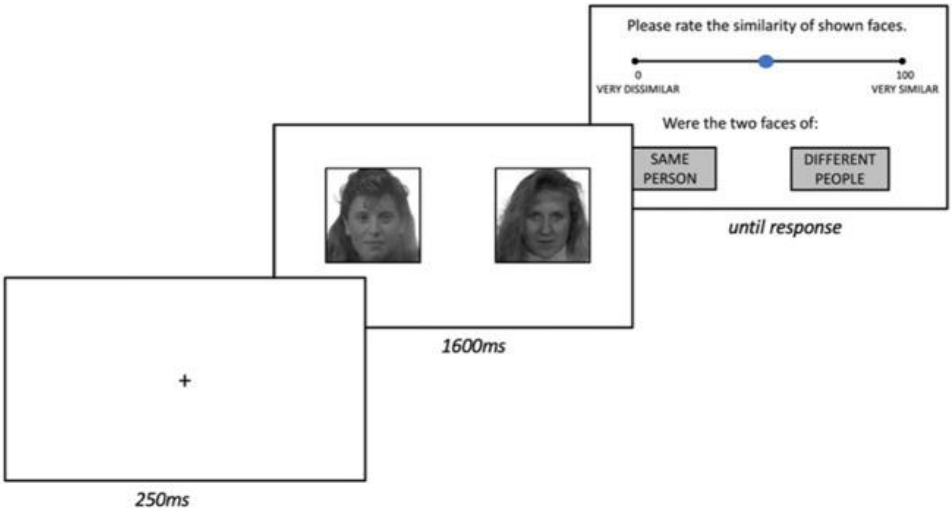

Figure 1.3 Illustration of an example trial from the Oxford Face Matching Test (OFMT; Stantic et al., 2021). Participants are presented with two faces simultaneously for 1600 ms and are asked to rate the similarity between the faces using a slider, ranging from 1 (very dissimilar) to 100 (very similar) and to determine whether the faces depicted the same person or different people. Figure adapted from Stantic et al. (2021), in 'The Oxford face matching test: a non-biased test of the full range of individual differences in face perception'. Image adapted and used under the Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0/).

The Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006) is widely regarded as the gold standard memory test for novel face recognition (Bate & Tree, 2017; Bowles et al., 2009; Dalrymple & Palermo, 2016). The test includes a clinical threshold score for identifying the presence of prosopagnosia (Bowles et al., 2009; Duchaine & Nakayama, 2006), which can be used in combination with self-report evidence, such as total scores on the Twenty-Item Prosopagnosia Index (PI20; Shah et al., 2015) to make a diagnosis of DP (Tsantani et al., 2021). See **Figure 1.4** for the task structure and example stimuli of the CFMT.

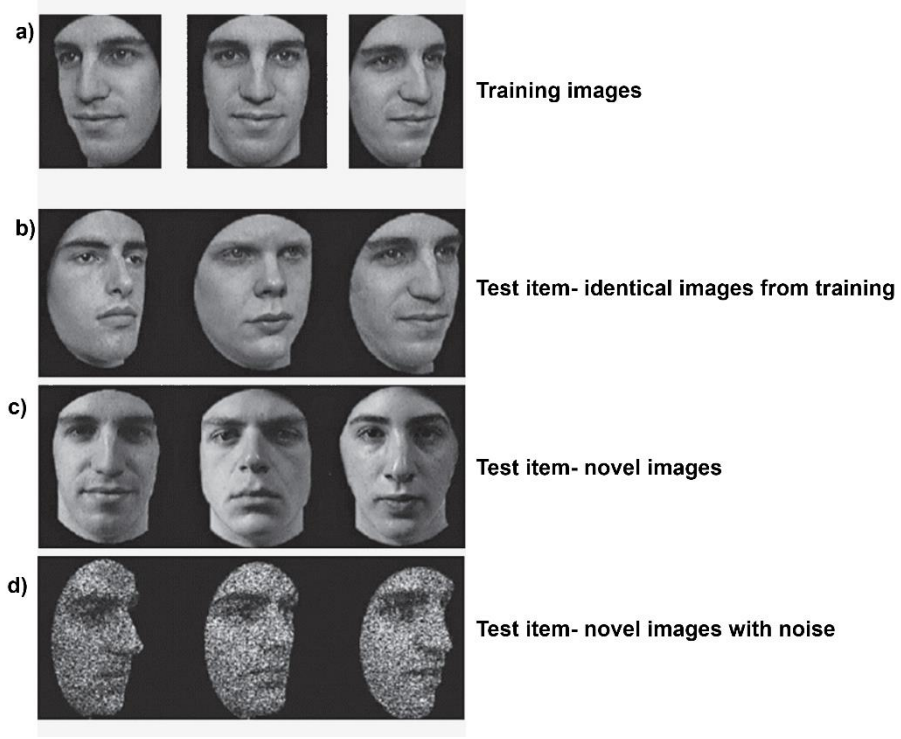

Figure 1.4 Task structure and example stimuli of the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006). Figure adapted from Duchaine & Nakayama (2006) in 'The Cambridge face memory test: results for neurologically intact individuals and an investigation of its validity using inverted face stimuli and prosopagnosic subjects'. Content adapted and reproduced with kind permission from Elsevier, obtained via RightsLink.© 2006 Elsevier. Licence number: 5834290022800.

The CFMT uses a three-alternative forced-choice format with unlimited response time and consists of three blocks that increase in difficulty (see **Figure 1.4**). On each test trial across all blocks, participants are required to identify a target face from a line-up of the target face

and two foils. In the first block (18 trials), participants are asked to memorise each individual target face (total of 6 individuals) from three different viewpoints (Figure 1.4, panel a). At test, participants are shown similar images and are asked to identify the target (Figure 1.4, panel b). In the second block (30 trials), participants identify the same target faces presented at different angles and/or lighting (Figure 1.4, panel c). The third block (24 trials) is similar to the second but includes Gaussian visual noise, reducing image quality and increasing difficulty, which encourages holistic face processing over feature-based processing (McKone et al., 2001) (Figure 1.4, panel d).

Previous research has shown that on average, autistic individuals perform poorly on the CMFT (Kirchner et al., 2011; Minio-Paluello et al., 2020; Stantić et al., 2021, 2023; Weigelt et al., 2012) compared to matched non-autistic individuals. However, researchers have suggested that poor performance on recognition tasks like the CFMT, may be driven by a combination of difficulties across face processing, including perceptual encoding, rather than face memory alone (Griffin et al., 2021; Stantić et al., 2023; Tang et al., 2015).

Neuroimaging studies have identified key brain regions involved in face processing, including the occipital and fusiform face areas (Kanwisher & Yovel, 2006; Pitcher et al., 2011). Extensive evidence suggests that autistic individuals often show differential responses in these areas compared to non-autistic individuals when viewing faces (Bird et al., 2006; Critchley et al., 2000; Humphreys et al., 2008; Pierce et al., 2001; Schultz et al., 2000). Specifically, research has found atypical neural responses in face-selective regions of the fusiform gyrus (FG), with some studies reporting hyperactivity (Corbett et al., 2009; Humphreys et al., 2008; Schultz et al., 2000) and others showing no differences (Hadjikhani et al., 2004) or hypoactivity only to unfamiliar faces (Pierce & Redcay, 2008). Additionally, variations in activation patterns have been observed in other brain regions, with the amygdala showing mixed responses to different facial expressions (Grelotti et al., 2005; Hadjikhani et al., 2007; Kleinhans et al., 2011). Furthermore, the N170 event-related potential, which appears around 170 ms after the onset of a face stimulus, is thought to

index the structural encoding of faces (Eimer, 2000). Research has shown delayed N170 components in many autistic participants, suggesting that they may process faces less efficiently than non-autistic individuals (Bentin et al., 1996; Kang et al., 2018; Rossion et al., 2000). Overall, these findings highlight the complexity and variability among autistic individuals who exhibit differential neural responses in key brain regions associated with face processing compared to non-autistic individuals (see meta-analysis by Ammons et al., 2021).

To date, however, the nature of face processing difficulties seen in autism remains poorly understood as highlighted in two previous systematic literature reviews (Tang et al., 2015; Weigelt et al., 2012) and a more recent quantitative meta-analysis (Griffin et al., 2021). In the section below, we will explore some of the leading explanations behind why some autistic individuals have problems in processing facial identities.

1.2.1 Explanation 1: The absence of holistic processing

Maurer, Le Grand and Mondloch (2002) propose that faces are analysed through three key processes: the analysis of both first-order relational properties (e.g., the typical alignment of facial features like horizontally aligned eyes above the nose and mouth) and second-order relational properties (variations in the spacing or shape of features within the facial outline) and through holistic processing (where all facial features and their spatial relationships are integrated into a unified whole). Facial identity and expression recognition primarily rely on holistic processing, which emphasizes perceiving the entire face rather than breaking it down into individual features (Farah et al., 1998; McKone & Yovel, 2009; Piepers & Robbins, 2012; Richler et al., 2011).

Research indicates that autistic individuals may process facial identity differently from non-autistic individuals, possibly due to the absence of holistic processing (G. Dawson et al., 2004; Gauthier et al., 2009; Tanaka & Sung, 2016). If this view is correct, one would expect autistic individuals to exhibit atypical performance on three well-established holistic

processing tasks: the face inversion task, the face composite task and the part-whole task. Findings from these tasks will be briefly reviewed.

1.2.1.1 The face inversion task

One of the best-known markers of holistic face processing is the face inversion effect, where recognition accuracy is greater for upright faces compared to inverted ones (Yin, 1969). This effect is particularly strong for faces compared to other objects and is even more pronounced for whole faces than for individual face parts (Rhodes et al., 1993). This finding can be explained by holistic processing. When judging inverted faces, individuals are unable to process the face holistically but instead rely on a slower and less accurate serial analysis of local features (Farah et al., 1998; McKone et al., 2007; Rossion, 2008; Yovel, 2016). Research on this task has shown that autistic individuals demonstrate similar face inversion effects as non-autistic individuals (Hobson et al., 1988; Lahaie et al., 2006; Scherf et al., 2008). For example, Lahaie et al. (2006) compared the accuracy performance between autistic and non-autistic adults using an immediate memory recognition task which measured the inversion effect across two types of stimuli: faces and Greebles (artificial objects). Autistic adults showed the expected disproportionate inversion effect for faces but not for Greeble stimuli. Therefore, these findings suggest that autistic individuals exhibit intact holistic processing for faces as evidenced by the similar inversion effect observed across both groups.

1.2.1.2 The face composite task

In the face composite task, participants are presented with a composite face arrangement made by combining the top half of one face (or bottom) with the bottom half (or top) of another (see **Figure 1.5**). When participants are asked to identify the person in the cued top or bottom half, while ignoring the un-cued half, non-autistic individuals struggle to selectively attend to the cued portion due to holistic interference from the to-be-ignored half (Young et al., 1987). This task provides strong evidence that face perception is holistic, as one half of

the face influences the perception of the other. Importantly, this holistic interference is diminished when halves are misaligned or inverted (Murphy et al., 2017; Rossion, 2013).

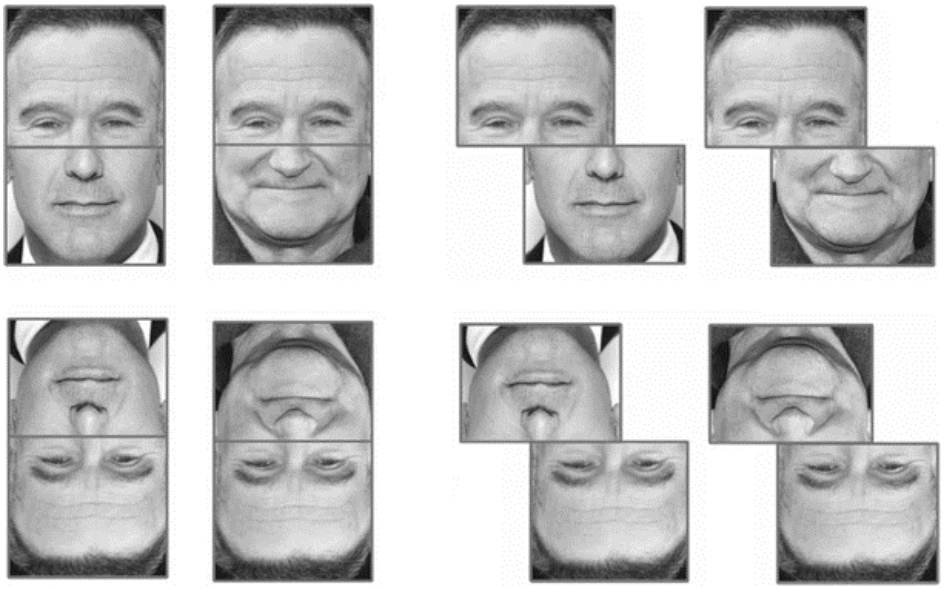

Figure 1.5 An example of the Composite Face Illusion. In the top left- when the upper regions of two composites are aligned with different lower halves, recognising their similarity is challenging. This illusion is significantly reduced when the composites are misaligned (top right). When shown upside-down, there is minimal illusion-induced interferences in both aligned (bottom left) and misaligned (bottom right) conditions. Figure reproduced from Murphy et al. (2017), in 'The composite face illusion' with kind permission from Springer Nature, obtained via RightsLink .© 2016 Springer Nature. Licence number: 5834290882075.

Research has shown that autistic individuals exhibit an atypical pattern of performance on this task. For example, Teunisse and de Gelder (2003) found that autistic adolescents recognised face halves well regardless of alignment or misaligned, suggesting a lack of holistic interference. Given that recognition performance was not superior in the misaligned condition as expected, this finding may imply that autistic individuals use a feature-based approach to process faces. However, a follow-up study by Gauthier et al. (2009) which, unlike previous studies, controlled for IQ differences between the groups and found that autistic individuals did experience holistic interference, which also extended to misaligned configurations. This suggests that autistic individuals may experience heightened levels of

holistic interference compared to non-autistic individuals. In summary, findings from face composite studies do not consistently support an association between autism and impaired holistic face processing.

1.2.1.3 The part-whole task

The part-whole task measures holistic memory for individual face features (see **Figure 1.6**). In this task, participants first briefly study a whole face. At test, participants must identify a feature or part of the target face by making a forced-choice recognition decision across two conditions. In the isolated condition, the target face part (e.g., an eye) is presented alongside a foil. In the whole face condition, the target and foil face parts are embedded within the original study face, ensuring that the surrounding facial context provides no additional diagnostic information. Holistic face processing is thought to enhance or “sharpen” the recognition of local features when they are viewed within the context of a whole face. This means that recognising a face part is usually more accurate when it is presented as part of the whole face rather than in isolation. This is because the holistic processing of the whole face improves the representation of individual features. Studies have supported this idea by demonstrating superior part recognition in the context of whole faces compared to scrambled faces, inverted faces, or non-face stimuli such as houses (Tanaka & Farah, 1993).

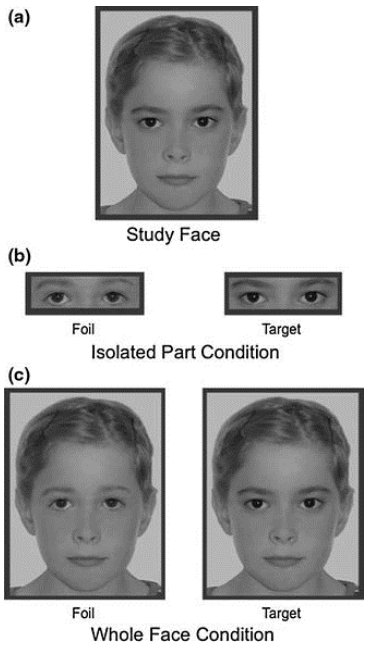

Figure 1.6 An example of a trial in the part-whole task. Participants are first shown a study face (a). During the test phase, they are asked to identify a specific 'part' of the target face, such as the eyes. This identification task is performed under two conditions: with the part presented in isolation (b) or within the whole face (c). In both conditions, the target and foil items differ only in the specific part of the face being tested (e.g., the eyes). Figure reproduced from Tanaka & Sung (2016), in 'The "eye avoidance" hypothesis of autism face processing' with kind permissions from Springer Nature, obtained via RightsLink .© 2016 Springer Nature. Licence number: 5834340664139.

Interestingly, some studies have indicated that autistic individuals exhibit the expected holistic effect, showing superior part recognition within the context of a whole face, but this effect seems to be specific to mouths rather than eyes (Joseph & Tanaka, 2003; López et al., 2004; Wolf et al., 2008). However, Faja et al. (2009) reported a stronger holistic effect for the eyes compared to the mouth in their study. Therefore, these mixed results imply that autistic individuals may process faces differently compared to non-autistic individuals.

In summary, the inconsistent findings from these three tasks do not strongly support the idea that autistic individuals struggle with recognising faces because of an absence of face specific holistic processing.

1.2.2 Explanation 2: A local processing bias

It has been proposed that autistic individuals may face challenges in face identity recognition due to an underlying visual bias towards detailed-focused and local processing styles. This difficulty is thought to arise from a "weak drive for global coherence" (Behrmann, Avidan, et al., 2006; Behrmann, Thomas, et al., 2006; Frith & Happé, 1994), suggesting that the issues with face identity recognition are not unique to face processing but reflect a broader visual processing bias. Supporting this view, research shows that autistic individuals often excel in tasks requiring local processing and detailed visual search, such as Block design completion tasks (Minshew et al., 1997; Shah & Frith, 1993) and Embedded figures task (Happé, 1996; Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983).

The key question is whether this strength in local processing interferes with global processing abilities and whether strong visual discrimination skills in autistic individuals contribute to difficulties in perceptual grouping, which is crucial for effective face recognition (Behrmann, Thomas, et al., 2006). This inquiry also relates to the broader debate about whether detailed-focused local processing always coincides with poor global processing or if these abilities can occur independently (Behrmann, Thomas, et al., 2006; Caron, 2006).

To explore these issues, a number of studies have explored local versus global processing in autism using categorisation tasks with hierarchically organised stimuli. For example, Koldewyn et al. (2013) examined how autistic children intuitively categorise Navon figures (Navon, 1983) to determine whether performance differences on local versus global tasks reflect differences in ability (poor global processing) or preference (a local processing bias). Participants categorised Navon shapes (for example, a figure of a triangle which is made up of smaller squares) first without guidance and then with instructions to focus on either the local or global level (see **Figure 1.7** for a depiction of stimuli used and the trial procedure). The findings revealed that while autistic children were less inclined to report global properties of the stimuli when given a choice, their ability to process global properties when instructed remained unimpaired. This suggests that differences in local versus global

processing in autism are more likely due to preference rather than an inability (Happé & Frith, 2006).

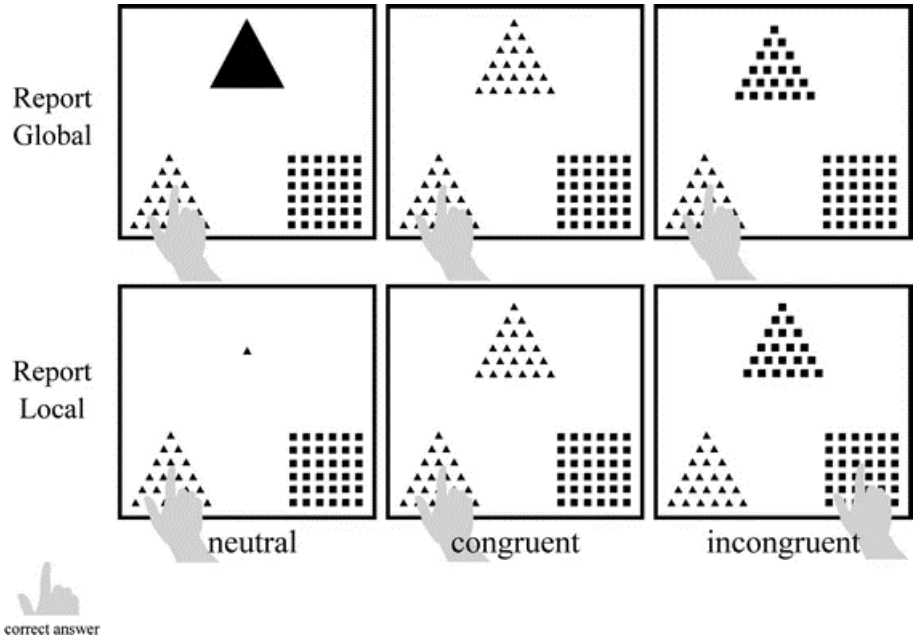

Figure 1.7 Illustration of the Navon stimuli (hierarchical shapes of triangles and squares) used and the trial procedure in Koldewyn et al.'s (2013) study. The two task blocks (global and local) were counterbalanced. Participants identified the larger shape in the global block, while in the local block, they determined the shapes comprising the stimulus. Response patches remained consistent across tasks. Congruent stimuli had consistent local and global information, incongruent stimuli had inconsistent information, and the neutral stimuli included only the instructed level to control for size-related task difficulty. The correct answer is shown with a hand icon. Figure reproduced from Koldewyn et al. (2013) in 'Global/Local processing in autism: not a disability, but a disinclination' with kind permission from Springer Nature, obtained via RightsLink .© 2013 Springer Nature. Licence number: 5834720254452.

Similarly, in face processing tasks, autistic individuals can exhibit global processing when directed. For example, in part-whole tasks where participants match a face part to a complete face or a face feature, autistic individuals demonstrate the global whole-face advantage when cued to focus on specific facial features (López et al., 2004). Moreover, autistic individuals are affected by face inversion effects, in tasks such as the Thatcher illusion (Rouse et al., 2004; Thompson, 1980). If autistic individuals were purely reliant on

local processing, their accuracy in detecting inverted features would be similar for both inverted and upright faces. Therefore, these findings suggest that autistic individuals are able to process faces at both local and global levels despite preferences to process at a local level (Happé & Frith, 2006).

1.2.3 Explanation 3: Poor perceptual learning

Some have argued that autistic individuals demonstrate difficulties in facial identity recognition due to impaired perceptual learning mechanisms. Differences in the recognition of unfamiliar and familiar faces have deepened our understanding of face learning, the process through which unfamiliar faces become familiar. One of the most striking differences between familiar and unfamiliar face perception is the ease with which we can recognise new exemplars (Murphy et al., 2015). Unlike the effortless recognition of familiar faces (e.g., family, friends, colleagues and celebrities), matching the faces of strangers across different photographs can be remarkably difficult (Bruce et al., 1999; White et al., 2014).

Evidence suggests that face learning is influenced by the time spent viewing faces. For example, participants who view faces for 45 seconds each perform better on recognition tasks than those who view the same faces for only 15 seconds (Memon et al., 2003). Furthermore, simple repetition of single facial images also improves the recognition of actors in dynamic video stimuli (Roark et al., 2006). Importantly, however, experiencing faces in different poses, situations, and lighting conditions (i.e., exemplar variation) enhances face learning independently of viewing time (Murphy et al., 2015).

Ambient images have been used in experimental paradigms to demonstrate how exemplar variation can aid subsequent facial identity recognition. These types of images are naturalistic images of faces that depict individuals from various viewing angles, with a range of expressions under different lighting conditions. Work by Murphy et al. (2015) demonstrated that at test, participants exposed to many variable exemplars of a single identity during training outperformed those exposed to a limited number of exemplars, even

with equal viewing time. Therefore, it has been suggested that the pooling of multiple exemplars is thought to help individuals form robust representations of the individuals depicted and once acquired, robust representations support the seemingly effortless recognition of familiar faces as they are considered to be relatively insensitive to variations such as lighting and pose (Burton et al., 2005; Murphy et al., 2015). Until a robust representation is acquired, identifying and matching unfamiliar faces remains effortful and inaccurate (Jenkins et al., 2011).

However, the nature of these representations is unclear. One perspective, the Averaging Hypothesis, suggests that the visual system creates a perceptual average from different exemplars of the same face, making it easier to match new instances (Burton et al., 2005). Alternatively, the Pictorial Coding Model suggests that each encounter with a face may be stored, and familiar faces are recognised by comparing them with previously stored instances (Longmore et al., 2008). According to this view, robust representations function as a comprehensive “instance database” that has been formed through many encounters with a given face in different poses, lighting, and viewing conditions. With increased encounters of the same face, in various conditions, observers densely sample the potential instance space, increasing the likelihood of matching a novel encounter to a stored instance, thus improving recognition performance (Longmore et al., 2008; Murphy et al., 2015).

In the autism literature, Ipser et al (2016) demonstrated that autistic participants were less able to form robust representations of facial identities presented using ambient images compared to non-autistic participants. In the training phase, participants learned 8 facial identities by viewing 96 ambient images of each identity. During the testing phase, participants were presented with a set of new exemplars, half depicting the learned facial identities and half depicting novel ones. Compared with non-autistic participants (74.70% correct), the autistic participants (62.20% correct) were less able to identify the individuals presented during the study phase. Therefore, considering these findings, it could be argued that autistic individuals may have differential and/or atypical perceptual learning

mechanisms, making it harder for them to derive a robust representation from multiple exemplars to aid accurate identity recognition.

1.2.4 Explanation 4: Poor face memory

According to Weigelt et al.'s (2012) influential review, the structural encoding of faces is broadly intact in autism as individuals demonstrate the same behavioural markers of expert face processing (e.g., face inversion effect) as non-autistic individuals. Rather, autistic individuals are thought to have a difficulty which impairs their ability to retain facial percepts in visual memory. This is evidenced by their poor performance on tasks that require the maintenance of face representations for longer than 30 seconds. In their review, Weigelt et al. (2012) evaluated studies examining group performance differences across tasks, both with and without memory demands, with a focus on paradigms related to simple face perception, fine-grained face perception, and standardised face recognition tests.

Studies that have used simultaneous presentation of sample and test stimuli have not found group performance differences (Behrmann, Avidan, et al., 2006; Boucher & Lewis, 1992; Deruelle et al., 2004; Hauck et al., 1998; Ozonoff et al., 1990; Riby et al., 2008). However, when a slight memory demand is introduced through sequential presentation, discrimination performance is worse for autistic participants (Scherf et al., 2008; Wilson et al., 2010). Performance on tasks which require fine-grained perception, such as discriminating subtle differences between facial features, is also poorer for autistic individuals when memory demands are included (Faja et al., 2009; Nishimura et al., 2008; Wallace et al., 2008). However, research has shown that this does not apply to all facial features, as autistic individuals exhibit specific difficulties in discriminating eyes, and this difficulty is independent of memory demands (Joseph et al., 2008; Riby et al., 2009; Rutherford et al., 2007; Wolf et al., 2008). Finally, autistic individuals consistently demonstrate difficulties in studies using standardised face recognition tasks with a memory component (e.g., CFMT) (Dwyer et al., 2019; Weigelt et al., 2012).

Although Weigelt et al.'s (2012) review seems to provide a comprehensive argument that face identity recognition difficulties in autism are due to difficulties in face memory, a follow-up review by Tang et al. (2015) challenges this conclusion. Their review, encompassing 25 studies, published after Weigelt et al.'s (2012) review or not previously included, demonstrated that autistic individuals have challenges not only in facial recognition but also in facial identity encoding and discrimination. This has been supported by Griffin, Bauer and Scherf's (2021) quantitative meta-analysis, where difficulties in facial discrimination and recognition in autism are thought to persist across age groups, sex, IQ scores and task type. They predict that autistic individuals are on average, likely to perform nearly 1 standard deviation below average neurotypical performance on both facial discrimination and recognition tasks.

1.2.5 Explanation 5: Eye-avoidance theory

Computational modelling has identified the eye-region as being particularly informative for recognising both facial identity (Peterson & Eckstein, 2012) and facial expressions (Peterson & Eckstein, 2011; Van Belle, 2010). However, eye-tracking studies suggest that autistic individuals tend to fixate less on the eye-region and more on the mouth-region than non-autistic individuals (Dalton et al., 2005; Pelphrey et al., 2002; Spezio, Huang, et al., 2007). This raises the possibility that the way autistic individuals process and represent faces differs from non-autistic individuals.

Tanaka and Sung (2016) have suggested that autistic individuals might perceive the eye-region as socially threatening, leading them to rely more heavily on mouth cues for recognition. This may explain some of the inconsistent findings in the literature, where tasks which require eye-region analysis, show greater group differences between autistic and non-autistic participants, compared to tasks which do not require a participant to discriminate between faces by using the eye-region alone (Langdell, 1978; Rutherford et al., 2007; Joseph et al., 2008; Wolf et al., 2008; Riby et al.,2009). However, it may not be that autistic individuals are repelled by the eyes but are rather drawn to the mouth. Kliemann et al.

(2012) explored this by asking autistic and non-autistic participants to categorise facial expressions (fearful, happy or neutral) while fixating on either the eye or mouth regions. When fixating on the eyes, autistic individuals made quicker and larger saccades away from the eyes, whereas non-autistic participants shifted their gaze from the mouth to the eyes more readily than autistic individuals. These findings suggest that autistic individuals may reflexively avoid the eye region, contributing to difficulties in recognising facial expressions. Kliemann et al. (2012) also found heightened amygdala activation when autistic participants averted their gaze from the eyes.

In summary, challenges in facial recognition for autistic individuals may stem from a reflex tendency to avoid looking at the eye-region, rather than specific face processing deficits.

1.2.6 Explanation 6: Social motivation hypothesis

The social motivation hypothesis offers another explanation for why some autistic individuals struggle with recognising both facial identities and expressions (Oruc et al., 2018). According to this hypothesis, social-communication difficulties in autism arise from limited visual experience with faces due to a lack of motivation to engage with others early in life. This lack of motivation leads to differences in developing a social brain network sensitive enough to perceive and understand the social environment accurately (Chevallier et al., 2012; G. Dawson et al., 2005; Grelotti et al., 2002; Schultz et al., 2003; Schultz, 2005).

This theory accords well with eye-tracking research conducted by Wilson, Brock and Palermo (2010). In their study, both autistic and non-autistic children passively viewed scenes containing people and objects while their eye movements were recorded. They also completed a separate face and object matching task. While both groups showed a preference for looking at people in these scenes, non-autistic children spent more time looking at people compared to objects, whereas autistic children showed no difference in viewing times between people and objects. Importantly, only in the autistic group was there an association between an individual's preference for looking at people first in scenes and

their performance on face matching tasks. The lack of an association in the non-autistic group in the context of significant correlations in the autistic group is consistent with the social motivation hypothesis of autism. This suggests that reduced social motivation limits exposure to faces, affecting the development of various face processing abilities. Therefore, differences in identity and expression recognition may stem from varying degrees of visual experiences with faces.

However, contrary to the predictions of the social motivation hypothesis, Shah et al. (2013) found intact involuntary exogenous orienting to face-like stimuli in autistic adults. In their study, both autistic and non-autistic participants were asked to identify a target letter from two letter arrays shown on either side of a fixation point. Before the arrays appeared, a protoface and an inverted control pattern were briefly presented at peripheral locations. A selective cueing effect was found for the protoface stimulus only, where both groups responded faster when the protoface correctly cued the target location (congruent trials) compared to incorrect cues (incongruent trials). Importantly, since the protoface stimulus was wholly task-irrelevant in this paradigm, this result provides evidence that autistic adults exhibit involuntary exogenous orientation as the protoface captures attention despite being unrelated to the instructed task. This robust orienting response challenges the social motivation hypothesis as it suggests that autistic individuals' attention to face-like stimuli is not inherently reduced. However, it remains possible that later voluntary attentional processes, such as deliberately redirecting attention from faces, could reduce overall face exposure and contribute to the observed processing difficulties. Findings like these raise questions about which specific aspects, if any, of social motivation contribute to the social difficulties observed in autism (Chevallier et al., 2012).

1.2.7 Explanation 7: Co-occurring Developmental Prosopagnosia

As mentioned previously, around 25% of autistic individuals perform poorly enough on face recognition tasks that they could qualify for a comorbid diagnosis of Developmental Prosopagnosia (DP) (Behrmann & Avidan, 2005; Hedley et al., 2011). Although DP is thought to co-occur more commonly in the autistic population than the neurotypical population, both conditions are independent. For example, autism can occur in the absence of face recognition difficulties, and many individuals with prosopagnosia are not autistic and/or report high levels of autistic traits (R. Cook & Biotti, 2016). As such, many autistic individuals perform comfortably within the typical range, and some exceed typical levels of performance on facial identity recognition tasks (Weigelt et al., 2012).

If a subgroup of autistic individuals with co-occurring DP characteristics exists, it could explain the inconsistent findings of face processing difficulties in the autism literature (Griffin et al., 2021; Tang et al., 2015; Weigelt et al., 2012). For example, group-level findings across studies would vary depending on the proportion of autistic individuals with co-occurring DP characteristics within samples from the autistic population (Kamensek et al., 2023; Lombardo et al., 2019). The nature of face recognition difficulties in DP is suggestive of impaired face encoding. For example, individuals with DP perform poorly on the Cambridge Face Perception Test (CFPT; Duchaine et al., 2007), which requires participants to sort simultaneously presented faces based on their similarity to a target face (Biotti et al., 2019; Duchaine et al., 2007). See **Figure 1.8** for an example trial of the CFPT. Therefore, if face processing difficulties in autism do resemble those seen in DP, we would expect autistic individuals to perform poorly on facial identity recognition tasks that have minimal memory demands. However, the research findings have been inconsistent (Fry et al., 2023; Kamensek et al., 2023; Minio-Paluello et al., 2020). Some studies suggest that face recognition problems in autism are due to issues with short-term face memory (Weigelt et al., 2012), while others argue these difficulties stem from problems with face encoding (Stantić et al., 2021).

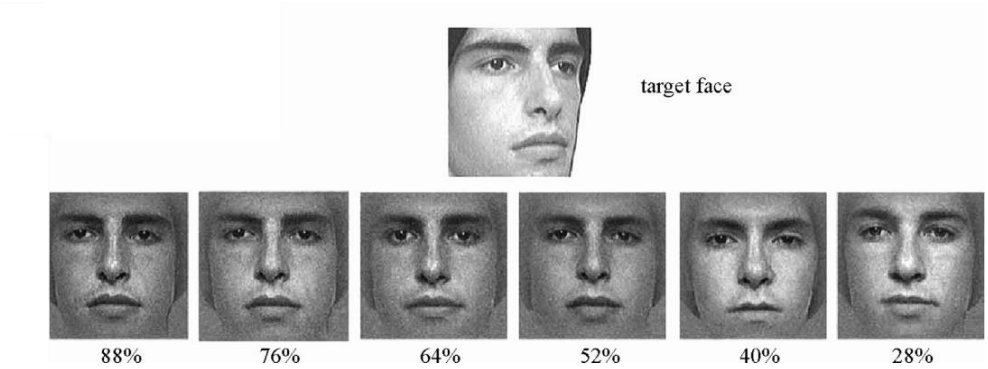

Figure 1.8 Images from an item in the Cambridge Face Perception Test (CFPT; Duchaine et al., 2007). The numbers below each morph image (frontal shots) indicate the percentage of the target face (shown at the top in a three-quarter view) in the morph. The six front shots are initially presented in random order, and participants sort them by their similarity to the target image. Figure reproduced from Bowles at al. (2009), in 'Diagnosing prosopagnosia: effects of ageing, sex, and participant-stimulus ethnic match on the Cambridge face memory test and Cambridge face perception test' with kind permission from Taylor & Francis.

1.3 Differences in Facial Expression Processing

It has been proposed that, in addition to challenges with recognising facial identities, autistic individuals also experience difficulties in facial expression recognition (Ashwin et al., 2006; Harms et al., 2010, 2010; Philip et al., 2010; Uljarevic & Hamilton, 2013). Here, facial expressions refer specifically to the arrangement or movement of the facial muscles that convey emotional states, such as happiness, sadness, anger, surprise or fear. Facial expressions often serve as visual, non-verbal cues which communicate a person's emotional state(Adolphs, 2002; Frith, 2009). While facial expressions can provide insight into a person's emotional state, they do not always provide a consistent indication of a person's intentions, particularly in autistic individuals. However, accurately recognising facial expressions is crucial for developing mentalizing and broader social cognitive mechanisms. When expression recognition is affected, it is likely to hinder social interactions and the development of complex mentalizing abilities (Frith & Frith, 2006).

The ability to recognise and appropriately respond to other's facial expressions is arguably a fundamental social perceptual skill that modulates many aspects of social interaction and communication. Autistic individuals are thought to have poorer facial expression recognition compared to individuals with other neurodevelopmental conditions, like ADHD (Yeung, 2022). Therefore, exploring expression recognition difficulties has been suggested as a potential marker to further define and understand social communication challenges in autism (Meyer-Lindenberg et al., 2022).

Research has suggested that autistic individuals show difficulties in facial expression recognition across all or at least a few basic emotions, such as anger, fear and surprise (Lozier et al., 2014; Uljarevic & Hamilton, 2013; Yeung, 2022). However, the specificity of these recognition difficulties remains unclear due to the use of varying task paradigms and differences in sample characteristics across studies (Harms et al., 2010). For example, Yeung's (2022) systematic review suggested that task type could be a moderator of facial expression recognition performance, with, for example, autistic individuals performing more poorly on matching expression recognition tasks compared to tasks where verbal cues are provided. This suggests that the poor ability to recognise facial expressions in autism may stem from difficulties in connecting perceptual information with cognitive concepts of expressions and in retrieving this conceptual knowledge to accurately categorise facial expressions (Lindquist et al., 2006; Nook et al., 2015; Schirmer & Adolphs, 2017). However, sample characteristics such as age and IQ have been reported to either influence or have no impact on performance in facial expression recognition tasks, whether in matching or labelling paradigms (Loth et al., 2018; Lozier et al., 2014; Uljarevic & Hamilton, 2013). Therefore, given the inconsistent literature, our understanding of how facial expressions are processed by autistic individuals remains unclear.

Over the last two decades, neuroimaging work has demonstrated facial expression processing differences between autistic and non-autistic individuals. This includes differential inspection of facial features and modulation of the N170 event-related potential during

expression recognition tasks (Black et al., 2017). In addition, functional neuroimaging studies have shown altered activity in the amygdala, fusiform face area, superior temporal sulcus and inferior frontal gyrus (Harms et al., 2010). However, brain activation in these regions can be moderated by task demands. For instance, in work by Piggot et al. (2004) and Wang et al. (2004) autistic individuals demonstrated lower levels of activation in the fusiform gyrus compared to non-autistic individuals when performing a perceptual expression matching task. However, these differences in neural activation were not evident during a more linguistically driven expression labelling task, even though both tasks used the same stimuli. Nevertheless, these alterations may contribute to difficulties in facial identity and expression tasks, especially those requiring complex motion recognition and holistic face processing (Philip et al., 2012). Finally, in non-autistic individuals, motion, familiarity and expression intensity are thought to modulate brain responses (Philip et al., 2012). However, autistic individuals do not show these effects, possibly due to reliance on compensatory strategies such as enhanced featural processing during facial expression recognition tasks (Harms et al., 2010; Philip et al., 2012).

In the following section, we will examine some of the main explanations as to why some autistic individuals have difficulties in recognising facial expressions. Facial expression recognition is thought to involve two main stages: i) the perceptual processing of facial stimuli and ii) the retrieval of conceptual knowledge and analysis of the emotions conveyed by the face (Adolphs, 2002; Yeung, 2022). Consequently, poor facial expression recognition in autistic individuals may arise from difficulties at the initial visuo-perceptual encoding stage or from broader interpretive and conceptual difficulties in processing facial expressions.

Some explanations outlined in the previous section (**1.2 Differences in Facial Identity Processing**) also predict difficulties in facial expression recognition in autism. Facial expressions are also thought to be analysed holistically as changes in one area of the face, like a smiling mouth, predict changes in other areas, such as creases around the eyes (Brewer et al., 2019; R. Cook et al., 2015; Jack et al., 2014). Previous research on the

composite face task has established that facial expressions also induce strong holistic interference effects in non-autistic individuals, thus supporting the idea that expression recognition is also dependent upon holistic processing (Calder et al., 2000; Murphy et al., 2017; Palermo et al., 2011; Tanaka et al., 2012). Furthermore, supporting the eye-avoidance account, the eye-region is crucial for recognising facial expressions (Peterson & Eckstein, 2011; Van Belle, 2010). Eye-tracking studies have demonstrated that autistic individuals reflexively avoid the eye region, which may predict subsequent difficulties in recognising facial expressions (Kliemann et al., 2012). The social motivation hypothesis also predicts both facial identity and expression recognition difficulties in autism. Oruc, Shafai and Iarocci (2018) tested autistic and non-autistic adults on identity and expression tasks while also measuring self-reported levels of social motivation. In line with the social motivation hypothesis, they found a significant association between performance in identity and expression tasks in autistic participants, but no such correlation was observed in the non-autistic group. Furthermore, in the autistic group, lower levels of social motivation were associated with poorer face processing abilities. In the non-autistic group, social motivation was not predictive of face processing ability. These results imply that face processing difficulties in autism likely stem from reduced visual input during early development, disrupting the development of both identity and expression domains (Oruc et al., 2018).

This section, however, will focus solely on theories specific to facial expression recognition.

1.3.1 Explanation 1: Amygdala theory

The amygdala theory of autism (Baron-Cohen et al., 2000) suggests that social interaction difficulties in autism are due to structural differences and abnormal activation and functioning of the amygdala. The human amygdala is thought to play a crucial role in face processing (Adolphs, 2008) and contains specialised neurons that are selective to faces and facial emotions (Fried et al., 1997; Kreiman et al., 2000). Difficulties in face processing in autism are thus hypothesised to originate from amygdala dysfunction (Baron-Cohen et al., 2000).

Although evidence supporting this hypothesis comes from both single-neuron recordings in the human amygdala (Rutishauser et al., 2013) and neuroimaging studies in autistic individuals (Dalton et al., 2005; Kliemann et al., 2012), the strongest evidence comes from similar behavioural performance levels on facial expression tasks for both autistic individuals and amygdala lesion patients (S. Wang & Li, 2023). For example, in the “Bubbles” task, participants are asked to discern expressions from sparsely sampled fear or happy faces. Both amygdala lesion patients (Adolphs et al., 2005) and autistic individuals (Neumann et al., 2006; Spezio, Adolphs, et al., 2007b; Spezio, Huang, et al., 2007) exhibit similar eye-tracking patterns in this task. They demonstrate diminished attention to the eyes and reduced utilisation of information from the eyes when making judgements about facial expressions. Furthermore, both autistic individuals and amygdala lesion patients have also shown similar difficulties in basic facial expression categorisation tasks (Adolphs et al., 1999, 2001; Kennedy & Adolphs, 2012). However, more recent studies looking at the encoding of expression intensity using morphs of fear-happy faces, revealed differences between autistic individuals and amygdala lesion patients. While autistic individuals showed reduced specificity in expression intensity judgements more generally, amygdala lesion patients exhibit a lowered intensity threshold required to report fearful expressions only (S. Wang et al., 2017; S. Wang & Adolphs, 2017). Nevertheless, taken together, these findings suggest amygdala dysfunction may affect facial expression recognition in autistic individuals, but not in the same aspects as amygdala lesion patients (S. Wang & Li, 2023).

However, considering that various aspects of social cognition, not just facial expression recognition, are believed to operate differently in autistic individuals, it is unlikely that differences between autistic and non-autistic individuals are limited to a single neural structure (Gaigg, 2012; S. Wang & Li, 2023). For example, abnormalities in the striatum, limbic system (amygdala and cingulate cortex), temporal cortices (superior temporal sulcus and gyrus, fusiform gyrus and temporal poles) and frontal cortical areas (medial prefrontal orbitofrontal and insular cortices) are linked to various aspects of social-emotional difficulties

in autism (Di Martino et al., 2009; Gaigg, 2012; Minshew & Keller, 2010; Philip et al., 2010, 2012; Sugranyes et al., 2011; Vissers et al., 2012). For a detailed review of the autistic social brain, see Gaigg (2012).

Interestingly, work by Langenbach et al. (2024) found no evidence for differences in amygdala activation when comparing autistic and non-autistic participants' performance on a facial expression matching task. Neither did they find differences between groups when considering co-occurring diagnoses of anxiety, depression, and ADHD. Findings like this question if the amygdala theory is an adequate explanation for facial expression recognition differences between autistic and non-autistic individuals.

1.3.2 Explanation 2: Poor mentalizing abilities and an impaired Theory of Mind (ToM)

The mentalizing account suggests that social-emotional difficulties seen within autism are due to poor mentalizing abilities, which affect face processing and expression recognition (Rice et al., 2015). Mentalizing, a concept from Theory of Mind (ToM) literature, refers to the ability to attribute mental states- such as beliefs, thoughts, feelings, plans, and intentions- to ourselves and others, recognising that others' mental states may differ from one's own (Baron-Cohen et al., 1985; Frith, 2001). This understanding allows individuals to predict and explain others' behaviours.

According to Baron-Cohen (2005) the ability to metalize relies on a Mindreading System. This system consists of six neuro-cognitive mechanisms: the intentionality detector (ID), eye direction detector (EDD), the emotion detector (TED), shared attention mechanisms (SAM), theory of mind mechanisms (ToMM), and the empathizing system (TESS). In neurotypical development, the ID, EDD and TED mature first, between birth and 9 months, enabling infants to understand mental processes, such as wanting (ID), seeing (EDD) or being angry (TED) in the context of Agent-Object relations. In autism, the functions of ID, EDD and TED are thought to be intact, but their development may be delayed. SAM, which matures

between 9 and 18 months, integrates information from ID, EDD, and TED to form complex representations of Self-Agent-Object relations, facilitating joint attention behaviours like gaze monitoring and proto-declarative pointing during social interactions. Behavioural studies have demonstrated that the absence of gaze monitoring and proto-declarative pointing behaviours are the first reliable clinical marker of autism (Bruinsma et al., 2004; Luyster et al., 2009). Furthermore, eye-tracking and behavioural evidence have suggested that autistic individuals have difficulties in extracting mental states from eye regions of the face (Baron-Cohen et al., 1997; Baron-Cohen, Wheelwright, Hill, et al., 2001; Dalton et al., 2005), which may be due to developmental issues with SAM, which integrates information from EDD and TED. The final components of the Mindreading System, ToMM and TESS, mature between 14 and 48 months, allowing children to understand that mental states do not always reflect reality (ToMM) and to respond appropriately to mental phenomena, like empathetically to the emotions of others (TESS). Both ToMM and TESS are thought to be affected in autism (Frith, 2003; Minio-Paluello et al., 2009; Smith, 2009). However, there are differing views on this conclusion (Bird et al., 2010; Bowler et al., 2005).

False belief tasks have been used to demonstrate that autistic individuals struggle with understanding the mental states of others. These tasks, which measure explicit mentalizing, involve an agent forming a belief about an object's location, which is later changed without the agent's knowledge. Participants are asked to identify where the agent believes the object is located. Failure to account for the agent's false belief was originally taken as evidence of impaired ToM in autistic children (Baron-Cohen et al., 1985). However, later studies have shown that many autistic individuals can pass false belief tasks (Bowler, 1992; Frith & Happé, 1994; Ozonoff et al., 1991).

These types of tasks rely on explicit reflection on other's mental states, while spontaneous mentalizing, which is thought to occur in everyday social interactions is less frequently studied. Nijhof et al. (2018) found that both spontaneous and explicit mentalizing involve overlapping brain regions, particularly the right temporoparietal junction (rTPJ). In their study,

autistic and non-autistic adult participants engaged in both spontaneous and explicit versions of a mentalizing task. While watching videos in which an agent formed a belief (true or false) about the location of an object, their brain activation was measured using functional magnetic resonance imaging (fmRI). Participants were only asked to report the agent's belief in the explicit version of the task. Behaviourally, there were no significant group differences, but fMRI results revealed that non-autistic participants showed greater rTPJ activation when processing false beliefs, especially when the agent expected the object. This rTPJ activation was absent in autistic participants. Additionally, whole brain analysis showed reduced activation in the anterior middle temporal pole in autistic adults during false belief trials. These findings suggest that although autistic adults perform similarly to non-autistic adults at the behavioural level, their brain activity differs, indicating underlying neural differences in processing the mental states of others. Therefore, it could be argued that an impaired ToM affects the accurate recognition of facial expressions in autism due to difficulties understanding the emotions and intentions behind those expressions, leading to challenges in social communication with others.

1.3.3 Explanation 3: The alexithymia hypothesis

There has been growing interest in the possibility that autistic individuals with and without co-occurring alexithymia differ in their expression recognition ability (R. Cook et al., 2013; Oakley et al., 2016; Ola & Gullon-Scott, 2020). Alexithymia is a trait associated with difficulties interpreting interoceptive (e.g., hunger, thirst, warmth) and emotional (e.g., happiness, anger, disgust) states (Brewer et al., 2015; Brewer, Biotti, et al., 2016). For example, individuals with high levels of alexithymia may often confuse feeling angry and feeling hot (Brewer, Biotti, et al., 2016). Importantly, despite the defining feature of alexithymia being difficulty in describing one's own affective and interoceptive states, individuals with high levels of alexithymia also exhibit difficulties in recognising the facial expressions of others (Grynberg et al., 2012). Importantly, high levels of alexithymia are more common in the autistic population than in the neurotypical population (Bird & Cook,

2013; Kinnaird et al., 2019). For example, it has been approximated that only ~5% of the neurotypical population describes high levels of alexithymia; in contrast, high levels of alexithymia may be seen in ~50% of autistic individuals (Kinnaird et al., 2019).

The alexithymia hypothesis proposes that these differences in expression recognition ability are attributable to co-occurring alexithymia, not autism per se (Bird & Cook, 2013; R. Cook et al., 2013). This suggests that only a subgroup of autistic individuals who have high levels of co-occurring alexithymia are thought to exhibit poor expression recognition. This theory may explain the inconsistent reports of difficulties in expression recognition in autism. Participant groups with many high-alexithymic autistic individuals tend to show below-average expression recognition, while groups with fewer high-alexithymic individuals perform similarly to the non-autistic population. Supporting evidence indicates that autistic individuals with higher levels of alexithymia, show greater difficulties with categorising static (Milosavljevic et al., 2016) and dynamic (Ola & Gullon-Scott, 2020) facial expressions. Additionally, in mixed samples of autistic and non-autistic participants, alexithymia severity strongly predicts the ability to classify static (R. Cook et al., 2013; Oakley et al., 2016) and dynamic (Keating, Fraser, et al., 2022) expressions.

Complementary neuroimaging studies further support these behavioural studies, showing that alexithymia is correlated with reduced activation in the face-processing network when autistic individuals view facial expressions (Ashwin et al., 2007; Pelphrey et al., 2007; Piggot et al., 2004). However, it remains unclear if alexithymia affects the visuo-perceptual processing of faces or the conceptual analysis of facial expressions (Adolphs, 2002). In relation to autism, recent research suggests that autistic traits influence early stages of expression recognition, while high levels of alexithymia impact later stages. For example, in Desai et al.'s (2019) research, event-related potentials (ERPs) were measured while participants viewed fearful and neutral faces. They suggested that autistic traits were associated with the structural encoding of faces (N170), whereas alexithymic traits were associated with decoding complex emotions (N250). Taken together, these findings raise the

question of whether autistic individuals would continue to show differences in expression recognition abilities if the influence of alexithymia is removed or if autistic traits themselves cause recognition differences between autistic and non-autistic individuals (Keating, Fraser, et al., 2022).

1.3.4 Explanation 4: Differential kinematic internal representations of expressions

To date, most research in this area has overlooked the inherently dynamic nature of facial expressions (Kilts et al., 2003; Sato et al., 2004). Dynamic facial expression information, which includes the spatial arrangement of facial features and the kinematics (speed of movement of these features), is essential for processing facial expressions in real-life (Dobs et al., 2018; Krumhuber et al., 2013). Recent work by Sowden et al. (2021) manipulated point-light face (PLF) stimuli to show that in non-autistic individuals, expression recognition accuracy varied with changes in speed and spatial movements of the expressions presented. They found that reduced speed and spatial range (at 50% level) led to less accuracy in identifying angry and happy expressions but improved accuracy for sad expressions. Conversely, exaggerated spatial movement and speed (at 150% level) increased accuracy for angry and happy expressions and decreased accuracy for sad expressions. Thus, high arousal emotions (happy and angry) are potentially recognised more accurately with faster and exaggerated movements of expressions, while low arousal emotions (sad) are less accurately recognised. This research shows that both spatial and kinematic facial cues affect expression recognition accuracy in non-autistic individuals.

In the autism literature, Keating et al. (2022) suggested that autistic adults may need higher intensity cues to identify facial expressions accurately, specifically the expression of anger (see **Figure 1.9** for example trial). In their work, they found autistic participants, compared to non-autistic participants, showed lower accuracy in recognising dynamic facial anger but not

happy or sad emotions at normal (e.g., 100%) speed and spatial movement. While non-autistic participants' recognition accuracy for anger improved with increased speed (e.g., 50% to 100% and 100% to 150%), autistic participants only showed improvement from the 100% to 150% speed. Importantly, these differences were attributed to autistic traits rather than alexithymia, as both groups were matched for levels of alexithymic traits. Therefore, autistic adults accurately identified anger at high speeds (150%) but performed less accurately at normal speeds (100%).

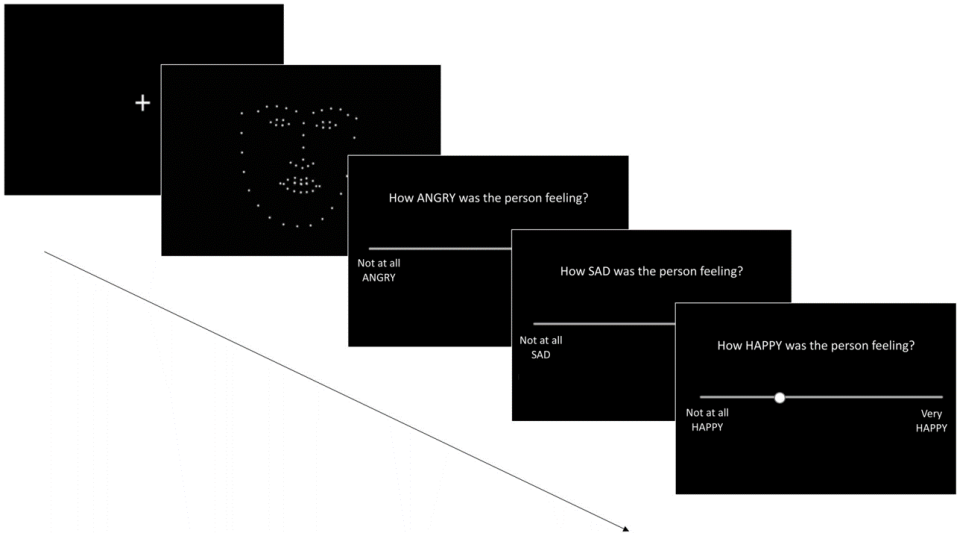

Figure 1.9 Example of a trial in the Point-light face task in Keating et al. (2022). Figure reproduced from Keating et al. (2022) in 'Differences between autistic and non-autistic adults in recognition of anger from facial motion remain after controlling for alexithymia'. Image used under the Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0/).

These findings suggest that difficulties in facial expression recognition in autistic individuals may not be due to a general impairment in emotion processing but rather their internal representations of facial expressions (i.e., the speeds at which they mentally visualise emotions) are characterised by very high-speed movements (Keating, Fraser, et al., 2022). These differential internal representations of facial expressions can affect expression recognition accuracy through various mechanisms. For example, according to 'Template Matching' models of expression labelling (Brewer, Biotti, et al., 2016; Scherer et al., 2019) individuals recognise expressions by comparing an observed expression to their internal

representation or template of the expression (Brewer, Biotti, et al., 2016; J. L. Cook et al., 2013). Therefore, autistic individuals may be seen to perform poorly on expression recognition tasks compared to non-autistic individuals, as their priors are based on faster movements (Jack & Schyns, 2015; Pellicano & Burr, 2012) but experimentally, behavioural tasks usually require participants to recognise stimuli presented at typical speeds, which would disadvantage autistic participants' performance (Keating, Fraser, et al., 2022; Keating, Sowden, et al., 2022). However, to date, literature in this area is inconsistent as it is unclear if autistic adults possess fast internal representations of all basic expressions, only specific expressions (i.e., anger) or none (Keating, Sowden, et al., 2022).

1.3.5 Explanation 5: Neurotypical individuals struggle to interpret autistic facial expressions

Difficulties in recognising the facial expressions of an interaction partner, regardless of whether they are autistic or neurotypical, can reduce the quality of social interactions (Brewer, Biotti, et al., 2016). However, little research has acknowledged that this process is inherently bi-directional, involving more than one individual and that the development of social cognition varies depending on the quality of engagements in these interactions (Halberstadt et al., 2001; Schilbach et al., 2013). Autistic individuals may have difficulties in recognising neurotypical expressions, but neurotypical individuals may also have difficulties in recognising autistic expressions due to differences in the kinematic movements and the physical display of facial expressions. During social interactions, when attempting to convey a particular expression, one must produce an expression which matches the internal representation of that expression held by one's interaction partner (J. L. Cook et al., 2013). If the physical facial display of expressions varies between autistic and neurotypical individuals, it is likely that internal representations of these expressions also vary. Therefore, during social interactions, a mismatch and subsequent difficulties in recognising expressions of others may not occur necessarily because of differential internal representations but because the physical execution of these expressions differs.

Brewer et al. (2016) examined the ability of neurotypical and autistic participants to recognise expressions produced by both neurotypical and autistic individuals. Three posing conditions were used to identify whether group recognition differences stemmed from either differential internal representations of expressions, a poor understanding of the communicative value of expressions or poor proprioceptive feedback. The results demonstrated that autistic expressions were more poorly recognised than neurotypical expressions, regardless of the observer group (autistic or neurotypical). As both neurotypical and autistic participants struggled equally to recognise autistic expressions, internal representations of expressions are likely idiosyncratic rather than systematic and shared in the autistic population (Brewer, Biotti, et al., 2016). Although the finding that autistic expressions were more poorly recognised than neurotypical expressions is consistent with previous work (Macdonald et al., 1989; Volker et al., 2009) findings in this study further address the problematic nature of these differences. The lack of interaction between poser and observer groups suggests that both neurotypical and autistic individuals may struggle to recognise autistic expressions- indicating a lack of shared internal representations of expressions within the autistic population. This suggests that autistic expressions are idiosyncratic, which can affect the success of social interactions between autistic and neurotypical individuals, but importantly also between other autistic individuals. This has significant implications for the success of social relationships, especially considering that many autistic individuals may prefer to interact with other autistic individuals (Brewer, Biotti, et al., 2016).

1.4 Face processing difficulties and mental health

Mental health conditions occur with a greater incidence in the autistic population than in the non-autistic population (Hossain et al., 2020; Lai, 2023; Lai et al., 2019). Research has suggested that approximately 80% of autistic adults in the UK experience mental health challenges that have a significant impact on their daily lives (Lord et al., 2022; Pukki et al., 2022). Among these challenges, anxiety disorders are most prevalent, affecting between

20% to 40% of autistic adults (Hollocks et al., 2019; Lai et al., 2019; Stark et al., 2021). Additionally, a review by Lai (2023) suggested that many autistic individuals face an increased risk of developing mental health conditions due to the additional challenges posed by co-occurring neurodevelopmental conditions such as attention deficit hyperactivity disorder (ADHD), which is estimated to occur in ~50% of autistic individuals (Lai et al., 2019; Rong et al., 2021; Stevens et al., 2016).

The high prevalence rates of mental health conditions have been associated with lower life satisfaction, social difficulties, loneliness and insomnia (Stark et al., 2021). Most concerningly, autistic individuals have a heightened risk of suicidal behaviours (including suicidal ideation, suicidal attempts or die by suicide), with over threefold greater odds compared to non-autistic individuals (Blanchard et al., 2021; Mournet et al., 2023; Newell et al., 2023; O'Halloran et al., 2022). Therefore, it is vital that we continue to understand how physiological and cognitive processing alongside social-contextual determinants intersect with neurodivergence to improve mental well-being in autistic individuals (Lai, 2023).

One predictor of anxiety in autism is the intolerance of uncertainty (Boulton & Guastella, 2021; Gaigg et al., 2020; Maisel et al., 2016; Ng-Cordell et al., 2022). This can also interact with the belief that the sensory environment is unstable. For example, research by South and Rodgers (2017) and Hwang et al. (2020) shows that sensory sensitivities in autistic individuals can increase anxiety, causing them to avoid unpredictable situations where they cannot anticipate sensory experiences. Stimming behaviours (formerly conceptualised as 'restrictive repetitive behaviours'), which serve as both manifestations of and coping mechanisms for anxiety, may offer a sense of control in such situations (Hwang et al., 2020). Further predictors of anxiety in autistic individuals include high levels of alexithymic traits and interoceptive differences (Bird & Cook, 2013; Huggins et al., 2021; Williams et al., 2023) and interpersonal factors such as perceiving oneself as a burden (Gaigg, 2012; Lai, 2023; Mournet et al., 2023).

At present, little is known about the psychosocial consequences of face recognition difficulties in autism. It could be argued that in some autistic individuals, face recognition difficulties may play a role in the development of social anxiety and feelings of loneliness. Non-autistic individuals with developmental prosopagnosia (DP) often experience heightened levels of social anxiety and depression (R. Cook & Biotti, 2016; Duchaine & Nakayama, 2006; Yardley et al., 2008). Research literature has shown that DP has profound and enduring psychosocial impacts on individuals across their lives. Adults with DP have reported struggling to recognise friends and teachers during childhood, which led to social isolation and internalising feelings of inadequacy (Dalrymple et al., 2014). As adults, many experience severe social anxiety due to their difficulties in recognising faces. This anxiety often leads to the development of avoidance behaviours and limited career choices (for example, choosing a career that minimises face-to-face interaction), which over time can have detrimental effects on their social relationships and wellbeing (R. Cook & Biotti, 2016; Yardley et al., 2008).

1.5 Summary and open questions

Despite the potential significance of the face processing problems seen in autism, there are notable gaps in our understanding.

First, it remains unclear whether face identity recognition difficulties in autistic individuals stem from deficits in face learning. Some suggest that autistic individuals may have differential or atypical perceptual learning mechanisms (Ipser et al., 2016). However, it could also be argued that the issue may lie in a more fundamental problem affecting the perceptual encoding of facial identity. This possibility is considered in Chapter 3.

Second, it is uncertain if autistic individuals have insight into their relative face recognition abilities. Specifically, whether they have the necessary insight to provide meaningful

responses to self-report measures (Gray et al., 2017; Minio-Paluello et al., 2020; Stantic et al., 2021). This question is the focus of Chapter 4.

Third, although there is a growing appreciation that autistic individuals have difficulties in facial expression recognition (Loth et al., 2018; Uljarevic & Hamilton, 2013), it remains unclear whether the presence and severity of co-occurring alexithymia impacts these difficulties (Bird & Cook, 2013; R. Cook et al., 2013). This question is addressed in Chapter 5.

Fourth, it is not clear if problems with face processing contribute to high rates of mental health difficulties reported in the autistic population (Lai, 2023; Lai et al., 2019). Where observed, face recognition problems in adults with DP are known to influence psychosocial outcomes (Dalrymple et al., 2014; Yardley et al., 2008). Therefore, it may be likely that poor face recognition (where observed) might also have a significant impact on the mental health of autistic individuals. This possibility is considered in Chapter 6.

Chapter 2: Online recruitment and testing

2.1 Introduction

In this thesis, participant testing and recruitment were conducted online. This approach has become increasingly common, in part owing to the difficulties of testing in-person during the COVID-19 pandemic (Lobe et al., 2020). Compared to in-person testing, this approach can also be more inclusive and successful in obtaining large sample sizes of participants who are typically underrepresented in research (Pellicano et al., 2023). However, using online methods may reduce the representativeness of autistic samples (Rødgaard et al., 2022).

This chapter will outline and evaluate our online recruitment and testing methods. I will address concerns about the gender representation of online samples.

2.2 Online recruitment

2.2.1 Autistic participants

Autistic participants were recruited via UK Autism Research (www.ukautismresearch.org). We invited individuals to participate in our research if they had received a diagnosis of autism (e.g., Autism Spectrum Disorder, Asperger's syndrome) from a clinical professional (e.g., General practitioner, Neurologist, Psychiatrist, or Clinical Psychologist) based in the UK. All autistic participants were also required to reach a cut-off score of 32 on the Autism Spectrum Quotient questionnaire (AQ; Baron-Cohen et al., 2001)

During recruitment, participants were also asked to provide their demographic information (age, sex, gender identity, first language and ethnicity) and to complete two questionnaires at this stage: the AQ questionnaire (Baron-Cohen, Wheelwright, Skinner, et al., 2001) and the Toronto Alexithymia Scale (TAS20; Bagby et al., 1994). Further details of these questionnaires are provided below (see **2.3 Initial assessment**). Due to time constraints, we did not further assess our autistic participants for other co-occurring neurodevelopmental and/or neurodivergent conditions at this stage (we screened for attention deficit hyperactivity

disorder (ADHD) in **Chapter 4**). To expand our database, we regularly used social media (e.g., Facebook) to advertise our website and research participation opportunities.

To improve the clarity of the information we provided to our participants, we invited a group of autistic participants who had previously shown keen interest in our research and research methodology to form a voluntary advisory board. We also invited Professor Dermot Bowler from City, University of London, to advise as a senior academic on this board, given his expertise in working with the autistic community for over three decades.

Given this project's time and financial constraints, the advisory board served as a mechanism by which we received voluntary and specific feedback on only the research materials we sent out.

2.2.2 Non-autistic participants

For each experiment we conducted, once we knew the size and profile of the autistic sample, we recruited a matched sample of non-autistic control participants via Prolific (www.prolific.co). Alongside the above eligibility criteria, all non-autistic participants did not identify as being autistic and/or neurodivergent and had a Prolific approval rate of at least 95%. Participants who reached the cut-off (a score of 32) on the AQ were replaced. Each experiment was completed by separate groups of participants; therefore, each sample was completely independent.

2.2.3 Eligibility criteria

To be eligible, all participants (autistic and non-autistic) had to be aged between 18 and 60, speak English as a first language, have normal or corrected-to-normal visual acuity and be current UK residents. We also confirmed that all participants had never received a diagnosis of schizophrenia, as this condition is believed to impact the early encoding stages of face processing in potentially similar and dissimilar ways to autism (Martínez et al., 2019; Marwick & Hall, 2008; Watson, 2013).

2.3 Initial assessment

All participants (autistic and non-autistic) took part in an extensive battery of assessments to measure abilities, traits, and individual differences. These assessments are outlined below.

2.3.1 Autistic traits

During recruitment, it was required that all autistic participants had a clinical diagnosis of autism from a professional in the UK (i.e., those who self-identified were not invited to take part in our research). We planned to further administer the Autism Diagnostic Observation Schedule- Second Edition (ADOS-2; Lord et al., 2012) to our participants to better characterise their autistic traits. However, this was not possible given the COVID-19 testing restrictions at the time. Therefore, to further validate that our groups varied based on the number of autistic traits, we administered the AQ questionnaire (Baron-Cohen et al., 2001) to all our participants.

The AQ is a 50-item self-report questionnaire which measures the number of autistic traits within an individual. These traits are measured across five domains: communication, social skills, attention switching, imagination and attention to detail. Each item is scored either 0 or 1 across a 4-point scale where the respondent rates how strongly they agree or disagree with each statement. Total scores range from 0 to 50. A cuff-off score of 32 or above has shown strong discriminative validity and test-retest reliability, making it effective for distinguishing between clinical samples of autistic and non-autistic individuals (Austin, 2005; Ruzich et al., 2015; Woodbury-Smith et al., 2005). Furthermore, previous research has shown differences in face processing ability as a function of scores on the AQ in neurotypical groups (Davis et al., 2017; Desai et al., 2019).

2.3.2 Non-verbal reasoning

Despite previous research suggesting that face processing ability is unrelated to intelligence (Shakeshaft & Plomin, 2015; Wilmer et al., 2014), a recent meta-analytic review by Walker et al (2023) suggests that these abilities may be sub-dimensions of intelligence. Abstract reasoning, a component of fluid intelligence, is considered to be a fundamental cognitive process which is essential for learning as it is the ability to solve novel problems without task-specific knowledge (Krawczyk, 2012). Research has suggested that face processing ability may also have a similar adaptive capacity to abstract reasoning, which is required to achieve novel goals using pre-existing perceptual-cognitive abilities to process faces (Walker et al., 2023).

To explore face processing differences between our autistic and non-autistic samples, we ensured that both groups were matched on non-verbal abstract reasoning ability. All participants completed the Matrix Reasoning Task (MRT). The MRT employed consists of forty items selected from The Matrix Reasoning Item Bank (Chierchia et al., 2019). We used their colour-blind-friendly palette 1. Participants were given 30 seconds (with a 5-second warning before the end of each trial) to complete each puzzle by selecting the correct answer from 4 options. Participants responded using keyboard number keys (1–4) and received no feedback. Each participant attempted all forty items. Participants had to complete 3 practice trials correctly before beginning the test (see **Figure 2.1** for examples of puzzles on the Matrix Reasoning Task).

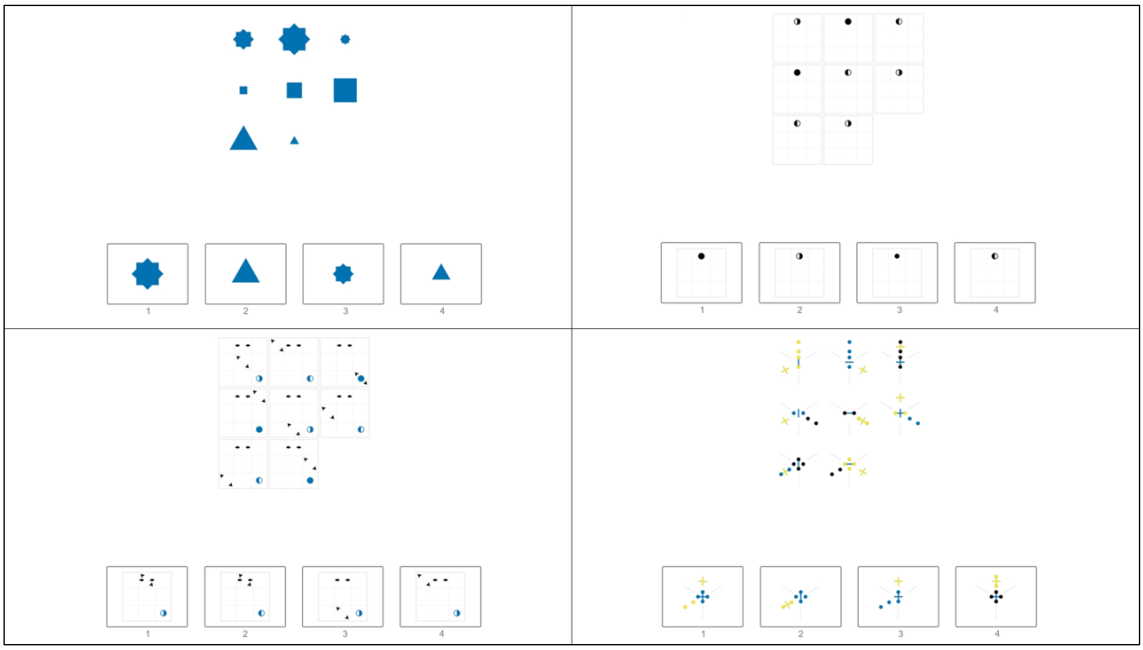

Figure 2.1 Image illustrating four example puzzles from the MRT. Note that only one puzzle was presented in each trial on the MRT. The puzzle images shown in the figure are from The Matrix Reasoning Bank (Chierchia et al., 2019).

To assess the test-retest reliability of this measure, 100 non-autistic participants (M_{age} = 34.90 years, SD_{age} = 10.16 years; 27 males, 73 females) were recruited through Prolific and asked to complete the task twice. The average interval between the first and second attempts was 170.2 days (range: 75 days to 297 days), during which time participants were given no feedback regarding their level of performance. The scores seen at the first attempt (M = 26.07, SD = 5.71) and second attempt (M = 26.13, SD = 6.53) did not differ significantly [t (99) = 0.131, p = 0.896]. We observed a strong positive correlation (Pearson's *r)* between the two sets of scores [N = 100, r_p = 0.727, p < 0.001]. See **Figure 2.2**.

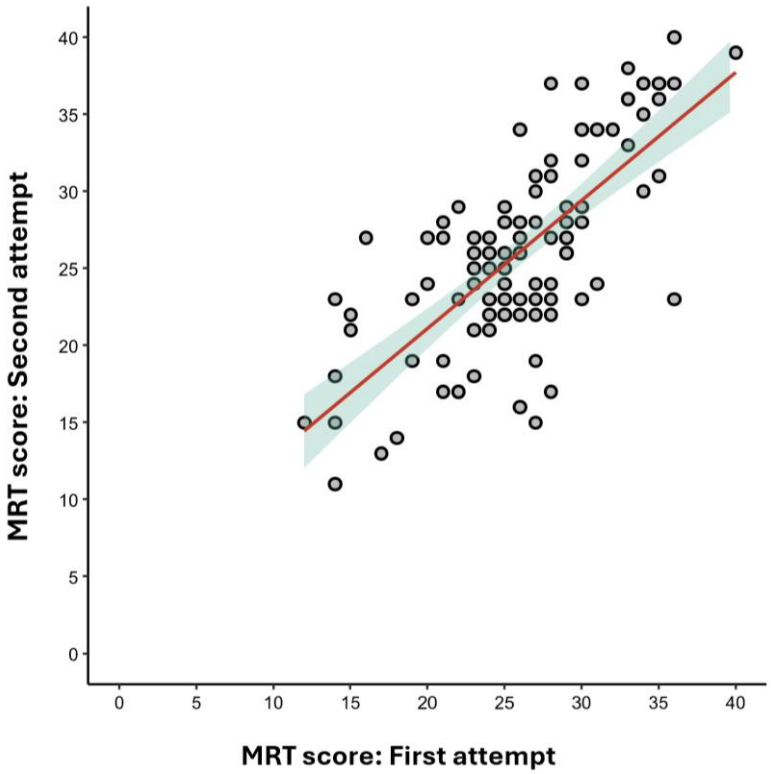

Figure 2.2 Scatterplot illustrating participant's scores on the Matrix Reasoning Task (MRT) at the first and second attempt. The red line represents the linear trend, and the shaded green area shows the 95% confidence interval.

2.3.3 Self-reported face recognition difficulties

The incidence of lifelong face recognition difficulties is particularly high amongst autistic individuals, many of whom experience problems when asked to identify or match faces (Hedley et al., 2011; Stantić et al., 2021). To assess the presence of DP between our autistic and non-autistic participants, we administered the PI20 questionnaire.

The PI20 (Gray et al., 2017; P. Shah, Gaule, et al., 2015; Tsantani et al., 2021) is a self-report questionnaire designed to provide standardised self-report evidence of face recognition difficulties to complement diagnostic evidence obtained from objective computer-based assessments such as the CFMT (Duchaine & Nakayama, 2006). The PI20 comprises 20 statements describing face recognition experiences drawn from qualitative and quantitative descriptions of individuals with lifelong face recognition difficulties. Participants

rate how well each statement describes their own experiences on a 5-point scale. PI20 scores range from 20 to 100. A score of 65 or higher indicates the likely presence of face recognition impairment. The items on the PI20 ask respondents to assess their face recognition ability relative to the rest of the population, either explicitly (e.g., “My face recognition ability is worse than most people”, “I am better than most people at putting a ‘name to a face’”, “I have to try harder than other people to memorize faces”) or implicitly (e.g., “When people change their hairstyle or wear hats, I have problems recognizing them”, “When I was at school, I struggled to recognize my classmates”).

2.3.4 Alexithymia

Alexithymia is a trait associated with difficulties interpreting interoceptive (e.g., hunger, thirst, warmth) and emotional (e.g., happiness, anger, disgust) states (Brewer, Cook, et al., 2016; Brewer et al., 2015). For example, individuals with high levels of alexithymia, may often confuse feeling angry and feeling hot (Brewer, Cook, et al., 2016). Compared to only ~5% of the general population, high levels of alexithymia are thought to co-occur within ~50% of the autistic population (Bird & Cook, 2013; Kinnaird et al., 2019). Interestingly, despite the defining feature of alexithymia being a difficulty in describing one’s own affective and interoceptive states, individuals with high levels of alexithymia also exhibit impaired recognition and descriptions of others’ facial affect (Grynberg et al., 2012). Research has shown that autistic individuals with and without co-occurring alexithymia differ in their expression recognition ability (R. Cook et al., 2013; Oakley et al., 2016; Ola & Gullon-Scott, 2020).

To measure the potential influence of high alexithymic traits on face processing ability, we administered the Toronto Alexithymia Scale (TAS20; Bagby et al., 1994) to both our autistic and non-autistic participants. The TAS20 is a 20-item self-report questionnaire which measures components of alexithymia through three subscales: difficulty in identifying feelings, difficulty describing feelings and externally oriented thinking. Respondents rate how much they agree with each statement across a 5-point scale. Total scores range from 20 to

100, with a cut-off score of 61 and above for high alexithymia. The TAS20 is considered to have good internal consistency and good levels of test-retest reliability (Bagby et al., 1994).

2.4 Online testing platforms

All experiments were programmed and conducted online through Gorilla Experiment Builder (A. L. Anwyl-Irvine et al., 2020). Previous research has demonstrated that the timing of stimulus presentation in Gorilla Experiment Builder is accurate (A. Anwyl-Irvine et al., 2021). All data (including response times) was logged directly on participants' computers to ensure that the data was unaffected by fluctuations in transmission speeds to the server.

Previous research has shown that carefully designed online tests of cognitive and perceptual processing can yield high-quality data, indistinguishable from that collected in the lab (Crump et al., 2013; Germine et al., 2012; Woods et al., 2015). Although there are some well-known limitations of this approach, such as limited control over the testing environment, participants' viewing distance or their monitor settings, this approach allowed us to collect data from larger samples (and thereby achieve more statistical power) amid the constraints of the COVID-19 pandemic (Lombardo et al., 2019).

All participants were given a unique participant code to ensure they could only participate in the experiments once and were reimbursed for their time accordingly. Autistic participants were provided with a UAR code (linked to their data file in the UK Autism Research Database). As non-autistic participants were recruited from Prolific, they were provided with their own internal participant code.

On Gorilla Experiment Builder, we implemented a manual screen calibration procedure at the start of our perceptual tasks to ensure consistent stimulus size and positioning across different monitors. Participants resized an image of a bank card to match the dimensions of a real card held up against their screen. This calibration adjusted the subsequent stimuli, displayed in centimetres, to ensure standardised presentation regardless of monitor size. All experiments had to be completed on a desktop or laptop computer; they would not run on a

mobile device or tablet. We also restricted the location; participants could only participate in the experiments if they were connected to a UK-based internet connection. We included a time-out limit to exclude participants who took longer than expected to complete an experiment.

2.5 Gender representation in online samples

Online recruitment has been criticised for its tendency to attract a disproportionately high number of female participants (Rødgaard et al., 2022). However, we do not think that this is prohibitive. In fact, online recruitment offers a key advantage by being an inclusive method that broadens participation.

Traditionally, it has been suggested that autism is more prevalent in males than females, with an estimated ratio of 3:1 (Loomes et al., 2017). However, many have argued that the 3:1 autistic male-to-female ratio is inaccurate as it is more likely to reflect biases in the current diagnostic conceptualisation of autism, which poorly captures the autistic female presentation rather than the true prevalence rates of autism between the sexes (Rubenstein et al., 2015). It is likely that over time, as we continue to increase our knowledge of the barriers to a diagnosis for girls and young women living across the Global North, we will see an increase in the proportion of females diagnosed as autistic (Lockwood Estrin et al., 2021).

In our autistic samples, as expected, we see a low male-to-female ratio (for example, in a sample of 77 participants, we have a 16:61 male-to-female ratio or ~20% males). In addition to this, it should be highlighted that when considering gender identity, ~20% of autistic participants in our samples identified as gender diverse/ expansive (e.g., non-binary, gender fluid, transgender). This accords well with previous findings of elevated rates of gender diversity between autistic adults compared to non-autistic adults (Strang et al., 2018; Warrier et al., 2020).

One factor that may have contributed to a male bias in previous research is the method researchers use to confirm autism diagnoses. It is common practice for researchers to

confirm a diagnosis of autism within a sample recruited through self-report by administering additional clinical diagnostic tools such as the ADOS-2 (D'Mello et al., 2022; Lord et al., 2012). However, this is problematic as autistic females are more likely to be excluded from participation at a disproportionately higher rate (~2.5 times higher) than autistic males, as these measures are more sensitive in capturing the male Kanner and Asperger type conceptualisations of autism (D'Mello et al., 2022; Gould & Ashton-Smith, 2011; Rea et al., 2022). Therefore, females are less likely to qualify for study participation through this validation process despite holding clinical diagnoses.

While having representative samples is important and remains a challenge in online research, this approach allows previously underserved autistic community members to participate in research. It is crucial to build research processes that responsibly embed and prioritise inclusive and accessible study designs, with online recruitment serving as a strong example. We believe that our online recruitment strategy effectively expanded participation opportunities for more autistic women and gender expansive individuals who have historically been underrepresented in autism research.

2.6 Chapter summary

This chapter has outlined and evaluated the online research processes we used to recruit both autistic and non-autistic participants, as well as the various measures administered to assess abilities, traits and individual differences related to face processing. It has also addressed concerns specific to gender representation in online samples of autistic individuals.

Chapter 3: Impaired grouping of ambient facial images in autism.

The research described in this chapter has been published in the following peer-reviewed journal article: Gehdu, B. K., Gray, K. L., & Cook, R. (2022). Impaired grouping of ambient facial images in autism. *Scientific Reports*, *12*(1), 6665.

3.1 Introduction

Experiencing faces in different poses, situations, and lighting conditions (i.e., exemplar variation) is thought to enhance face learning independently of face viewing time (Murphy et al., 2015). Ambient images are naturalistic images of faces that depict individuals from a variety of viewing angles, with a range of expressions under different lighting conditions. The exemplar variation present within ambient images is thought to help individuals form robust representations of the individuals depicted (Burton et al., 2005; Murphy et al., 2015). Once acquired, robust representations are thought to aid the seemingly effortless recognition of familiar faces. Until a robust representation has been acquired, the identification and matching of unfamiliar faces remains effortful and inaccurate (Jenkins et al., 2011). In their work, Jenkins et al. (2011) challenged the assumption that photographs reliably capture a person's appearance by demonstrating that photos fail to account for significant within-person variability. In their study, participants were shown 20 ambient images (sourced from the internet) of the same two celebrities. They found that unfamiliar viewers frequently mistook images of the same person for different individuals, whereas familiar viewers could accurately identify them. These results suggest that familiarity gained from seeing a face in various conditions helps create a more complete and accurate mental representation of that face. This comprehensive representation allows for easier recognition even when there are variations in lighting or angles. Thus, a representation is considered 'robust' if it remains reliable despite these changes, thereby supporting accurate facial identity recognition.

However, the nature of these representations is unclear. One perspective, the Averaging Hypothesis, suggests that the visual system creates a perceptual average from different exemplars of the same face, making it easier to match new instances (Burton et al., 2005). Alternatively, the Pictorial Coding Model suggests that each encounter with a face may be stored, and familiar faces are recognised by comparing them with previously stored instances (Longmore et al., 2008). According to this view, robust representations function as a comprehensive “instance database” that has been formed through many encounters with a given face in different poses, lighting, and viewing conditions. With increased encounters of the same face, in various conditions, observers densely sample the potential instance space, increasing the likelihood of matching a novel encounter to a stored instance, thus improving recognition performance (Longmore et al., 2008; Murphy et al., 2015).

Ipser et al. (2016) demonstrated that autistic participants were less able to form robust representations of facial identities presented using ambient images compared to non-autistic participants. In the training phase, participants learned 8 facial identities by viewing 96 ambient images of each identity. During the testing phase, participants were presented with a set of new exemplars, half depicting the learned facial identities and half depicting novel ones. Compared with non-autistic participants (74.70% correct), the autistic participants (62.20% correct) were less able to identify the individuals presented during the study phase. Therefore, considering these findings, it could be argued that autistic individuals may have differential and/or atypical perceptual learning mechanisms, making it harder for them to derive a perceptual average from multiple exemplars to aid accurate identity recognition.

Although Ipser et al. (2016) speculated that autistic individuals may possess differential and/or atypical perceptual learning (or “exemplar pooling”) mechanisms, it could be argued that autistic individuals may have a more fundamental problem that affects the perceptual encoding of the people depicted in ambient images (i.e., the learning mechanisms may be intact, but receive low-quality input from face encoding processes). This possibility aligns

well with research that has shown that autistic individuals struggle on face matching tasks with low memory demands (Stantić et al., 2021).

3.2 Aims of the study

The study described in this chapter sought to determine whether slow learning of facial identity, described by Ipser et al. (2016) reflects i) atypical perceptual learning mechanisms or ii) problems in the perceptual encoding of individual exemplars.

3.3 Methods

3.3.1 The Oddball task

We examined whether autistic people are less able to group ambient images of unfamiliar individuals based on their identity. Every trial depicted a novel combination of individuals, thereby ensuring that participants had little or no opportunity for perceptual learning across trials. As such, the task was intended to be a pure measure of participants' ability to group ambient images of unfamiliar people in the absence of any face learning and robust representation. Crucially, the variation present within the ambient images was very similar to that present in the images employed by Ipser and colleagues (2016). Should autistic participants perform poorly on this task, it would suggest that previous evidence of poor face learning from variation (Ipser et al., 2016) may be attributable to low-quality perceptual input, not atypical learning mechanisms.

Trials began when a large cross appeared, dividing the participants' display into four quadrants. After 1000 ms, four ambient images appeared on the display, one in each quadrant. On each trial, three of the ambient images depicted the same person. The fourth oddball image depicted a different person of broadly similar appearance. The four ambient images were presented for 5000 ms. During this time, participants were asked to identify which of the four images was the oddball. After 5000 ms, the ambient images disappeared and were replaced with the response screen. Participants indicated which of the four images was the oddball by pressing the corresponding number key (see **Figure 3.1**). This approach

ensured that all participants inspected the to-be judged images for the same length of time, thereby mitigating any speed-accuracy trade-off.

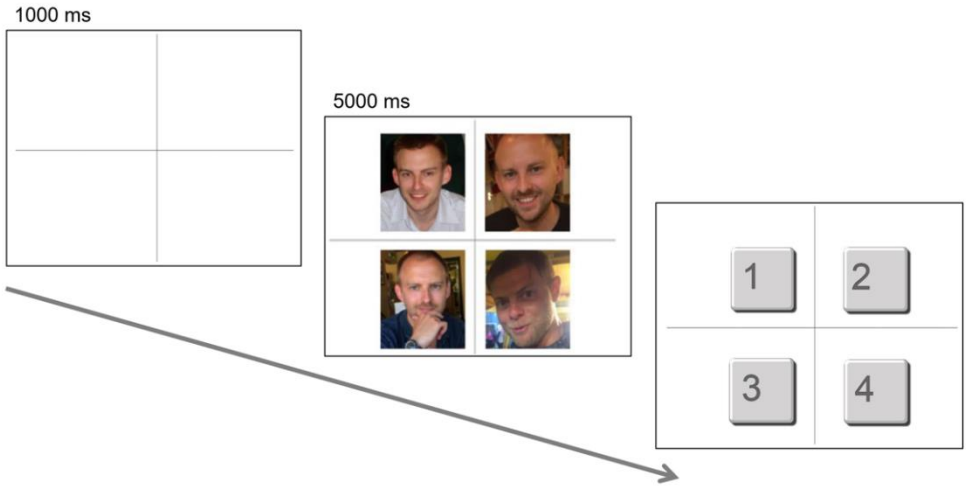

Figure 3.1 Schematic illustration of an experimental trial on the Oddball task. The images shown in the figure were not used in the study but are representative of the ambient images employed. The research supervisor (Professor Richard Cook) owns the images shown. The individuals depicted have given informed consent for the open-access publication of the photos.

Participants completed 40 experimental trials in a randomised order, consisting of 20 trials depicting White females and 20 trials depicting White males. Participants were invited to take a short break after 10, 20, and 30 trials. At the end of the procedure, participants were asked if they recognised any of the people depicted. None of the faces were recognised. In total, the experiment required 160 ambient images (80 male, 80 female) that were sourced online from various websites. Before the task started, participants completed 3 practice trials to ensure they understood what the task required. Practice trials had the same format as the experimental trials; however, images of cartoon characters were used instead of photographic ambient images. Participants had to get all practice trials correct before progressing to the experimental trials. Four catch trials were interspersed within the experimental trials. The catch trials had an identical format to the practice trials. A calibration procedure at the start of the experiment ensured that each ambient image appeared 5 cm

high, positioned centrally within each quadrant, irrespective of the dimensions of each participant's monitor.

The experiment had to be completed on a desktop or laptop computer; it would not run on a mobile device or tablet. We created two versions of this task, both versions are available as Open Materials at gorilla.sc (https://app.gorilla.sc/openmaterials/332894).

3.3.2 Statistical procedures

The ability of the two groups to identify the oddball images was assessed through independent samples t-tests (α = 0.05, two-tailed). Correlations were assessed by computing Pearson correlation coefficients (α = 0.05, two-tailed). The data supporting all of the analyses described are available via the Open Science Framework (https://osf.io/fj7de/).

3.3.3 Ethics

Ethical clearance was granted by the Departmental Ethics Committee for Psychological Sciences, Birkbeck, University of London and the experiment was conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent before taking part.

3.4 Experiment 1

We assessed the sensitivity of our paradigm by testing non-autistic participants with varying levels of autism-related traits. Autism-related traits are no longer thought to be confined within clinically diagnosed populations, as differences associated with autism are thought to lie on a continuum (Hoekstra et al., 2007). The AQ questionnaire has been shown to reliably differentiate between autistic and non-autistic adults without accompanying intellectual disabilities (Baron-Cohen, Wheelwright, Skinner, et al., 2001). Based on this, using variability on AQ scores has been deemed as an appropriate substitute when large samples of autistic individuals cannot be recruited as participants in a pilot study (Hoekstra et al., 2011).

3.4.1 Participants

We recruited a non-autistic sample from Prolific (N = 100, M_{age} = 36.05 years, SD_{age} = 10.44 years). After completing the Oddball task, participants were asked to complete the AQ questionnaire. We predicted that task performance (% correct) would be significantly associated with levels of autism-related traits, higher levels of autism-related traits would be negatively associated with task performance.

3.4.2 Results

We found strong evidence of a negative correlation between higher AQ scores (M = 19.29, SD = 8.37) and performance on the task (M = 72.53%, SD = 11.87%), r = - 0.322, p < 0.001. See **Figure 3.2**. This suggested that non-autistic individuals with higher levels of autism-related traits correctly identified fewer oddball images.

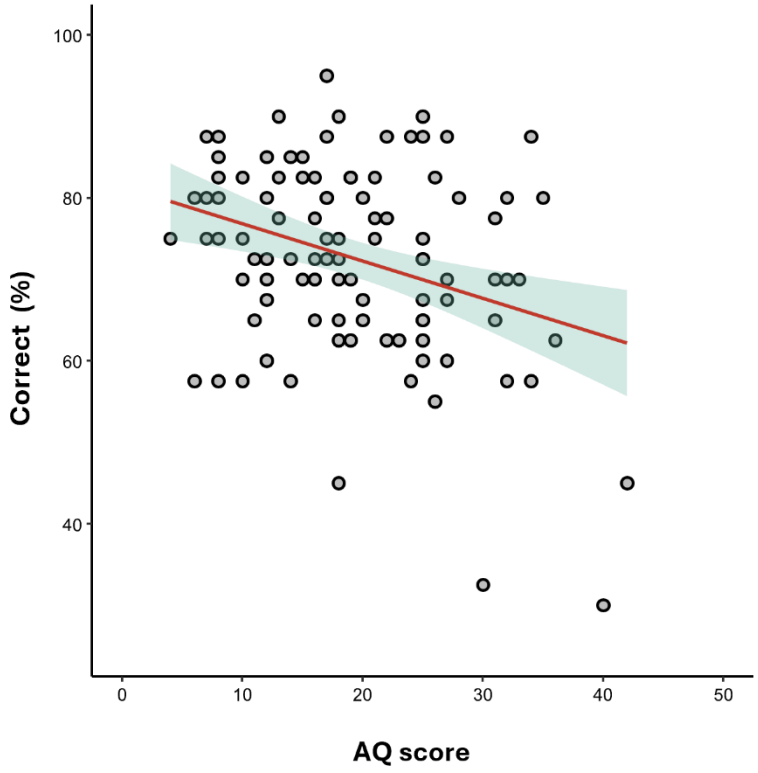

Figure 3.2 Scatterplot illustrating a strong negative correlation between performance on the Oddball task and AQ scores in Experiment 1 (r = - 0.322, p < 0.001). The red line represents the linear trend, and the shaded green area shows the 95% confidence interval.

3.5 Experiment 2

3.5.1 Participants

We sought to determine whether individuals with a clinical diagnosis of autism make more errors on this task than a non-autistic comparison group matched for age and sex. We recruited sixty participants with a clinical diagnosis of autism (M_{age} = 32.75 years, SD_{age} = 11.25 years) from our UK Autism Research Database. Of the 22 individuals who described their sex as male, 16 described their gender identity as male, 4 identified as non-binary, 1 identified as female, and 1 preferred not to state their gender identity. Of the 38 individuals who described their sex as female, 28 described their gender identity as female, 7 identified as non-binary, and 3 identified as male. All participants in the autistic group also reached the cut-off (a score of 32) on the AQ. The mean AQ score of the autistic group was 41.27 (*SD* = 4.26).

Sixty non-autistic individuals (M_{age} = 33.63 years, SD_{age} = 7.99 years) were recruited through Prolific. Of the 60 participants in the non-autistic group, 25 described their sex and gender identity as male and 35 described their sex and gender identity as female. All non-autistic participants scored below the cut-off (a score of 31 or less) on the AQ. The mean AQ score of the non-autistic group was 18.18 (*SD* = 6.77).

The autistic and non-autistic participants were matched on age [t (118) = 0.496, p = 0.621] and sex [$X^2_{(1)}$ = 0.315, p = 0.575]. However, groups did differ in terms of participants' gender identity [$X^2_{(2)}$ = 13.381 p = 0.004]. Consistent with previous reports (Minio-Paluello et al., 2020; Stantić et al., 2021) the PI20 scores of the autistic participants (*M* = 65.20, *SD* = 15.28) were significantly higher than those of the non-autistic controls (*M* = 46.83, *SD* = 12.28) [t (118) = 7.258, p < 0.001]. Both groups were also matched on levels of non-verbal abstract reasoning. Scores on the MRT did not differ significantly between autistic participants (*M* = 25.62, *SD* = 5.72) and the non-autistic controls (*M* = 26.48, *SD* = 5.42) [t

(118) = 0.852, p = 0.396]. Autistic participants had also previously completed the TAS20 (Bagby et al., 1994). See **Chapter 2** for more information about these measures.

3.5.2 Results

Autistic participants (M = 65.96%, SD = 12.72%) correctly identified fewer oddball images than the non-autistic controls (M = 74.71%, SD = 13.74%) [t (118) = 3.620, p < 0.001, d = 0.661]. See **Figure 3.3, Experiment 2**. All participants responded correctly on at least 3 of the 4 catch trials.

In the combined sample (N = 120) significant correlations were seen between participants' AQ scores (r = − 0.276, p = 0.002) and PI20 scores (r = − 0.374, p < 0.001) and their % correct achieved on the experimental task. Separate hierarchical regression analyses revealed that PI20 scores [β = − 0.287, t = 2.809, p = 0.006] but not AQ scores [β = 0.044, t = 0.221, p = 0.826] were predictive of task performance once the effect of Group (autistic, non-autistic) [β = − 0.316, t = 03.620, p < 0.001] was removed. No correlation was seen between task performance (% correct) and participants' scores on the MRT (r = 0.170, p = 0.064). In the autistic sample (N = 60), a significant correlation was seen between task performance (% correct) and participants' PI20 scores (r = − 0.279, p = 0.031). The correlations between % correct and AQ scores (r = − 0.157, p = 0.232) and TAS20 scores (r = − 0.188, p = 0.151) were all non-significant.

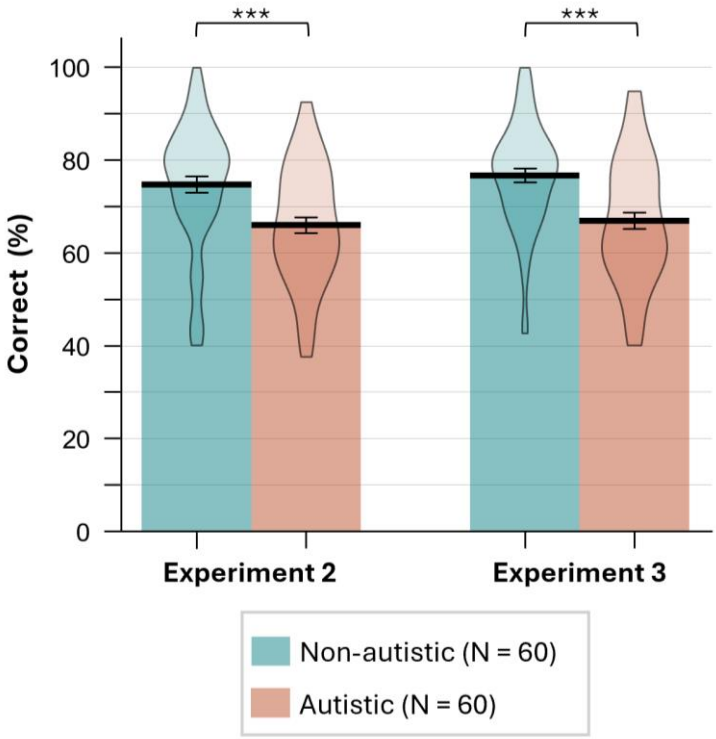

Figure 3.3 Mean performance accuracy (%) on the Oddball task across Experiments 2 and 3 between non-autistic and autistic groups. Bars depict mean performance accuracy. Distribution plots illustrate the spread of accuracy within each group. Error bars ±1SE. ***$p < 0.001$.

3.6 Experiment 3

The results from the second experiment suggest that autistic individuals are less able to group ambient images according to the identity of the people depicted. In our third experiment, we used an entirely different set of ambient images to confirm that the group difference seen in Experiment 2 was not attributable to the particular images used. By definition, ambient images are uncontrolled. For example, faces are shown at different scales, with different poses and expressions. Similarly, the images are captured using different cameras, at different distances, under different lighting conditions. Because of the random variation present within sets of ambient images, the danger that effects are due to idiosyncratic stimulus features is greater than when using facial images drawn from standardised databases (Dalrymple et al., 2013; Langner et al., 2010).

Therefore, it is important to confirm that group differences seen in Experiment 2, also generalise to different image sets. The new set of 160 images (80 male, 80 female) were sourced in the same manner as the first set. Once again, the variation present within the ambient images was similar to that present in the set employed by Ipser et al.(2016). With the exception of the images used, the methods of Experiment 2 and 3 were identical.

3.6.1 Participants

The same sixty autistic participants completed the third experiment. The autistic participants completed the second and third experiments during separate testing sessions. We were unable to contact and recruit the same group of non-autistic controls that completed Experiment 2. We therefore recruited a new group of 60 non-autistic controls (M_{age} = 30.75 years, SD_{age} = 7.50 years) through Prolific. Of the 60 participants in the non-autistic group, 30 described their sex and gender identity as male and 28 described their sex and gender identity as female. Two participants preferred not to reveal their sex and gender identity. All non-autistic participants scored below cut-off (a score of 31 or less) on the AQ. The mean AQ score of the non-autistic group was 17.65 (SD = 7.30).

The autistic and non-autistic participants were matched in terms of age [t (118) = 1.146, p = 0.254] and sex [$X^2_{(1)}$ = 4.746, p = 0.093]. However, groups differed in terms of gender identity [$X^2_{(2)}$ = 13.417, p = 0.004]. The PI20 scores of the autistic participants (M = 65.20, SD = 15.28) were significantly higher than those of the non-autistic controls (M = 42.55, SD = 11.96) [t (118) = 9.041, p < 0.001]. The scores of the autistic (M = 25.62, SD = 5.72) and non-autistic participants (M = 24.93 SD = 6.51) on the MRT did not differ significantly [t (118) = 0.611, p = 0.543].

3.6.2 Results

Similar to the second experiment, the autistic participants (M = 66.92%, SD = 13.54%) correctly identified fewer oddball images than the non-autistic controls (M = 76.67%, SD = 11.48%) [t (118) = 4.255, p < 0.001, d = 0.777], (see **Figure 3.3, Experiment 3**). All participants responded correctly on at least 3 of the 4 catch trials.

In the combined sample (N = 120), significant correlations were seen between participants' AQ scores (r = − 0.405, p < 0.001) and their PI20 scores (r = − 0.287, p = 0.001) and their % correct achieved on the oddball task. Separate hierarchical regression analyses revealed that AQ scores [β = − 0.392, t = 2.079, p = 0.040] but not PI20 scores [β = − 0.085, t = 0.761, p = 0.448] were predictive once the effects of Group (autistic, non-autistic) [β = − 0.365, t = 4.255, p < 0.001] were removed. No correlation was seen between task performance (% correct) and participants' scores on the MRT (r = − 0.025, p = 0.789). In the autistic sample (N = 60) the correlations between % correct and participants' AQ scores (r = − 0.116, p = 0.379) PI20 scores (r = 0.066, p = 0.617) and TAS20 scores (r = − 0.181, p = -0.165) were all non-significant.

3.7 Discussion

In the present study, we conducted two experiments to assess the ability of autistic participants to group ambient images by the identity of the people depicted. In order to correctly group individuals depicted in ambient images, participants must identify commonalities in facial structure across instances and disregard image-specific variation (e.g., differences in pose and lighting). In Experiments 2 and 3, participants were shown arrays of four ambient images for 5000 ms. Each array contained 3 images of one person and a single image of a different person. Participants were tasked with finding the oddball facial image within each array. In both experiments across two different sets of ambient images, autistic participants (N = 60) found this task more challenging—they were less accurate—than matched non-autistic control participants (N = 60).

3.7.1 Implications for face learning in autism

Exposure to the facial variation present in ambient images is thought to facilitate face learning (Burton et al., 2005, 2016; Murphy et al., 2015; Ritchie & Burton, 2017). Seeing to-be-learned individuals in a variety of poses appears to help observers form an accurate representation of their facial appearance that helps them identify that person in subsequently encountered instances. Robust representations may take the form of an average (Burton et al., 2005) or a comprehensive database of previously encountered instances (Longmore et al., 2008).

Previous research has shown that autistic individuals derive less benefit from facial variation than non-autistic individuals when learning faces (Ipser et al., 2016). However, in light of the present findings, it could be argued that what may superficially appear to be evidence of atypical face learning, in fact, reflects poor quality input into perceptual learning mechanisms. For example, if the perceptual description of individual exemplars is noisy and imprecise, this will make it harder for the visual system to derive a high-quality average of the instances encountered (Burton et al., 2005). The resulting person specific averages may be less distinctive than the equivalent representations derived by non-autistic observers.

A further possibility is that poor face encoding may cause autistic participants to make “sorting errors”. In order to acquire robust representations of to-be-learned facial identities—say Matt Damon and Brad Pitt—the visual system must somehow group the instances of Matt Damon together, and the instances of Brad Pitt together. Having been sorted, instances can be combined to form an average representation (Burton et al., 2005) or pooled in an instance database (Longmore et al., 2008). However, if instances of Matt Damon are mistakenly tagged as Brad Pitt, the robust representation of Brad Pitt will be derived from a mix of instances depicting Brad Pitt and Matt Damon. Such a representation would likely hinder recognition of Brad Pitt in subsequently encountered instances.

Impaired perceptual encoding of faces offers a single, comprehensive explanation for the current findings and those described by Ipser et al. (2016). However, it is possible that

autistic individuals could still have a secondary difficulty affecting face learning, which our results do not rule out. Demonstrating an additional face learning deficit in autistic participants with impaired perceptual encoding of unfamiliar faces would be challenging. Nevertheless, if deficits in face learning and perceptual encoding can occur independently, there may be autistic individuals who exhibit unimpaired face encoding but have difficulties with face learning.

3.7.2 The nature of face processing difficulties in autism

Weigelt et al.'s (2012) systematic review concluded that autistic individuals can form accurate perceptual descriptions of faces but have difficulty retaining these facial percepts in visual memory for more than a few seconds. They suggested that difficulties in facial identity recognition in autism might result from difficulties with short term face memory rather than poor perceptual encoding. However our findings, along with recent results (Stantić et al., 2021), challenge this conclusion. Our Oddball task had very low memory demands since all four faces were presented simultaneously, requiring minimal need to retain face percepts in visual memory. Despite this, autistic participants performed less accurately than non-autistic control participants, suggesting that face encoding may be affected in this group of individuals.

Previous explanations have characterised face recognition difficulties in autism as potentially co-occurring with DP a separate neurodevelopmental condition associated with severe, lifelong face recognition difficulties (Cook & Biotti, 2016; Duchaine & Nakayama, 2006). Various neurodevelopmental conditions such as attention deficit hyperactivity disorder (Leitner, 2014), developmental coordination disorder (Dziuk et al., 2007), alexithymia (Bird & Cook, 2013), specific language impairment (Conti-Ramsden et al., 2006), dyslexia (C. R. G. Jones et al., 2009), and synaesthesia (Baron-Cohen et al., 2013), occur more frequently in the autistic population than in the general population. Given that the co-occurrence of neurodevelopmental conditions is common, an elevated rate of DP in the autistic population would not be surprising.

It is evident that autism and DP are distinct conditions. Many people present with DP without signs of autism (Duchaine et al., 2009). Conversely, many autistic individuals also perform average or above on face recognition tasks (Hedley et al., 2011; Stantić et al., 2021). Nevertheless, a significant number of autistic individuals do experience severe face recognition difficulties (Kracke, 1995). This variability was evident in our data, where some autistic participants struggled with the task while others achieved near-perfect levels of performance. This variability is precisely what one might expect if autism and DP were independent neurodevelopmental conditions with a high level of co-occurrence (R. Cook & Biotti, 2016; Gray & Cook, 2018). In this context, it is important to consider whether the face recognition issues in autism are similar to those in DP. Notably, individuals with DP perform poorly on face recognition tasks with minimal memory demands, indicating difficulties in face encoding. For example, people with DP struggle on the CFPT, which requires sorting six simultaneously presented faces by their resemblance to a target face (Biotti et al., 2019; Duchaine et al., 2007). If face recognition problems in autism were due to short-term face memory issues, one could argue that different types of face processing deficits are seen in autism and DP. However, evidence of impaired face encoding observed here and elsewhere (Stantić et al., 2021) suggests that the face processing difficulties in autism do resemble those seen in DP.

It is also of interest that many of our autistic participants (30 out of 60; 50%) scored above the cut-off for DP on the PI20. By comparison, far fewer non-autistic participants (12 out of 120; 10%) reached this cut-off. Similar findings have been reported elsewhere (Minio-Paluello et al., 2020; Stantić et al., 2021). The PI20 questionnaire assesses traits associated with DP based on qualitative experiences such as difficulty recognising people when they change their hairstyle or wear hats and challenges following movies due to difficulty recognising characters. The fact that many autistic individuals are scoring above the cut-off suggests that they recognise the experiences described and are responding as though they have DP.

3.8 Chapter summary

The results of our three experiments suggest that autistic individuals are less able to group ambient facial images according to the identities of those depicted than non-autistic individuals. Consistent with recent findings (Stantić et al., 2021) these results indicate that autistic individuals perform poorly on face identification tasks with minimal memory demands, suggestive of impaired face encoding. It has previously been shown that autistic people derive less benefit from facial variability when learning new facial identities (Ipser et al., 2016). The present findings suggest that this may well reflect poor perceptual input into learning mechanisms, not atypical perceptual learning per se.

Chapter 4: Autistic adults have insight into their relative face recognition ability

The research described in this chapter has been published in the following peer-reviewed journal article: Gehdu, B. K., Press, C., Gray, K. L., & Cook, R. (2024). Autistic adults have insight into their relative face recognition ability. *Scientific Reports*, *14*(1), 17802.

4.1 Introduction

Historically, lifelong face recognition difficulties were thought to be extremely rare (H. R. McConachie, 1976). Over the last twenty years, however, there has been growing appreciation that 'congenital' or 'developmental' prosopagnosia is far more common than was once believed (Behrmann & Avidan, 2005; R. Cook & Biotti, 2016; Duchaine & Nakayama, 2006; Wilmer, 2017). Indeed, around 2% of the general population describe lifelong face recognition problems severe enough to disrupt their daily lives (Kennerknecht et al., 2006, 2008). The incidence of lifelong face recognition difficulties is particularly high amongst autistic individuals, many of whom experience problems when asked to identify or match faces (Gehdu et al., 2022; Hedley et al., 2011; Kamensek et al., 2023; Stantić et al., 2021).

Increasing awareness of these difficulties has fuelled the development of tools for the identification and assessment of face recognition impairments. As outlined in **Chapter 1**, one well-known measure is the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006) a standardised objective test of face recognition ability, originally developed to identify cases of DP. On each trial (72 in total), participants are asked to identify recently learned target faces from a line-up of three options (a target and two foils). The addition of view-point changes and high-spatial frequency visual noise increases task difficulty in the later stages. The CFMT has good internal reliability (Duchaine & Nakayama, 2006; McKone et al., 2011)

and correlates well with other measures of face identification, such as the CFPT (Biotti et al., 2019).

A second measure developed to aid the identification of DP is the Twenty Item Prosopagnosia Index (PI20; Gray et al., 2017; Shah et al., 2015; Tsantani et al., 2021). This self-report questionnaire was designed to provide standardised self-report evidence of face recognition difficulties, to complement diagnostic evidence obtained from objective computer-based assessments such as the CFMT. The PI20 comprises 20 statements describing face recognition experiences drawn from qualitative and quantitative descriptions of individuals with lifelong face recognition difficulties. Respondents (typically adults) rate how well each statement describes their own experiences on a 5-point scale. Scores can range from 20 to 100. A score of 65 or higher is thought to indicate the likely presence of face recognition impairment. The PI20, originally written in English, has been translated into multiple languages (e.g., Italian, Portuguese, Danish, Japanese & Mandarin) and applied in various cultural contexts (Estudillo & Wong, 2021; Nørkær et al., 2023; Oishi et al., 2024; Tagliente et al., 2023; Ventura et al., 2018).

The items on the PI20 ask respondents to assess their face recognition ability relative to the rest of the population, either explicitly (e.g., “My face recognition ability is worse than most people”, “I am better than most people at putting a ‘name to a face’”, “I have to try harder than other people to memorize faces”) or implicitly (e.g., “When people change their hairstyle or wear hats, I have problems recognizing them”, “When I was at school, I struggled to recognize my classmates”).

There has been considerable debate about whether participants have the necessary insight into their relative face recognition ability to provide meaningful responses to self-report measures (Arizpe et al., 2019; Bobak et al., 2019; Burns et al., 2023; Matsuyoshi & Watanabe, 2021). However, there is now strong evidence that the PI20 scores of non-autistic participants correlate with their performance on objective measures of face recognition accuracy (Gray et al., 2017; P. Shah, Gaule, et al., 2015; P. Shah, Sowden, et

al., 2015; Tsantani et al., 2021). While participants may lack fine-grained insight into their face recognition ability (e.g., whether they fall within the 45th or 55th percentile), these findings suggest that respondents have enough insight to provide meaningful responses on the PI20, i.e., they appear to have some idea whether their face recognition is impaired or unimpaired.

This may not be true of autistic individuals, however. Minio-Paluello and colleagues (2020) reported that the PI20 scores of autistic adults (N = 63) exhibited little or no correlation with their performance on the CFMT. A similar result was described by Stantić and colleagues (2021). In this study, the authors observed a non-significant correlation of $r = -0.17$ between the PI20 scores of 31 autistic adults and their performance on the CFMT. If found to be robust, these results have important theoretical implications: they raise the possibility that face recognition in autism may be subject to a metacognitive deficit, whereby autistic individuals are unable to infer whether (or not) their face recognition ability is impaired relative to the wider population. There is also an important substantive implication. These results suggest that the PI20 may not be suitable for screening autistic participants for face recognition difficulties. This would be a non-trivial limitation, not least because face recognition difficulties appear to be far more prevalent in the autistic population than in the non-autistic population (Gehdu et al., 2022; Hedley et al., 2011; Kamensek et al., 2023; McKone et al., 2011; Stantić et al., 2021).

There are several reasons to be cautious when interpreting these findings. First, previous research suggests that metacognitive differences in autistic adults, tend to be small and subtle, if observed at all (Carpenter & Williams, 2023). Second, the study described by Stantić et al. (2021) was not designed to examine individual differences. Any conclusions about face recognition variability and correlations therewith, are limited by the relatively small size of the study's autistic sample (N = 31). Correlation estimates obtained with small samples are notoriously unstable (Schönbrodt & Perugini, 2013). Third, both results were obtained using the original version of the CFMT (CFMT-O; Duchaine & Nakayama, 2006).

This version of the CFMT is now easily accessible online; it is hosted by several websites, and various prosopagnosia forums and pop-science resources link to this test.

Consequently, many individuals with face recognition difficulties have attempted the CFMT-O on multiple occasions (Murray & Bate, 2020). Where practice benefits arise, participants may achieve higher scores than might be expected based on their PI20 score.

4.2 Aims of the study

In light of the foregoing observations, we were keen to re-examine the relationship between the PI20 scores and CFMT performance of autistic individuals. To this end, a group of 77 autistic participants completed the PI20 questionnaire and two variants of the CFMT: the original (CFMT-O; Duchaine & Nakayama, 2006) and the Australian (CFMT-A; McKone et al., 2011) versions. The CFMT-O and CFMT-A share an identical format and differ only in terms of the (White male) facial identities used. Unlike the CFMT-O, however, the CFMT-A is not widely available to the members of the general public.

It has been noted previously that the face recognition abilities of autistic participants vary widely (Gehdu et al., 2022; Hedley et al., 2011; Kamensek et al., 2023; Minio-Paluello et al., 2020; Stantić et al., 2021). At present, however, little is known about the nature and origin of this variability. Some of this variance might be explained by differences in autism severity (Keating, Fraser, et al., 2022). However, performance on face processing tasks may also be affected by differences in non-verbal intelligence (Walker et al., 2023) and the presence of co-occurring conditions, notably alexithymia (Bird & Cook, 2013; Gehdu et al., 2023) and attention deficit hyperactivity disorder (ADHD) (Seernani et al., 2021; Thoma et al., 2020). We therefore took this opportunity to explore which of these factors, if any, predicted face recognition performance in our autistic sample.

4.3 Methods

4.3.1 Participants

We recruited seventy-seven participants with a clinical diagnosis of autism (M_{age} = 35.99 years, SD_{age} = 11.60 years) via UK Autism Research. Of the 16 individuals who described their sex as male, 13 described their gender identity as male, 2 identified as non-binary and 1 identified as female. Of the 61 individuals who described their sex as female, 48 described their gender identity as female, 9 identified as non-binary, 1 as male and 3 preferred not to say. All participants reached the cut-off score of 32 on the AQ (Baron-Cohen, Wheelwright, Skinner, et al., 2001).The mean AQ score of participants was 42.45 (*SD* = 4.17).

4.3.2 Measures

The principal aim of the study was to elucidate the relationship between participants' PI20 scores and their performance on the CFMT. To this end, all participants completed the PI20 questionnaire (P. Shah, Gaule, et al., 2015) and two versions of the CFMT: the CFMT-O (Duchaine & Nakayama, 2006) and the CFMT-A (McKone et al., 2011). All participants completed the PI20 before attempting the CFMTs. The PI20, TAS20 and MRT were routinely administered to all participants recruited through Autism Research UK (see **Chapter 2**). A self-report measure of ADHD traits, the Adult ADHD Self-Report Scale (ASRS; Kessler et al., 2005) was also administered in this study.

The ASRS is a self-report questionnaire that assesses the presence of traits associated with inattention, hyperactivity, and impulsivity. The ASRS consists of two parts: Part A is a 6-item screener that has been shown to effectively discriminate clinical cases of adult ADHD from non-cases (Kessler et al., 2007). Each response is scored as either 0 or 1, thus screener scores can range from 0 to 6. A score of 4 or above is thought to be associated with clinically significant levels of ADHD traits. Part B consists of 12 follow-up items that can be used to probe symptomology. Part B was not employed here.

4.3.3 Statistical procedures

The correlational analyses described below (all $\alpha = 0.05$, two-tailed) were conducted using Pearson's r (r_p), and Spearman's rho (r_s). The comparison of autistic subgroups was assessed using independent samples *t*-tests ($\alpha = 0.05$, two-tailed). For each *t*-test, we also provide the associated Bayes factor (BF), calculated in JASP (*JASP Team*, 2022) with default prior width. We interpret BFs of less than 3.0 as anecdotal evidence for the null hypothesis. BFs of greater than 3.0 are treated as substantial evidence for the null hypothesis (Jeffreys, 1961).The data supporting all the analyses described are available via the Open Science Framework (https://osf.io/tesk5/).

4.3.4 Ethics

Ethical clearance was granted by the Departmental Ethics Committee for Psychological Sciences, Birkbeck, University of London and the experiment was conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent before taking part.

4.4 Results

The mean scores obtained for each measure are shown in **Table 4.1**. As expected, we saw a strong correlation between performance on the CFMT-O and CFMT-A ($N = 77$, $r_p = 0.744$, $p < 0.001$), underscoring the good psychometric properties of our two dependent measures. We also observed a number of significant correlations between our predictor variables (see **Table 4.1**). Reassuringly, several of these relationships are predicted by the existing literature (Bird & Cook, 2013; Hours et al., 2022; Leitner, 2014) including the AQ-TAS20 correlation ($N = 77$, $r_p = 0.526$, $p < 0.001$) and the AQ-ASRS correlation ($N = 77$, $r_p = 0.322$, $p = 0.004$). The mean PI20 score ($M = 62.43$) accords well with the mean PI20 score described by Stantić and colleagues (2021) ($M = 63.30$) but is a little higher than that reported by Minio-Paluello and colleagues (2020) ($M = 55.50$).

Table 4.1 Mean performance of the autistic sample on the measures employed in the study and their respective correlations (r_p).

Variable	M (*SD*)	α	1	2	3	4	5	6	7
1. CFMT-O	67.95 (*15.80*)	0.912	-						
2. CFMT-A	70.67 (*15.22*)	0.909	0.744***	-					
3. PI20	62.43 (*20.19*)	0.947	-0.486***	-0.464***	-				
4. AQ	42.45 (*4.17*)	0.699	-0.190	-0.173	0.301**	-			
5. TAS20	67.82 (*12.23*)	0.865	-0.177	-0.252*	0.292**	0.526***	-		
6. MRT	25.32 (*5.95*)	0.817	-0.090	0.001	0.214	-0.089	0.046	-	
7. ASRS	4.21 (*1.67*)	0.680	0.077	0.064	0.267*	0.322**	0.453***	0.090	-

Note. CFMT-O: Cambridge Face Memory Test – Original version. CFMT-A: Cambridge Face Memory Test – Australian version. PI20: Twenty-item Prosopagnosia Index. AQ: Autism-Spectrum Quotient. TAS20: Toronto Alexithymia Scale. MRT: Matrix Reasoning Test. ASRS: Adult ADHD Self-Report Scale. *p < 0.05; **p < 0.01, ***p < 0.001.

4.4.1 Does the autistic sample exhibit poor face recognition?

The present study had two principal aims: first, to establish whether or not the PI20 scores of autistic adults correlate with their CFMT performance. Second, to explore whether differences in non-verbal intelligence and the presence of co-occurring conditions (alexithymia and ADHD) account for the enormous variability in face recognition ability seen in the autistic population. Thus, the focus of our investigation is the variability in face recognition performance observed within the autistic sample. At the outset of our analyses, however, we first sought to evaluate the overall performance of the autistic sample on the CFMT-O (M = 67.95, SD = 15.80) and CFMT-A (M = 70.67, SD = 15.22). For this purpose, we employed comparison data reported by Tsantani et al. (2021). See **Figure 4.1**. These data were obtained from 238 non-autistic individuals (131 females, 104 males, 3 non-binary; M_{age} = 36.56, SD_{age} = 11.72), who completed online versions of the CFMT-O (M = 73.96, SD = 13.77) and CFMT-A (M = 75.37, SD = 12.48) under similar conditions. The participants in this sample were recruited via Prolific. Thirteen of the 238 participants (5.46%) reached the PI20 cut-off score of 65 (M = 44.85, SD = 10.70).

As expected, the scores of the autistic participants in our sample were significantly below those seen in this comparison sample, both for the CFMT-O [t (313) = 3.207, p = 0.001, d = 0.420, BF_{01} = 0.057] and the CFMT-A [t (110.97) = 2.453, p = 0.016, d = 0.356, BF_{01} = 0.221]. Note, for this latter comparison, it was necessary to correct the degrees of freedom because the variance in our autistic sample was greater than that seen in the non-autistic comparison data [F (1, 313) = 5.387, p = 0.021]. The fact that the CFMT scores of our autistic sample tended to be lower than those of the non-autistic comparison sample accords well with the existing literature (Gehdu et al., 2022; Hedley et al., 2011; Kamensek et al., 2023; Stantić et al., 2021). This finding suggests that, in terms of face recognition ability, our autistic sample is broadly comparable with autistic samples described elsewhere.

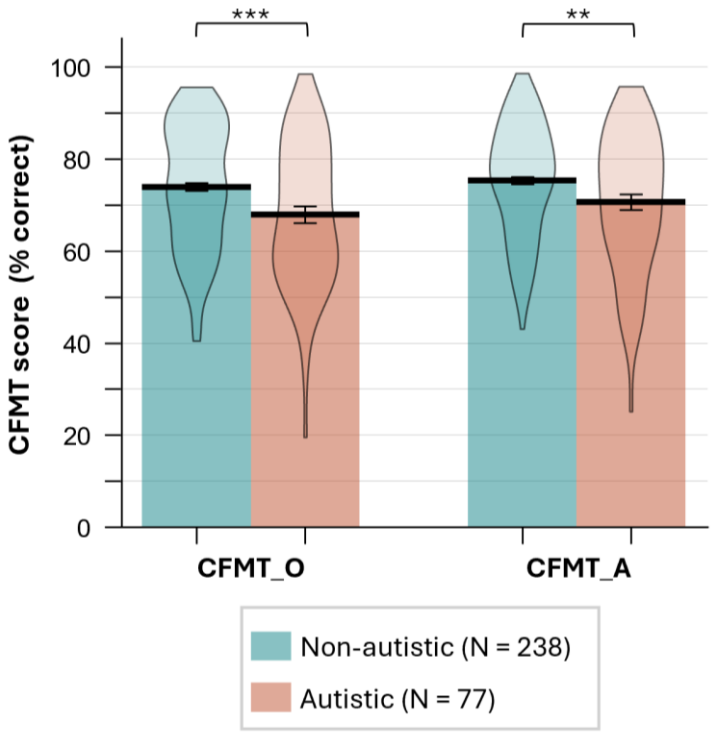

Figure 4.1 Mean performance accuracy (%) on the CFMT-O and CFMT-A for the autistic sample. The non-autistic comparison data illustrated is taken from Tsantani et al. (2021). Bars depict mean performance accuracy. Distribution plots illustrate the spread of accuracy within each group. Error bars ±1SE. **p < 0.01, ***p < 0.001.

4.4.2 Do PI20 scores predict CFMT scores?

Next, we sought to determine whether the PI20 scores of our autistic participants were predictive of their CFMT performance. To begin, we examined the simple correlations between participants' PI20 and CFMT scores. Contrary to the findings of Minio-Paluello et al. (2020) and Stantić et al. (2021) we observed significant correlation between PI20 scores and performance on both the CFMT-O [$N = 77$, $r_p = -0.486$, $p < 0.001$] and CFMT-A [$N = 77$, $r_p = -0.464$, $p < 0.001$] (see **Figure 4.2**). Similar correlations were seen when the raw scores were transformed into ranks for both the CFMT-O [$N = 77$, $r_s = -0.435$, $p < 0.001$] and CFMT-A [$N = 77$, $r_s = -0.469$, $p < 0.001$].

We also conducted a complementary subgroup analysis based on the established PI20 cut-off of 65. We split our sample of 77 autistic participants into those who met the cut-off ($N = 42$, $M_{age} = 37.40$, $SD_{age} = 11.61$) and those who did not ($N = 35$, $M_{age} = 34.29$, $SD_{age} = 11.51$). The autistic participants who met the PI20 cut-off achieved significantly lower scores than those who did not on both the CFMT-O [low-scorers: $M = 76.23$, $SD = 13.59$; high-scorers: $M = 61.04$, $SD = 14.21$; $t(75) = 4.762$, $p < 0.001$, $d = 1.090$, $BF_{01} < 0.001$] and the CFMTA [low-scorers: $M = 77.54$, $SD = 12.60$; high-scorers: $M = 64.95$, $SD = 14.97$; $t(75) = 3.946$, $p < 0.001$, $d = 0.903$, $BF_{01} = 0.007$] (see **Figure 4.3**). Moreover, the autistic participants who met the PI20 cut-off performed worse on the CFMT-O [$t(278) = 5.576$, $p < 0.001$, $d = 0.933$, $BF_{01} < 0.001$] and CFMT-A [$t(278) = 4.835$ $p < 0.001$, $d = 0.809$, $BF_{01} < 0.001$] than the non-autistic participants tested by Tsantani and colleagues (2021) (see **Figure 4.3**). In contrast, the CFMT-O scores [$t(271) = -0.914$, $p = 0.362$, $d = -0.165$, $BF_{01} = 3.556$] and CFMT-A scores [$t(271) = -0.960$, $p = 0.338$, $d = -0.174$, $BF_{01} = 3.419$] of the autistic participants who did not meet the PI20 cut-off did not differ significantly from the comparison distributions described by Tsantani et al. (2021).

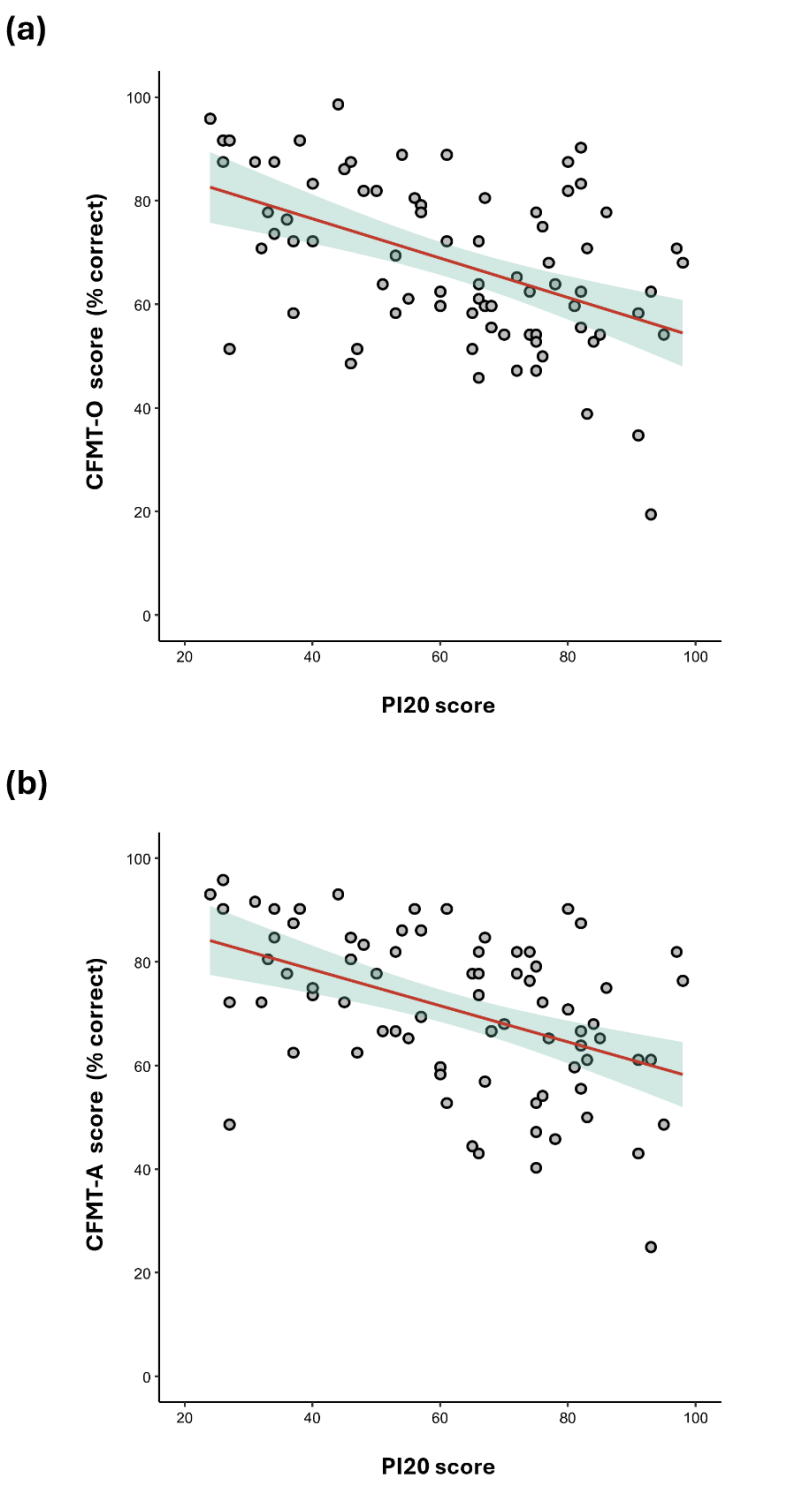

Figure 4.2 Scatterplots of the relationship between PI20 scores and performance on **(a)** the CFMT-O and **(b)** the CFMT-A. The red line represents the linear trend, and the shaded green area shows the 95% confidence interval.

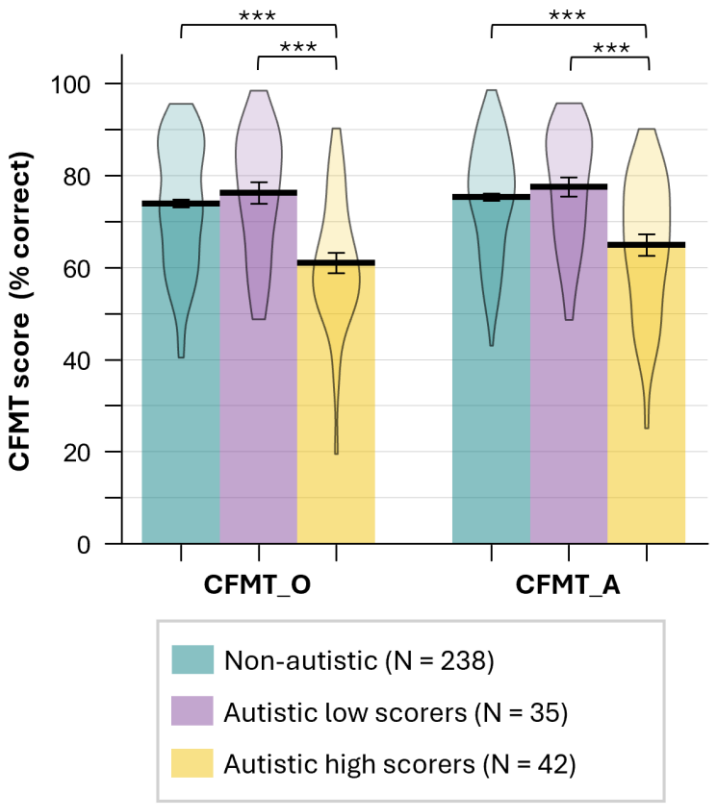

Figure 4.3 Mean performance (% correct) on the CFMT-O and CFMT-A for those autistic participants who reached the PI20 cut-off score (high-scorers) and those who did not (low-scorers). The non-autistic comparison data illustrated is taken from Tsantani et al. (2021). Bars depict mean performance accuracy. Distribution plots illustrate the spread of accuracy within each group. Error bars ±1SE. ***$p < 0.001$.

4.4.3 Do co-occurring alexithymia and ADHD predict face recognition in autism?

Scores on the TAS20—a measure of alexithymia— were negatively correlated with performance on the CFMT-A [$N = 77$, $r_p = -0.252$, $p = 0.027$], indicating that higher levels of reported alexithymic traits were associated with poorer performance. A significant negative correlation was also observed between TAS20 scores and average performance across the CFMT-O and CFMT-A [$N = 77$, $r_p = -0.229$, $p = 0.045$]. However, we failed to observe a significant relationship with CFMT-O scores independently [$N = 77$, $r_p = -0.177$, $p = 0.125$].

We also note that the significant TAS20-CFMT correlations described above do not survive correction for multiple comparisons. No significant correlation was observed between scores on the ASRS—a measure of ADHD traits—and either CFMT-O scores [N = 77, r_p = 0.077, p = 0.504] or CFMT-A scores [N = 77, r_p = 0.064, p = 0.580]. Interestingly, we observed a noteworthy positive correlation between TAS20 and ASRS scores [N = 77, r_p = 0.453, p < 0.001]; i.e., those autistic participants who reported high levels of alexithymic traits also reported higher levels of ADHD traits. See **Figure 4.4**.

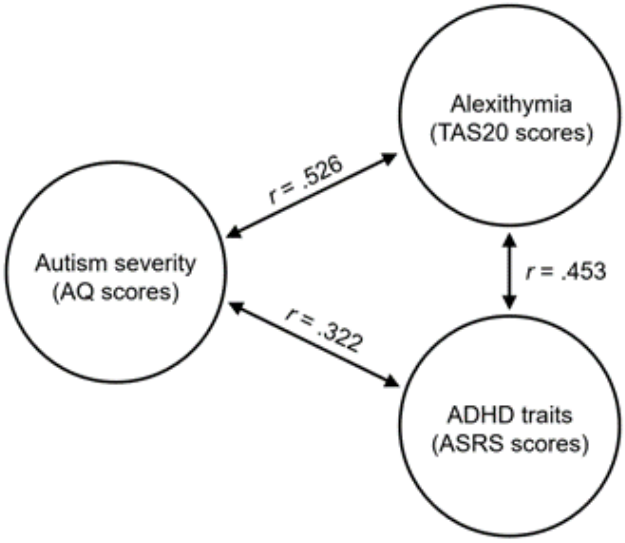

Figure 4.4 Simple correlations observed between autism severity (inferred from scores on the AQ questionnaire), levels of alexithymia (inferred from TAS20 scores), and the presence of ADHD traits (inferred from the ASRS screener). All correlations are significant at p < 0.001 (N = 77).

Like the PI20, both the TAS20 and the ASRS have established cut-offs associated with clinically significant levels of alexithymia and ADHD traits, respectively. We, therefore, examined whether subgroup analyses of TAS20 and ASRS scores would reveal evidence of a predictive relationship with CFMT. Of the 77 autistic participants, 59 met the TAS20 cut-off for clinically significant levels of alexithymia, while 18 did not. Those who met cut-off and those who did not, did not differ in their scores on the CFMT-O [low-scorers: M = 70.22, SD = 14.78; high-scorers: M = 67.26, SD = 16.15; t (75) = 0.694, p = 0.490, d = 0.187, BF_{01} = 3.016] or on the CFMT-A [low-scorers: M = 74.15, SD = 11.32; high-scorers: M = 69.61, SD

= 16.60; t (75) = 1.110, p = 0.271, d = 0.299, BF_{01} = 2.212]. Similarly, 51 autistic participants met the ASRS cut-off for clinically significant ADHD traits, while 26 did not. Once again, there was little sign that CFMT-O scores [low-scorers: M = 66.61, SD = 18.64; high-scorers: M = 68.63, SD = 14.29; t (75) = 0.527, p = 0.600, d = 0.127, BF_{01} = 3.586] or CFMT-A scores [low-scorers: M = 71.53, SD = 16.29; high-scorers: M = 70.23, SD = 14.80; t (75) = 0.351, p = 0.727, d = 0.084, BF_{01} = 3.831] differed across these subgroups.

4.4.4 Is face recognition in autism affected by non-verbal intelligence or autism severity?

No significant correlation was observed between AQ scores and CFMT-O scores [N = 77, r_p = − 0.190, p = 0.098] or between AQ scores and CFMT-A scores [N = 77, r_p = − 0.173, p = 0.131]. Note, however, meeting the AQ cut-off score was part of the study inclusion criteria; hence, all 77 autistic participants had an AQ score of 32 or higher. Similarly, no significant correlation was observed between MRT scores and CFMT-O scores [N = 77, r_p = − 0.090, p = 0.436] or between MRT scores and CFMT-A scores [N= 77, r_p = 0.001, p = 0.992]. In sum, we find no evidence in our data that non-verbal intelligence or autism severity influences the face recognition abilities of autistic participants.

4.5 Discussion

There is now considerable evidence that the PI20 scores of non-autistic participants correlate with their performance on objective measures of face recognition accuracy (Gray et al., 2017; P. Shah, Sowden, et al., 2015, 2015; Tsantani et al., 2021). These findings suggest that respondents have enough insight into their relative face recognition ability to provide meaningful responses on the PI20. Recently, however, Minio-Paluello et al. (2020),reported that the PI20 scores of autistic participants (N = 66) exhibited little or no correlation with their performance on the CFMT. A similar finding was described by Stantić et al. (2021), albeit with a smaller sample (N = 31). These reports are potentially important because they suggest the possibility that autistic individuals may experience a metacognitive deficit,

whereby they are unable to infer whether (or not) their face recognition ability is impaired. Moreover, these results raise the possibility that the PI20 may be unsuitable for screening autistic participants for face recognition difficulties.

Contrary to these reports, however, we find clear evidence of association between the PI20 scores of autistic participants (N = 77) and their performance on the CFMT-O and the CFMT-A. This association was evident both in simple correlation analyses, and in subgroup analyses where the autistic sample was split into those who met the established cut-off for DP and those who did not. The mean score of those autistic participants who met cut-off was ~ 15% and ~ 12.5% lower than those that did not, on the CFMT-O and CFMTA, respectively. Indeed, those autistic participants who did not meet the PI20 cut-off exhibited similar levels of performance to a non-autistic comparison sample described previously (Tsantani et al., 2021). Together, these analyses provide clear evidence that the PI20 scores of autistic participants predict their CFMT performance.

4.5.1 Explanations for the lack of association between PI20 and CFMT scores in previous reports

The most likely explanation for the failure of Stantić et al. (2021), to detect a correlation between scores on the PI20 and the CFMT is the relatively small size of their autistic group (N = 31). As mentioned in the introduction, (1) this study was not designed to examine the individual differences seen within the autistic population, and (2) correlation estimates obtained with small samples are notoriously unstable (Schönbrodt & Perugini, 2013). Post-hoc power analysis indicates there is a 38% chance of failing to detect a significant correlation of r = 0.40 with a sample of this size (α = 0.05, two-tailed).

Assuming the authors scored the PI20 correctly, the null correlation described by Minio-Paluello et al.(2020) is harder to explain. One relevant factor may be the wide range of general cognitive abilities present in their autistic sample (N = 63). As a self-report scale, the PI20 has relatively high verbal demands potentially making it unsuitable for individuals with

intellectual disability. Moreover, five of the twenty items are reverse scored. Respondents must, therefore, read individual items carefully to respond appropriately. If some of the participants tested by Minio-Paluello et al. (2020) struggled to interpret scale items, and were unable to respond appropriately, this might also explain why the mean PI20 score was lower than that reported here and elsewhere (Stantić et al., 2021).

4.5.2 What does the variability within our autistic sample suggest about face recognition problems within this population?

It is now beyond doubt that the face recognition abilities of autistic participants vary enormously (Gehdu et al., 2022; Hedley et al., 2011; Kamensek et al., 2023; P. Shah, Sowden, et al., 2015; Stantić et al., 2021). Like **Chapter 3**, we saw evidence of this variability in our sample. On the one hand, 13 of our 77 autistic participants (16.90%) scored 65 or higher on the PI20 and scored less than 60% on both versions of the CFMT. These individuals would meet the diagnostic criteria for DP employed by the vast majority of research groups (Duchaine & Nakayama, 2006; Tsantani, Gray, et al., 2022). On the other hand, 10 of the 77 autistic participants (13.0%) scored 85% or higher on both tests, suggestive of excellent face recognition (McKone et al., 2011; Tsantani et al., 2021).

There was little sign in our data that variability in face recognition ability is attributable to differences in non-verbal intelligence (as measured by MRT score), autism severity (as measured by AQ score), or the presence co-occurring ADHD traits (as measured by ASRS score). There was some hint of a potential relationship between the presence of co-occurring alexithymia and face recognition ability: TAS20 scores were negatively correlated with performance on the CFMT-A and with average CFMT performance. However, TAS20 scores did not exhibit significant correlation with CFMT-O scores independently, and the foregoing correlations do not survive correction for multiple-comparisons.

In order to better understand this variability, as outlined in **Chapter 3**, we favour the view that, like alexithymia and ADHD, DP is a neurodevelopmental condition that can occur

independently of autism but that also frequently co-occurs with autism (R. Cook & Biotti, 2016; Gehdu et al., 2022; Gray & Cook, 2018; Kracke, 1994). This view not only accounts for the severe lifelong face recognition problems seen in some autistic individuals, but also explains why many other autistic individuals exhibit excellent face recognition. Moreover, this account accords with the prevailing view that the co-occurrence of neurodevelopmental conditions is the 'norm' rather than the exception (Bird & Cook, 2013; Conti-Ramsden et al., 2006; Dziuk et al., 2007; Gilger & Kaplan, 2001; Hours et al., 2022; Leitner, 2014). Given what we know about neurodevelopmental conditions more broadly, it would be hugely surprising if the incidence of DP was not elevated in the autistic population.

Recently, some authors have rejected this account citing evidence that autistic samples still exhibit below average face recognition when those who meet the diagnostic criteria for prosopagnosia are removed (Kamensek et al., 2023). However, this critique overlooks two issues. First, diagnostic assessments for DP are imperfect (Burns et al., 2023). Many autistic individuals with severe co-occurring prosopagnosia may fail to meet diagnostic thresholds simply because of measurement error. Second, the severity of DP is thought to vary (DeGutis et al., 2023). While some autistic individuals may experience severe DP, others may experience relatively mild forms. These latter individuals may fail to meet conservative diagnostic criteria for DP but still exhibit below-average face recognition.

While it was not the focus of our study, we observed a striking correlation between the presence of alexithymia and ADHD traits in our autistic participants. The fact that those autistic participants who report high levels of alexithymia also tend to report high levels of ADHD traits is potentially significant for understanding social cognitive differences in autism. In recent years, there has been increasing suggestion that many social perception difficulties traditionally attributed to autism—such as atypical interpretation of facial expressions (R. Cook et al., 2013; Gehdu et al., 2023) and reduced eye-region fixations (Bird et al., 2011; Cuve et al., 2021; Tanaka & Sung, 2016) may actually be products of co-occurring alexithymia. Likewise, there is some suggestion that other socio-cognitive differences

attributed to autism, for example, atypical attentional cueing by gaze direction (Seernani et al., 2021) may be partly attributable to co-occurring ADHD. To date, however, authors have tended to assess the presence of either co-occurring alexithymia or co-occurring ADHD. In future research, it may prove valuable to establish the extent to which these constructs exert independent or interactive effects in these domains.

4.6 Chapter summary

Contrary to recent reports, we observed a significant correlation between PI20 scores and performance on both the CFMT-O and CFMT-A in autistic adults. This finding indicates that autistic individuals are able to infer whether (or not) their face recognition ability is impaired and confirms that the PI20 can be used to screen autistic participants for face recognition difficulties. Consistent with previous research, the face recognition performance within our autistic sample varied considerably. While some individuals approached ceiling levels of recognition accuracy, others met the prevailing diagnostic criteria for DP. This variability showed little or no association with non-verbal intelligence, autism severity, or the presence of co-occurring alexithymia or ADHD.

Chapter 5: The role of alexithymia in facial expression recognition in autism

The research described in this chapter has been published in the following peer-reviewed journal article: Gehdu, B. K., Tsantani, M., Press, C., Gray, K. L., & Cook, R. (2023). Recognition of facial expressions in autism: Effects of face masks and alexithymia. *Quarterly Journal of Experimental Psychology*, *76*(12), 2854-2864.

5.1 Introduction

There is considerable interest in the ability of autistic individuals to interpret facial expressions (for reviews, see Harms et al., 2010; Uljarevic & Hamilton, 2013). In neurotypical populations, facial expressions are considered to be a key form of non-verbal communication that can be used to infer someone's emotional state and likely intentions (Adolphs, 2002; Frith, 2009). As such, the accurate recognition of expressions is important for the development of mentalizing and wider mechanisms of social cognition. Where observed, poor expression recognition may hinder social interaction and the development of complex mentalizing abilities (Frith & Frith, 2006).

Many studies have sought to compare the expression recognition of autistic participants with samples of matched non-autistic controls drawn from the general population (Harms et al., 2010; Uljarevic & Hamilton, 2013).However, the findings described are inconsistent. Some results suggest that autistic individuals exhibit broadly typical expression recognition (Adolphs et al., 2001; Brewer et al., 2017; Castelli, 2005; Neumann et al., 2006) while others suggest that expression recognition may be impaired (Ashwin et al., 2006; Humphreys et al., 2007; Loth et al., 2018).

In principle, there are several possible reasons for these inconsistent findings, including differences in participant age and methodology (Harms et al., 2010). Similarly, differences in the diagnostic criteria employed mean that participants' verbal and social abilities may vary

between studies. However, one suggestion that has received considerable attention is the possibility that subgroups exist within the autistic population that possess different cognitive and perceptual profiles (Happé et al., 2006; Happé & Ronald, 2008). In particular, there is growing interest in the possibility that autistic individuals with and without co-occurring alexithymia differ in their expression recognition ability (R. Cook et al., 2013; Keating, Fraser, et al., 2022; Oakley et al., 2016; Ola & Gullon-Scott, 2020). Alexithymia is a trait associated with difficulties interpreting interoceptive (e.g., hunger, thirst, warmth) and emotional (e.g., happiness, anger, disgust) states (Brewer, Cook, et al., 2016; Brewer et al., 2015). High levels of alexithymia is also associated with impaired recognition and description of others' facial affect (Grynberg et al., 2012; Parker et al., 1993).

Importantly, high levels of alexithymia are much more common in the autistic population than in the general population (Bird & Cook, 2013; Kinnaird et al., 2019). Only ~5% of the general population describes high levels of alexithymia (Kinnaird et al., 2019). In contrast, high levels of alexithymia may be seen in ~50% of autistic individuals (Kinnaird et al., 2019). Indeed, in a large sample of female autistic individuals, more than 70% met the cut-off for high levels of alexithymia (Ola & Gullon-Scott, 2020).

According to the alexithymia hypothesis, expression recognition difficulties in autistic individuals are attributable to co-occurring alexithymia, not autism per se (Bird & Cook, 2013; R. Cook et al., 2013). In other words, only those autistic individuals with high levels of co-occurring alexithymia are thought to exhibit poor expression recognition. This account potentially explains the inconsistent reports of impaired expression recognition in autism. Autistic samples that contain high numbers of high-alexithymic autistic participants may exhibit below-average expression recognition at the group level. Conversely, autistic samples that contain relatively low numbers of high-alexithymic autistic participants may exhibit similar performance to samples drawn from the general population.

Evidence in support of the alexithymia hypothesis is mounting. Autistic individuals with high levels of alexithymia have more difficulty categorising both static (Milosavljevic et al., 2016)

and dynamic (Ola & Gullon-Scott, 2020) facial expressions compared to those with low levels of alexithymia. In mixed samples of autistic and non-autistic participants, alexithymia severity strongly predicts the ability to classify static (R. Cook et al., 2013; Oakley et al., 2016) and dynamic (Keating, Fraser, et al., 2022) expression stimuli.

5.2 Aims of the study

There is now considerable evidence that levels of co-occurring alexithymia affect expression recognition in samples of autistic participants (R. Cook et al., 2013; Keating, Fraser, et al., 2022; Oakley et al., 2016; Ola & Gullon-Scott, 2020). In light of these findings, a key question is whether there is any association between autism and expression recognition ability once the influence of alexithymia is accounted for—whether there is an independent effect of autism per se (Keating, Fraser, et al., 2022).

In the present study, we sought to address the possibility that the respective contributions of autism and alexithymia depend on the type of stimuli being judged, and as a result, a unique contribution of autism may have been overlooked in the existing literature. When viewing faces, autistic individuals are thought to fixate less on the eye-region than non-autistic individuals, but exhibit typical or heightened interest in the mouth-region (Dalton et al., 2005; Spezio, Huang, et al., 2007). It has been suggested that autistic individuals may find the eye-region socially threatening and thus exhibit a different pattern of fixation behaviour from non-autistic individuals (Tanaka & Sung, 2016).These findings raise the possibility that autistic individuals may be more reliant on information from the mouth-region when judging facial expressions. For example, they may develop particular expertise that aids the detection, encoding, and interpretation of mouth cues, but fail to develop equivalent expertise for eye-region cues. If correct, autistic participants may be at a particular disadvantage when forced to base expression judgements on the eye-region alone (i.e., where the rest of the face is occluded). Thus, it may be easier to detect expression recognition deficits attributable to autism—and not alexithymia—when participants must focus on the eye-region.

Consistent with this suggestion, several studies have found that autistic participants tend to achieve lower scores on the Reading the Mind in the Eyes Test (RMET; Baron-Cohen et al., 2001) than non-autistic participants (Baron-Cohen, Wheelwright, Hill, et al., 2001; Golan et al., 2007; Kirchner et al., 2011; Wilson et al., 2014). In this task, participants view cropped expressive eye-region stimuli and must identify the most appropriate verbal label (e.g., Serious, Ashamed, Alarmed or Bewildered; Reflective, Aghast, Irritated, or Impatient). The verbal and mentalizing demands of the RMET may be higher than most expression recognition tasks used in this field (Peñuelas-Calvo et al., 2019). Nevertheless, these findings accord with the view that autistic participants have difficulty detecting and interpreting expression cues from the eye-region.

In the present study, we compared the ability of 66 autistic participants (46 with and 20 without high levels of co-occurring alexithymia) and 66 matched non-autistic controls to categorise facial expressions in an eyes-only condition and in a whole-face condition. In the eyes-only condition, expression stimuli were presented with a surgical mask occluding the mouth-region. This allowed us to occlude expression signals from the mouth and nose region of our stimuli, while retaining a naturalistic appearance. In the whole-face condition, participants judged the same expression stimuli but without any occlusion (see **5.3 Methods, Figure 5.1** for details of the task).

Several studies of the alexithymia hypothesis have previously employed non-autistic control groups that were matched for alexithymia (R. Cook et al., 2013; Oakley et al., 2016). These control groups include individuals who are recruited because they describe high levels of alexithymia, but who have not been diagnosed with a psychiatric condition prior to the study. In this design, the alexithymia hypothesis predicts that the autistic and non-autistic groups will exhibit similar levels of expression recognition. Our approach was different: we sought to compare the expression recognition of autistic individuals (with and without co-occurring alexithymia) against a representative control group drawn from the general population. According to the alexithymia hypothesis, some studies find evidence of expression

recognition deficits in autism, while others do not, because of differences in the levels of co-occurring alexithymia present in autistic samples (Bird & Cook, 2013). Crucially, the inconsistent results that the alexithymia hypothesis seeks to explain are typically obtained using samples of non-autistic controls drawn from the general population (i.e., the levels of alexithymia within these samples were not manipulated).

Thus, a key assumption of the alexithymia hypothesis is that high-alexithymic autistic participants—but not low-alexithymic autistic participants—exhibit impaired expression categorisation relative to representative samples of non-autistic participants drawn from the general population. By comparing the performance of high-alexithymic autistic participants and low-alexithymic autistic participants with a sample drawn from the general population, we sought to test this critical assumption.

5.3 Methods

5.3.1 Participants

We recruited as many autistic participants as possible via UK Autism Research. Once we knew the size and profile of the autistic sample, we recruited a matched sample of non-autistic controls via Prolific. All participants were required to be current UK residents and to have remained in the UK throughout the COVID-19 pandemic. This requirement ensured that all participants had similar experiences of the COVID-19 pandemic and the use of face masks, which were used in our experimental stimuli.

Sixty-six participants with a clinical diagnosis of autism (M_{age} = 33.09 years, SD_{age} = 11.14 years) were recruited for the study. Of the 23 individuals who described their sex as male, 18 described their gender identity as male, 4 identified as non-binary, and 1 identified as female. Of the 43 individuals who described their sex as female, 33 described their gender identity as female, 9 identified as non-binary, and 1 identified as male. All participants in the autistic group also reached the cut-off (a score of 32) on the AQ questionnaire (Baron-Cohen et al., 2001). The mean AQ score of the autistic group was 41.23 (*SD* = 4.59).

Sixty-six non-autistic individuals (M_{age} = 32.89 years, SD_{age} = 9.54 years) were recruited to serve as controls. Of the 66 participants in the non-autistic group, 23 described their sex and gender identity as male and 43 described their sex and gender identity as female. All non-autistic participants scored below the cut-off (a score of 31 or less) on the AQ. The mean AQ score of the non-autistic group was 17.21 (*SD* = 7.21).

The autistic and non-autistic participants did not differ significantly in terms of participants' age [t (130) = 0.109, p = 0.913] or sex [$X^2_{(1)}$ = 0.000, p = 1.000]. However, the groups did differ in terms of participants' gender identity [$X^2_{(2)}$ = 14.433, p < 0.001]. As expected, the autistic (*M* = 41.23, *SD* = 4.59) and non-autistic (*M* = 17.21, *SD* = 7.21) groups differed in their AQ scores [t (130) = 22.82, p < 0.001]. Both groups were also matched on levels of non-verbal abstract reasoning. Scores on the MRT did not differ significantly between autistic participants (*M* = 25.59, *SD* = 5.63) and the non-autistic controls (*M* = 24.36, *SD* = 5.66) [t (130) = 1.249, p = 0.214]. For a detailed outline of the MRT, see **Chapter 2**.

The presence of alexithymia was assessed in all participants using the TAS20 (Bagby et al., 1994; Taylor et al., 2003). The TAS20 scores of the autistic participants (*M* = 65.50, *SD* = 12.75) were significantly higher than those of the non-autistic controls (*M* = 43.18, *SD* = 11.61) [t (130) = 10.517, p < 0.001]. Of the 66 autistic participants, 46 (69.70%) reached the cut-off (⩾61) for high levels of alexithymia. Of the 66 non-autistic participants, 6 (9.10%) reached this cut-off. Based on participants' TAS20 score, we split the autistic group into two subgroups: low-alexithymic autistic individuals and high-alexithymic autistic individuals. The details of the two subgroups are shown in **Table 5.1**.

Table 5.1 Detailed breakdown and comparison of the low-alexithymic autistic and high-alexithymic autistic subgroups. Information from the non-autistic control group is provided for context only.

	Low-alexithymic (*N* = 20)	**High-alexithymic (*N* = 46)**	**Difference**	**Non-autistic (*N* = 66)**
Age	31.50 (*10.45*)	33.78 (*11.46*)	$p > 0.40$	32.89 (*9.54*)
Sex	8 male	15 male	$p > 0.50$	23 male
	12 female	31 female		43 female
Gender identity	5 male	14 male	$p > 0.70$	23 male
	10 female	24 female		43 female
	5 non-binary	8 non-binary		
AQ	39.85 (*3.93*)	41.83 (*4.80*)	$p > 0.10$	17.21 (*7.21*)
MRT	25.60 (*5.52*)	25.59 (*5.73*)	$p > 0.90$	24.36 (*5.66*)
TAS20	50.05 (*8.06*)	72.22 (*7.42*)	$p > 0.001$	43.18 (*11.61*)

Note. AQ: Autism Spectrum Quotient; MRT: Matrix Reasoning Task; TAS20: Twenty-item Toronto Alexithymia Scale. Standard deviations are shown in parentheses.

The non-autistic and low-alexithymic autistic participants did not differ significantly in terms of age [t (84) = 0.560, p = 0.577] sex [$X^2_{(1)}$ = 0.177, p = 0.674] or visuospatial non-verbal reasoning ability [t (84) = 0.860, p = 0.392]. However, the groups did differ in terms of gender identity [$X^2_{(2)}$ = 17.53, p < 0.001]. Participants further differed significantly in terms of AQ [t (84) = 13.44, p < 0.001] and TAS scores [t (84) = 2.467, p = 0.016] with low-alexithymic autistic participants scoring higher on both measures. The non-autistic group did not differ significantly from the high-alexithymic autistic group in terms of age [t (110) = 0.446, p = 0.656] sex [$X^2_{(1)}$ = 0.061, p = 0.805] or visuospatial non-verbal reasoning ability [t (110) = 1.116, p = 0.266]. Once again, however, the groups differed in gender identity [$X^2_{(2)}$ = 12.401, p = 0.002]. As expected, the groups also differed significantly in terms of AQ [t (110) = 20.217, p < 0.001] and TAS scores [t (110) = 14.958, p < 0.001] with the high-alexithymic autistic group scoring higher on both measures.

5.3.2 Experimental Task

The Facial expression recognition task employed was developed by Tsantani et al. (2022). Face stimuli were obtained from the Radboud Faces Database (Langner et al., 2010). Masked versions were created by superimposing surgical-type masks over the nose and mouth using Adobe Photoshop (see **Figure 5.1a**).

Participants viewed 10 identities (5 female, 5 male), each posing 7 facial expressions: neutral, happy, sad, angry, fearful, disgusted, and surprised. Each expression stimulus was presented twice: once wearing a face mask and once without a mask. In total, participants completed 140 trials (10 identities × 7 expressions × 2 viewing condition) in a random order. Images appeared 4.8 cm × 7 cm on participants' displays. Trials began with a fixation cross (1,000 ms) followed by a face image presented for 500 ms (see **Figure 5.1b**). The stimulus image was replaced by a mask constructed of high-contrast greyscale ovals (500 ms), followed by a response screen on which participants selected one of seven response options (neutral, happy, sad, angry, fearful, disgusted, surprised). There was no time limit on participants' responses. The experiment was conducted online using Gorilla Experiment Builder (A. L. Anwyl-Irvine et al., 2020). The experimental task is available as Open Materials at gorilla.sc (https://app.gorilla.sc/openmaterials/276504).

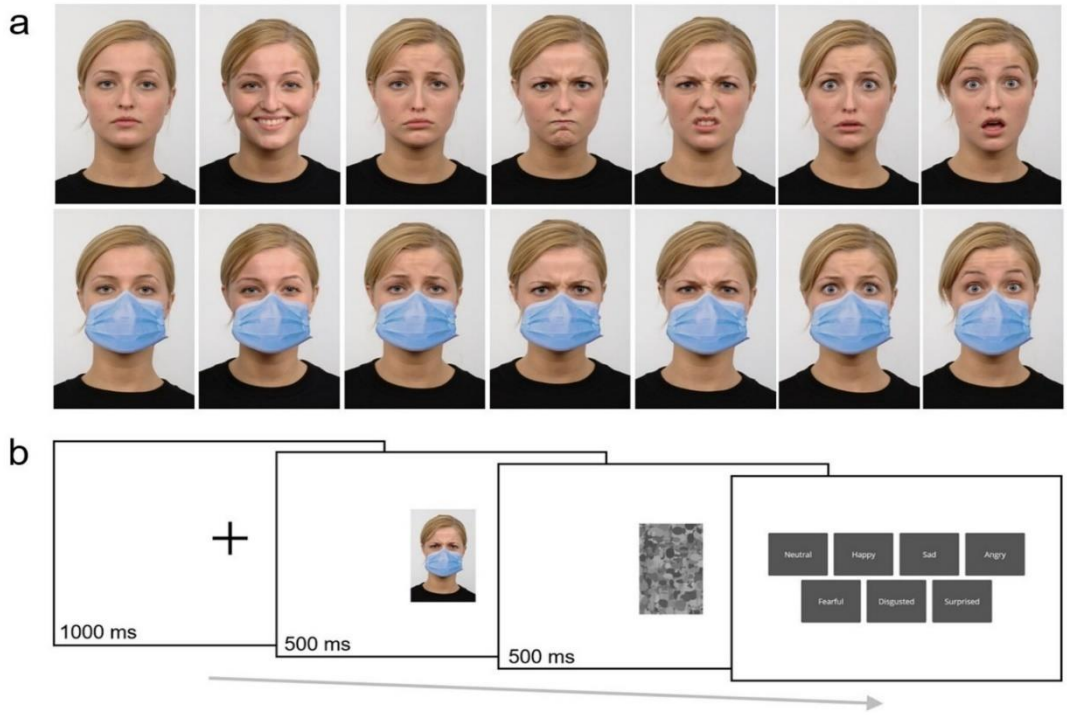

Figure 5.1 Schematic overview of the Facial expression recognition task. **(a)** Example stimuli from the experimental task. The original images were sourced from the Radboud Face Database (Langner et al., 2010). **(b)** Illustration of a trial sequence.

5.3.3 Statistical procedures

In both studies, participants' emotion recognition performance was evaluated using ANOVA and *t*-tests (α = 0.05, two-tailed). For the ANOVAs, we report partial eta squared (η_p^2) as a measure of effect size. For the paired samples *t*-tests, we report Cohen's *d,* calculated by dividing the mean pairwise difference by the standard deviation of the pairwise differences. For the independent samples *t*-tests, we report Cohen's *d*, calculated by dividing the difference between the group means by the pooled standard deviation. All comparisons were planned. Unless otherwise stated, comparisons survive Bonferroni correction. For each *t*-test, we also provide the associated Bayes factor (BF), calculated in JASP (JASP Team, 2022) with default prior width. We interpret BFs of less than 3.0 as anecdotal evidence for the null hypothesis. BFs of greater than 3.0 are treated as substantial evidence for the null hypothesis (Jeffreys, 1961).

5.3.4 Ethics

Ethical clearance was granted by the Departmental Ethics Committee for Psychological Sciences, Birkbeck, University of London and the experiment was conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent before taking part.

5.4 Results

We computed separate performance measures (% correct) for each participant for the unmasked and masked conditions. The mean performance of the autistic and non-autistic participants in the two viewing conditions is shown in **Table 5.2, Figures 5.2 and 5.3**. The supporting data are available via the Open Science Framework (https://osf.io/axc4s/).

The results described below are calculated using the entire control group (*N* = 66), including the six non-autistic participants who reached cut-off for high levels of alexithymia. We opted to retain these individuals to ensure that our sample of non-autistic controls remained representative of the general population (i.e., the levels of alexithymia within the control group were not manipulated). A virtually identical pattern of results was obtained when these individuals were removed from the control group.

Table 5.2 The mean performance of the autistic and non-autistic participants in the unmasked and masked conditions of the Facial expression recognition task.

	Unmasked	**Masked**
Non-autistic (*N* = 66)	84.26% (*7.54%*)	63.68% (*7.03%*)
Autistic (*N* = 66)	79.13% (*11.20%*)	56.49% (*13.92%*)
Low-alexithymic autistic (*N* = 20)	83.79% (*7.55%*)	63.64% (*8.66%*)
High-alexithymic autistic (*N* = 46)	77.11% (*11.98%*)	53.39% (*14.58%*)

Note. Standard deviations are shown in parentheses.

5.4.1 Traditional group analysis

To begin with, the accuracy scores were analysed using ANOVA with Viewing Condition (unmasked, masked) as a within-subjects factor and Group (non-autistic, autistic) as a

between-subjects factor (see **Figure 5.2** for mean recognition accuracy across both groups). This first analysis reflects the traditional approach of combining low-alexithymic and high-alexithymic autistic individuals in a single “autistic” group.

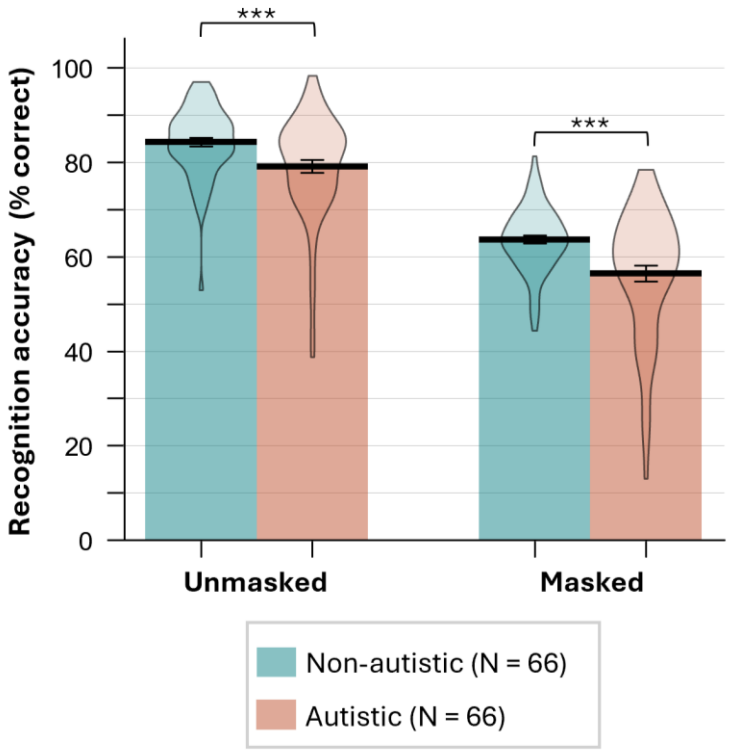

Figure 5.2 Mean recognition accuracy (% correct) performance on the Facial expression recognition task between the non-autistic and autistic groups. Bars depict mean performance accuracy. Distribution plots illustrate the spread of accuracy within each group. Error bars ±1SE. ***$p < 0.001$.

We observed a significant main effect of Group [F (1,130) = 14.585, $p < 0.001$, $\eta_p^2 = 0.101$] whereby the non-autistic controls were more accurate than the autistic participants, and a significant main effect of Viewing Condition [F (1,130) = 747.764, $p < 0.001$, $\eta_p^2 = 0.852$] whereby participants were more accurate in the unmasked condition. We observed no Group × Viewing Condition interaction [F (1,130) = 1.692, $p = 0.196$, $\eta_p^2 = 0.013$]. The accuracy scores of the autistic participants were significantly lower than those of the non-autistic participants in both the unmasked condition [t (130) = 3.086, $p < 0.001$, $d = 0.537$, $BF_{01} = 0.077$] and the masked condition [t (130) = 3.743, $p < 0.001$, $d = 0.652$, $BF_{01} = 0.011$].

5.4.2 Alexithymia subgroup analysis

Next, the accuracy scores were analysed using ANOVA with Viewing Condition (unmasked, masked) as a within-subjects factors and Group (non-autistic, high-alexithymic autistic, low-alexithymic autistic) as a between-subjects factors (see **Figure 5.3** for mean recognition accuracy across the autistic subgroups and the non-autistic group). This analysis examined the possibility that autistic individuals with and without high levels of alexithymia might differ in their expression recognition ability.

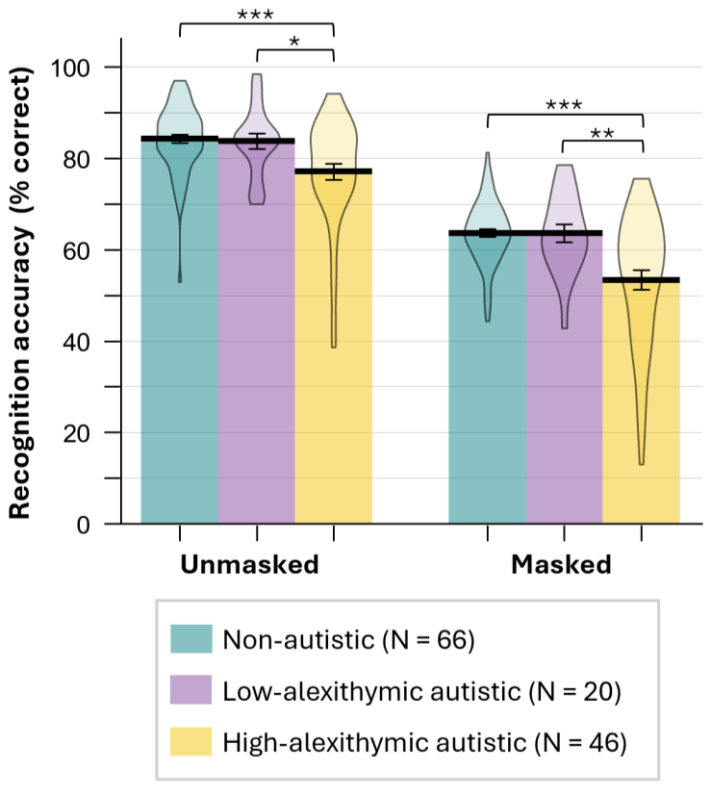

Figure 5.3 Mean recognition accuracy (% correct) performance on the Facial expression recognition task between the low-alexithymic and high-alexithymic autistic subgroups and in relation to the non-autistic group. Bars depict mean performance accuracy. Distribution plots illustrate the spread of accuracy within each group. Error bars ±1SE. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

We observed a significant main effect of Group [F (2, 129) = 14.294, $p < 0.001$, $\eta_p^2 = 0.181$] and a significant main effect of Viewing Condition [F (2, 129) = 585.149, $p < 0.001$, $\eta_p^2 = 0.819$]. Once again, there was no Group × Viewing Condition interaction [F (2, 129) = 1.949,

$p = 0.147$, $\eta_p^2 = 0.029$]. The non-autistic and low-alexithymic autistic groups did not differ in their categorisation accuracy in either the unmasked condition [t (84) = 0.248, $p = 0.804$, d = 0.063, $BF_{01} = 3.749$] or in the masked condition [t (84) = 0.019, $p = 0.985$, $d = 0.005$, BF_{01} = 3.847]. However, the accuracy scores of the high-alexithymic autistic participants were significantly below those of the non-autistic controls in both the unmasked condition [t (110) = 3.876, $p < 0.001$, d =.745, $BF_{01} = 0.008$] and in the masked condition [t (110) = 4.946, $p <$ 0.001, $d = 0.950$, $BF_{01} < 0.001$]. The accuracy scores of the high-alexithymic autistic participants were also significantly below those of the low-alexithymic autistic individuals in both the unmasked condition [t (64) = 2.296, $p = 0.025$, $d = 0.615$, $BF_{01} = 0.429$] and in the masked condition [t (64) = 2.904, $p = 0.005$, $d = 0.778$, $BF_{01} = 0.123$]. However, the difference between the high-alexithymic and low-alexithymic autistic participants in the unmasked condition does not survive Bonferroni correction.

The above results suggest that the low-alexithymic autistic participants and the non-autistic controls did not differ in their expression recognition in either the masked or unmasked conditions. The interpretation of these null results is complicated by the fact that 46 of our 66 autistic participants reached the cut-off for high levels of alexithymia. As such, we have more statistical power to detect differences in the high-alexithymic group than in the low-alexithymic group. Nevertheless, the Bayesian analyses (BFs > 3.0) provide statistical evidence for the null hypothesis—that the expression categorisation accuracy of low-alexithymic autistic participants and non-autistic controls does not differ.

5.5 Discussion

There has been great interest in whether the recognition of facial expression is impaired in autism (Harms et al., 2010; Uljarevic & Hamilton, 2013). To date, however, the literature is inconsistent. While some studies suggest that autistic and non-autistic participants show similar levels of expression recognition (Adolphs et al., 2001; Brewer et al., 2017; Castelli,

2005; Neumann et al., 2006) other findings suggest that autistic participants are less able to categorise facial affect (Ashwin et al., 2006; Humphreys et al., 2007; Loth et al., 2018).

The alexithymia hypothesis offers an explanation for these equivocal findings (Bird & Cook, 2013). According to this account, reports of impaired expression recognition in autism are attributable to co-occurring alexithymia—a trait that (a) occurs with higher incidence in the autistic population than in the general population (Kinnaird et al., 2019) and (b) is associated with expression recognition difficulties (Grynberg et al., 2012). Samples that contain a high proportion of high-alexithymic autistic individuals may be more likely to exhibit poor expression recognition at the group level than samples with a low proportion of high-alexithymic autistic individuals (Bird & Cook, 2013).

Consistent with the alexithymia hypothesis, there is mounting evidence that differences in alexithymia are predictive of poor expression recognition in autistic participants (Milosavljevic et al., 2016; Ola & Gullon-Scott, 2020) and in pooled samples of autistic and non-autistic participants (Bird & Cook, 2013; Keating, Fraser, et al., 2022; Oakley et al., 2016). To date, however, it remains unclear if or how the respective contributions of autism and alexithymia vary according to the type of expression stimuli being judged. As a result, a unique contribution of autism may have been overlooked in the existing literature.

It has been argued that autistic individuals may exhibit particular problems when required to make perceptual decisions about the eye-region (Tanaka & Sung, 2016).When viewing faces, they are thought to fixate less on the eye-region than non-autistic individuals, but exhibit typical or heightened interest in the mouth-region (Dalton et al., 2005; Spezio, Adolphs, et al., 2007a). Autistic individuals may therefore develop expertise that aids the detection and interpretation of mouth cues but fail to develop equivalent expertise for the eye-region. If this view is correct, expression recognition deficits attributable to autism—not alexithymia—may be easier to detect when participants are forced to base their judgements on the eye-region. To test this possibility, we asked 66 autistic participants (46 with and 20 without high levels of co-occurring alexithymia) and 66 non-autistic controls to categorise

facial expressions when the whole face was visible, and when the lower portion of the face was covered with a surgical mask.

When high-alexithymic autistic and low-alexithymic autistic participants were combined in a single autistic sample, we found evidence for a modest expression recognition deficit at the group level—on average, the autistic participants were less accurate than the non-autistic controls. However, analysis of the two subgroups revealed a more nuanced picture. The high-alexithymic autistic participants showed clear evidence of expression recognition difficulties: they correctly identified fewer expressions than both the low-alexithymic autistic individuals and the non-autistic controls. In contrast, the low-alexithymic autistic individuals were unimpaired relative to the nonautistic controls. Importantly, the same pattern of results was seen when judging the whole face (unmasked condition) and just the eye-region (masked condition). We observed no evidence that autistic participants—either those with or without high levels of alexithymia—were disproportionately impaired when basing decisions on the eye-region alone.

These results provide important new evidence for the alexithymia hypothesis. The fact that high-alexithymic autistic individuals showed expression recognition impairment, while low-alexithymic autistic individuals did not, suggests that these difficulties are attributable to alexithymia, not autism per se. These results accord well with previous reports that autistic individuals with high levels of alexithymia have more difficulties categorising facial expressions, than autistic individuals with low levels of alexithymia (Milosavljevic et al., 2016; Ola & Gullon-Scott, 2020).

Importantly, however, we show that the high-alexithymic autistic group—but not the low-alexithymic autistic group—was impaired relative to non-autistic controls drawn from the general population. This finding provides key evidence for the view that the inconsistent reports of expression recognition impairment in the extant literature reflect differences in the relative proportions of high-alexithymic and low-alexithymic autistic participants in research samples (Bird & Cook, 2013).

5.5.1 How do our findings accord with the eye-region avoidance accounts?

It is perhaps unsurprising that the high-alexithymic autistic individuals showed poor expression recognition in both the unmasked and masked viewing conditions. Alexithymia is associated with functional (Feldmanhall et al., 2013; Kano et al., 2003; Moriguchi et al., 2007) and structural (Ihme et al., 2013) differences in the anterior insula and anterior cingulate cortex-regions which are implicated in the subjective experience of emotion and affect recognition (Etkin et al., 2011; Singer et al., 2009).

Poor expression recognition in alexithymia is thought to reflect an aberrant top-down contribution from these structures that hinders the interpretation of affective stimuli (Bird & Cook, 2013).The resulting deficit appears to impact a wide range of affective decisions. For example, those with high levels of alexithymia also find it hard to describe the emotional content of vocal stimuli (Heaton et al., 2012) and music (Allen et al., 2013).

It is more surprising that the low-alexithymic autistic individuals showed typical expression recognition in both the unmasked and masked viewing conditions. It has been suggested that autistic individuals may have particular problems using information from the eye-region (Tanaka & Sung, 2016). As such, one might well expect all autistic participants—even those without high levels of alexithymia—to struggle in the masked condition, in which participants were forced to focus on the eye-region. Nevertheless, our findings accord with a previous result described by Oakley and colleagues (2016). In a pooled sample of non-autistic controls (N = 23) and autistic participants (N = 19), Oakley et al. (2016) found that participants' alexithymia scores were predictive of performance on the RMET. Consistent with our results, participants' AQ scores—a measure of autistic symptomatology—were not predictive of RMET performance once individual differences in alexithymia were accounted for.

Our findings add to those of Oakley and colleagues (2016) in two ways. First, our larger sample of autistic participants allowed us to consider low-alexithymic and high-alexithymic subgroups separately. This analysis confirmed that autistic individuals with low-levels of

alexithymia exhibit typical levels of expression categorisation accuracy. This overcomes any potential difficulties interpreting the null effect of AQ scores—viewed by some as an imperfect measure of autistic symptomatology (Ashwood et al., 2016)— described by Oakley et al. (2016). Second, the RMET is an unconventional expression recognition task. Its verbal and mentalizing demands are especially high (Peñuelas-Calvo et al., 2019) and there is variability in gaze direction (i.e., different targets are shown with mutual and averted gaze)—a feature that is tightly controlled in most tests of expression recognition, including the present one. Despite these differences, however, our findings accord well with those described by Oakley and colleagues (2016). The results of both studies suggest that autistic individuals with low levels of alexithymia are able to detect and interpret expression cues from the eye-region.

This conclusion is hard to reconcile with the view that autism is associated with problems using information from the eye-region (Tanaka & Sung, 2016). One possibility is that eye-region avoidance in autism is actually attributable to alexithymia; i.e., where observed, atypical fixation behaviour is a product of co-occurring alexithymia, not autism. For example, difficulties interpretating facial affect may cause alexithymic observers to sample facial regions idiosyncratically. Conversely, autistic individuals with low levels of co-occurring alexithymia may have no difficulty attending to the eye-region. Consistent with this possibility, it has been reported that participants' level of alexithymia is predictive of eye-region fixations when viewing faces (Cuve et al., 2021) and complex social scenes (Bird et al., 2011). Alexithymia has also been linked to elevated levels of anxiety in autism (Maisel et al., 2016). This is noteworthy as it is argued that autistic individuals avoid the eye-region because they find it socially threatening (Tanaka & Sung, 2016).

A second possibility is that autistic individuals may have a reduced *propensity* to use facial information from the eye-region, not a reduced *ability* to use facial information from the eye-region. Autistic individuals may often elect to avoid the eye-region because they find it threatening. However, when forced to attend to the eyes (e.g., when interactants are wearing

surgical masks), they may be able to detect and interpret cues from this region without impediment. While this is perfectly plausible, one might still expect low-alexithymic autistic participants to show expression recognition deficits in the whole-face condition if they were extracting less information from the eye-region. For example, the expression categorisation of non-autistic participants is less accurate when the eye-region of each stimulus faces is occluded (Noyes et al., 2021). Contrary to this prediction, we find that low-alexithymic autistic individuals exhibit unimpaired expression recognition in the whole-face condition.

5.5.2 Face masks and social interaction

Our findings confirm previous reports that expression recognition is greatly impaired by the presence of a face mask (Carbon, 2020; Noyes et al., 2021; Tsantani, Gray, et al., 2022). For example, Noyes and colleagues (2021) presented facial stimuli that were angry, disgusted, fearful, happy, sad, surprised, or emotion neutral, for 1 s. When the expression stimuli were presented unmasked, mean categorisation accuracy was higher (80.50%) than when faces were shown with a face mask (61.50%). Several facial expressions (happiness, sadness, disgust, fear, surprise, but not anger) are also judged to be less intense when the mouth and nose regions are occluded by a face mask (Tsantani, Podgajecka, et al., 2022). These findings support the prevailing view that the use of face masks hinders non-verbal communication and social interaction (Pavlova & Sokolov, 2022; Saunders et al., 2021).

We found no evidence that face masks disproportionately impact the expression recognition of autistic participants, relative to non-autistic participants. On average, recognition accuracy dropped by ~20% in autistic and non-autistic groups, irrespective of the presence of high or low levels of alexithymia. It is possible, however, that the detrimental effects of widespread mask wearing during the COVID-19 pandemic may have been felt particularly keenly by high-alexithymic autistic individuals. A drop in accuracy of ~20% may represent a mild inconvenience for those whose expression recognition approaches ceiling levels under normal circumstances. However, a performance decrement of ~20% may be far more

problematic for those who already find expression recognition challenging—i.e., an inconvenience may become debilitating.

5.6 Chapter summary

High-alexithymic autistic participants correctly identified fewer expressions than non-autistic controls. In contrast, the expression recognition of low-alexithymic autistic participants was unimpaired relative to non-autistic controls. The same pattern of results was seen when judging the whole-face and the eye-region alone. We find no evidence that autistic participants—either with or without co-occurring alexithymia—are disproportionately impaired when forced to base decisions on the eye-region. These results lend further support to the view that reports of impaired expression recognition in samples of autistic individuals are attributable to co-occurring alexithymia, not autism per se (Bird & Cook, 2013; Keating, Fraser, et al., 2022; Oakley et al., 2016; Ola & Gullon-Scott, 2020).

Chapter 6: Psychosocial consequences of face recognition difficulties in autism

The research described in this chapter has been published in the following peer-reviewed journal article: Gehdu, B. K., Gray, K. L., & Cook, R. (2024). Poor face recognition predicts social anxiety in autism: A short report. *Autism*, 13623613241272031.

6.1 Introduction

Mental health conditions occur with a greater incidence in the autistic population than in the non-autistic population (Hossain et al., 2020; Lai, 2023; Lai et al., 2019). Research has suggested that approximately 80% of autistic adults in the UK experience mental health challenges that have a significant impact on their daily lives (Lord et al., 2022; Pukki et al., 2022). Among these challenges, anxiety disorders are most prevalent, affecting between 20% to 40% of autistic adults (Hollocks et al., 2019; Lai et al., 2019; Stark et al., 2021).

The high prevalence rates of mental health conditions within the autistic population have been linked to an elevated risk of suicidal behaviours (Blanchard et al., 2021; Mournet et al., 2023; Newell et al., 2023; O'Halloran et al., 2022). Therefore, it is vital that we continue to understand how physiological and cognitive processing alongside social-contextual determinants intersect with neurodivergence to improve mental well-being in autistic individuals (Lai, 2023).

At present, little is known about the psychosocial consequences of face recognition difficulties in autism. Where observed, face recognition problems are known to influence psychosocial outcomes. For example, non-autistic adults with developmental prosopagnosia (DP)- an independent neurodevelopmental disorder characterised by lifelong face recognition difficulties- frequently cite high levels of social anxiety, social interaction difficulties, feelings of inadequacy and associated avoidance behaviours (e.g. choosing

careers that minimise face-to-face interaction arising from their face recognition problems (Dalrymple et al., 2014). .

6.2 Aims of the study

Many autistic people exhibit severe face recognition problems (Gehdu et al., 2022; Hedley et al., 2011; Kamensek et al., 2023; Minio-Paluello et al., 2020; Stantić et al., 2021). Recent research suggests that 15% to 30% of autistic participants exhibit face recognition impairments comparable with those seen in DP (Kamensek et al., 2023; Minio-Paluello et al., 2020). At present, little is known about the psychosocial consequences of these difficulties. However, given that individuals with DP describe heightened levels of social anxiety (Dalrymple et al., 2014; Yardley et al., 2008) we reasoned that poor face recognition (where observed) might also increase autistic individuals' experience of social anxiety.

In addition to face recognition and social anxiety, we also assessed the presence of traits associated with alexithymia and ADHD in our sample. Alexithymia and ADHD are known to co-occur with autism and are thought to be associated with higher levels of social anxiety (Bird & Cook, 2013; Koyuncu et al., 2015, 2019; Pickard et al., 2020). Therefore, in this chapter, across Experiments 1 and 2, we sought to establish whether face recognition difficulties (as measured by scores on both the CFMT-O and CFMT-A), influence social anxiety and loneliness in autism, independently of co-occurring ADHD and alexithymia. All participant CFMT data used in this chapter were obtained from studies detailed in earlier chapters of this thesis. No new participants were recruited for Experiments 1 and 2.

6.3 Experiment 1

6.3.1 Participants

We recruited sixty participants with a clinical diagnosis of autism (M_{age} = 36.60 years, SD_{age} = 11.26 years) via UK Autism Research. Of the 12 individuals who described their sex as male, 9 described their gender identity as male, 2 identified as non-binary and 1 identified as

female. Of the 48 individuals who described their sex as female, 40 described their gender identity as female, 6 identified as non-binary, and 2 preferred not to say.

6.3.2 Measures

6.3.2.1 Social Interaction Anxiety Scale (SIAS)

To assess social interaction anxiety, all participants completed the Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998). This scale has demonstrated high internal consistency in autistic adults (Cronbach's alpha = 0.92-0.95) and has also shown strong convergent validity (Maddox & White, 2015; Spain et al., 2016). The SIAS consists of twenty self-report items designed to measure anxiety, specifically in relation to social interaction. Participants rate how well each statement describes them on a 5-point scale, from 0 (not at all characteristic or true of me) to 4 (extremely characteristic or true of me). Total SIAS scores range from 0 to 80. Higher scores suggest higher levels of social interaction anxiety. A score of 36 and above is thought to reflect clinically significant levels of social anxiety (Peters, 2000). Note, we updated the wording of item 14 'I have difficulty talking to attractive persons of the opposite sex' to 'I have difficulty talking to someone I find attractive'.

6.3.2.2 Depression, Anxiety and Stress Scale (DASS-21)

To assess mental wellbeing, participants also completed the Depression, Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995). This scale consists of twenty-one self-report items designed to measure the severity of a range of core symptoms of depression (7 items), anxiety (7 items), and stress (7 items). Although the DASS-21 alone is not a diagnostic tool, studies support its validity in adequately differentiating between specific anxiety and depression symptoms in both clinical and non-clinical population groups (Antony et al., 1998; Ng et al., 2007). It has also been considered a viable self-report screening measure for depression, anxiety and stress in autistic individuals without intellectual disabilities (Park et al., 2020). Participants rate the presence of a symptom over the previous week on a 4-point scale, from 0 (did not apply to me at all) to 3 (applied to me very much or most of the time). Scores across each sub-scale are summed, ranging from 0 to 21. As the

DASS-21 is a short-form version of the DASS (42 items), the final score for each sub-scale is multiplied by two to calculate the final severity levels (normal, mild, moderate, severe, extremely severe), ranging from 0 to 42. We used the recommended cut-off scores to assess severity levels across depression, anxiety and stress subscale (Antony et al., 1998; Lovibond & Lovibond, 1995). See **Table 6.1** for the recommended cut-off scores for each severity level across depression, anxiety and stress.

Table 6.1 The recommended cut-off scores for severity levels across subscales on the DASS-21.

	Depression	**Anxiety**	**Stress**
Normal	0-9	0-7	0-14
Mild	10-13	8-9	15-18
Moderate	14-20	10-14	19-25
Severe	21-27	15-19	26-33
Extremely Severe	28+	20+	34+

Note. Scores on the DASS-21 are multiplied by 2 to calculate the final score across each subscale.

6.3.2.3 Face recognition survey

In addition to these well-established psychometric instruments, we also administered a bespoke 3-item survey that enquired about participants' experiences of face recognition and social interaction. The items were: 1) Poor face recognition makes social interaction difficult for me; 2) Face recognition problems have influenced my choice of job / career, or otherwise limited my employment opportunities; 3) Face recognition problems have hindered my ability to make friends. Each item was scored on a 5-point scale: Strongly disagree / disagree / neither agree nor disagree / agree / Strongly agree. For each item, participants were also given a free-response text box in which they could elaborate on their response if they wished.

6.3.3 Statistical procedures

For the purposes of the analyses described below, we split the sample into two face recognition subgroups based on CFMT scores. The poor face recognition group (N = 18,

M_{age} = 36.72, SD_{age} = 12.33) included those who scored less than 65% on both versions of the CFMT (M = 50.58, SD = 9.67). The good face recognition group (N = 42, M_{age} = 36.55, SD_{age} = 10.93) included those who achieved a score of 65% or more on one or both variants (M = 76.50, SD = 8.95). While meeting this criterion does not constitute a formal diagnosis of DP it has been used previously to distinguish those whose face recognition ability is likely to fall within the impaired range from those whose face recognition ability is average or above-average (e.g., Tsantani, Vestner, & Cook, 2021).

The differences between subgroup responses on the social interaction anxiety measure, the measure of mental wellbeing, and responses on the bespoke survey were assessed through independent samples *t*-tests (α = 0.05, two-tailed). Correlations were assessed by computing Pearson correlation coefficients (α = 0.05, two-tailed).

6.3.4 Ethics

Ethical clearance was granted by the Departmental Ethics Committee for Psychological Sciences, Birkbeck, University of London and the experiment was conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent before taking part.

6.3.5 Results

6.3.5.1 Social Interaction Anxiety Scale (SIAS)

Overall, the SIAS scores were relatively high (M = 55.70, SD = 12.95) and 55 of the 60 autistic participants met the cut-off (score of 36 and above) for clinically significant levels of social anxiety. Critically, however, the subgroup with poor face recognition reported higher levels of social anxiety (M = 61.78, SD = 9.27) than those with average or above-average face recognition (M = 53.10, SD = 13.51) [t (58) = 2.482, p = 0.016, d = 0.699]. See **Figure 6.1**.

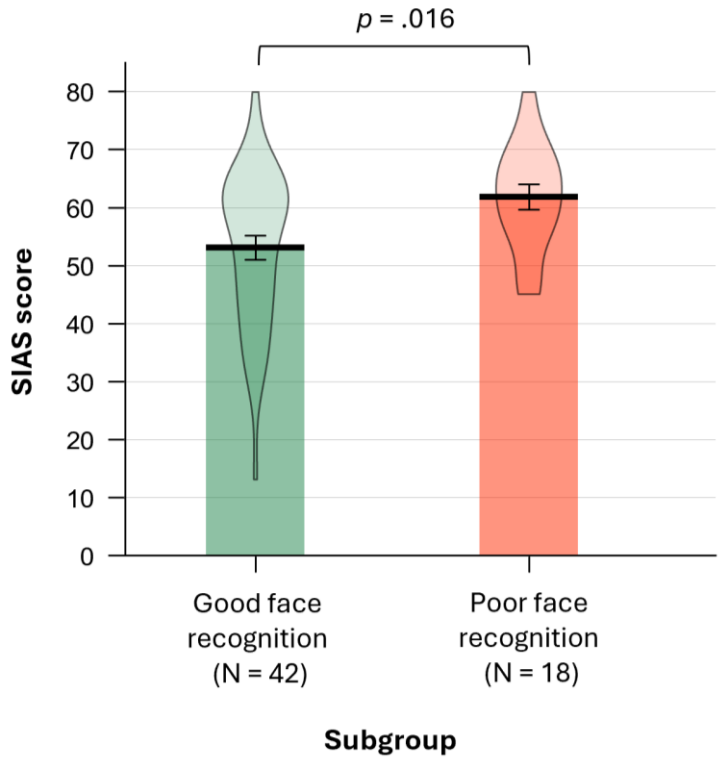

Figure 6.1 Mean scores on the Social Interaction Anxiety Scale between good face recognition and poor face recognition subgroups. Bars depict mean scores. Distribution plots illustrate the spread of scores within each group. Error bars ±1SE.

Participants' SIAS scores were also predicted by their scores on the AQ [M = 42.25, SD = 4.13, r_p = 0.300, p = 0.010] the TAS-20 [M = 67.77, SD = 12.98, r_p = 0.398, p < 0.001] and on the ASRS [M = 4.10, SD = 1.70, r_p = 0.386, p < 0.001]. See **Table 6.2** for correlations between measures. In other words, those who exhibited more traits associated with autism, alexithymia, and ADHD, also tended to report greater social anxiety. However, when entered into a multiple regression with these other predictors [F (4, 55) = 5.641, p < 0.001, R^2 = 0.291], the presence of face recognition impairment remained a significant predictor of SIAS scores [β = 0.283, t = 2.373, p = 0.021]. See **Table 6.3**.

Table 6.2 Mean performance of the autistic sample on the SIAS, AQ, TAS20 and ASRS, along with their respective correlations (r_p).

Variable	*M (SD)*	1	2	3	4
1. SIAS	55.70 *(12.95)*	-			
2. AQ	42.25 *(4.13)*	0.300*	-		
3. TAS20	67.77 *(12.98)*	0.398**	0.511***	-	
4. ASRS	4.10 *(1.70)*	0.386**	0.355**	0.448***	-

Note. SIAS: Social Interaction Anxiety Scale. AQ: Autism-Spectrum Quotient. TAS20: Toronto Alexithymia Scale. ASRS: Adult ADHD Self-Report Scale. *p < 0.05, **p < 0.01, ***p < 0.001.

Table 6.3 Summary of the multiple regression model of participants' scores on the social interaction anxiety scale (SIAS).

Predictor	*β*	*t*	*p*
Autism severity (AQ scores)	0.037	0.276	0.784
Alexithymia severity (TAS-20 score)	0.184	1.293	0.201
ADHD traits (ASRS score)	0.307	2.341	0.023
Presence of face recognition impairment	0.283	2.373	0.021

Note. All participants scored above cut-off on the AQ.

6.3.5.2 Depression, Anxiety and Stress Scale (DASS-21)

DASS-21 severity subscale scores could range from 0 and 42 (see **Table 6.1**). Overall, the mean Anxiety score (M = 16.30, SD = 10.67) was in the severe range (15-19), whereas the mean Depression (M = 18.50, SD = 12.62) and Stress (M = 22.77, SD = 10.77) scores were in the moderate range (14-20 and 19-25 respectively). See **Table 6.4**.

Despite the poor face recognition group scoring higher across all three Depression, Anxiety, and Stress subscales, we did not find a significant effect at the group level (all ps > 0.100, two-tailed). See **Figure 6.2**. We also found no significant difference in the total severity score between the good face recognition group (M = 54.00, SD = 29.73) and the poor face recognition group (M = 65.89, SD = 31.11) [t (58) = 1.375, p = 0.179, d = - 0.394].

Table 6.4 Summary of the DASS-21 severity scores between good face recognition and poor face recognition groups.

		Depression	Anxiety	Stress	Total severity score
Good face recognition	*mean*	16.90	15.19	21.90	54.00
N= 42	*s.d.*	12.08	10.53	10.95	29.73
	range	0-42	0-38	2-42	10-120
Poor face recognition	*mean*	22.22	19.89	24.78	65.89
N=18	*s.d.*	13.39	10.85	10.36	31.11
	range	2-40	4-42	4-40	10-114

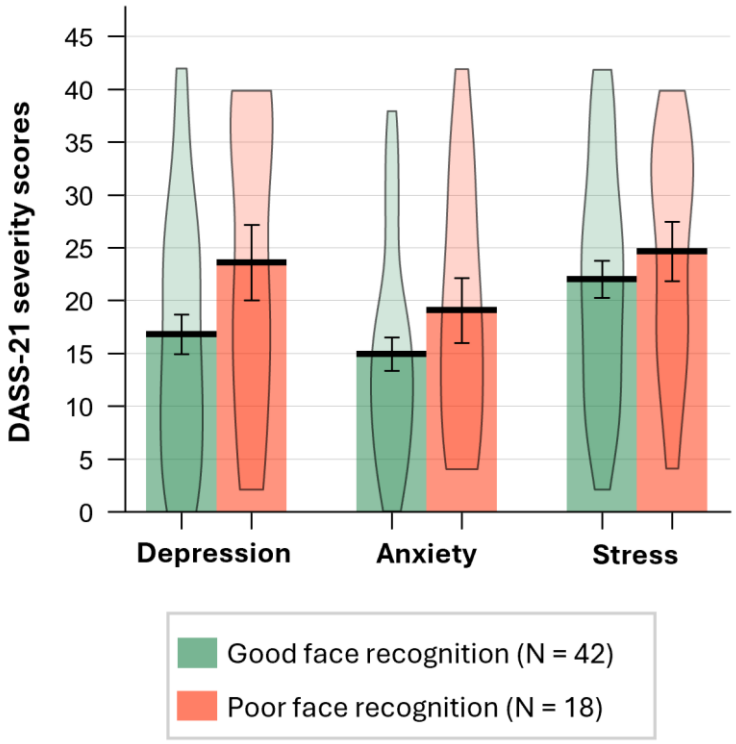

Figure 6.2 Mean scores on DASS-21 between good face recognition and poor face recognition subgroups. Bars depict mean scores. Distribution plots illustrate the spread of scores within each group. Error bars ±1SE.

6.3.5.3 Face recognition survey

Thirty-seven of the 60 participants (61.70%) expressed agreement (either 'Agree' or 'Strongly agree') with the first item of the survey ("Poor face recognition makes social interaction difficult for me") while 14 participants (23.30%) indicated disagreement (either

‘Disagree’ or ‘Strongly disagree’). Nine participants (15.0%) neither agreed nor disagreed with the statement. Many of the free-text comments described hesitant or stressful social interaction stemming from face recognition difficulties. For all items, illustrative comments are provided in **Table 6.5**.

Only 9 of the 60 participants (15.0%) expressed agreement with the second survey item (“Face recognition problems have influenced my choice of job/career, or otherwise limited my employment opportunities”). Thirty-eight participants (63.30%) expressed disagreement. Thirteen participants (21.7%) neither agreed nor disagreed with the statement. One or two of the free-text comments described vocational difficulties caused by poor face recognition. However, many of the comments alluded to other factors (e.g., disabilities and issues with travel) that prevented individuals from pursuing employment/career opportunities.

Twenty-two of 60 participants (36.70%) expressed agreement with the third survey item (“Face recognition problems have hindered my ability to make friends”) while 23 participants (38.30%) expressed disagreement. Fifteen participants (25.0%) neither agreed nor disagreed with the statement. Several respondents felt that poor face recognition meant they were viewed as rude or aloof. Others also described how uncertain face recognition and the potential for embarrassment made it harder to approach new acquaintances.

For each participant, we computed their total questionnaire score. Scores could range from 3 to 15 (assuming: Strongly disagree = 1; Strongly agree = 5). The mean score of the poor face recognition group (M = 10.17, SD = 2.90) exceeded the mean of the good face recognition group (M = 8.07, SD = 3.06) [t (58) = 2.467, p = 0.017, d = 0.695].

Table 6.5 Illustrative quotes from the face recognition survey

Statement	Example quotes
Poor face recognition makes social interaction difficult for me.	“I have to use people's voices a lot for recognition, and then any other hints such as the context of where I encounter a person… I would recognise a particular friend if I met them in a setting, I would expect to find them but would completely not recognise them if I bumped into them on the street or in a shop, for example.” “I struggle to recognise people, quite often, so typically wait until they speak to me first to avoid confusing them with someone else.” “People don’t always introduce themselves and I’m focussing on trying to work out who they are instead of listening properly to the conversation, so then I miss chunks of what is said.” “I can really struggle to recognise people and know whether or not I should recognise them. It can make me feel embarrassed, or worried about potential embarrassment.” “At school I used to recognise people based on their coats and bags so would get annoyed if they changed these because I would have to put in extra effort into recognising them.” “I get stressed because often people recognise me, and I have no idea who they are.”
Face recognition problems have influenced my choice of job/career or otherwise limited my employment opportunities.	“I have struggled to develop work colleague/customer relationships based on not being able to remember people when I see them… I have struggled to figure out who they are, and they thought I was being rude, ignoring them or not interested… I have missed out on job progression opportunities due to not being [able] to develop good work relationships.” “I found that this hindered my ability to function as a Supply Teacher, which was my only option into the teaching profession due to lack of job opportunities. I cannot cope with new faces every day as I can't learn their voices in a timely way.” “…my anxiety around socialisation, some caused by facial recognition issues, has limited my working opportunities.” “I work in healthcare. It helps that colleagues wear name badges.” “Face recognition problems aren't usually considered by me when it comes to employment, given I've been unemployed for so long.” “There are other factors that were more limiting to my employment opportunities (mainly, ability to travel independently).”
Face recognition problems have hindered my ability to make friends.	“I don’t remember people's faces very well, so it makes it more complicated making and maintaining friendships.” “People tend to be very offended if you don’t recognise them immediately, and this can cause relationships to start on a negative footing.” “…I won't approach someone in case I have mistaken them for someone else, which has happened on more than one occasion, but it makes me really anxious I can't figure out what to say, who are they, where have we met, have we met at all… I get so stressed I end up retreating to safe space and abandon the thought of speaking to them.” “People have thought I'm standoffish when I didn't recognise them after meeting them.” “Definitely, as people have been upset that I forgot their face.” “I do struggle with recognising people, but I think the problems with making friends are more due to awkwardness around what to say, how to stand, etc.”

6.4 Experiment 2

The high rate of social anxiety seen in autism represents a significant mental health challenge (Lai, 2023; Pickard et al., 2020; Spain et al., 2018). A related challenge is the high rate of loneliness seen in this population (Grace et al., 2022). A comprehensive systematic review on autistic loneliness by Grace et al (2022) revealed similar predictors between social anxiety and loneliness. Loneliness has been predicted by heightened anxiety, depressive symptoms and suicidal ideation. Similarly, their review highlighted that some autistic individuals avoid socialising due to past negative experiences of socialising, learned helplessness and sensory avoidance. As mentioned above, a lack of social acceptance and understanding of autism from others can lead to increased feelings of loneliness (Ee et al., 2019; Grace et al., 2022, 2023).

In Experiment 1, noticeably, more than half of our sample felt that poor face recognition hampered their social interaction, while over a third thought that poor face recognition had undermined their efforts to make friends. Given these findings, we felt it was valuable to further investigate the link between face recognition and loneliness in autistic individuals.

6.4.1 Participants

We invited the same sixty participants who completed Experiment 1 to participate in Experiment 2. Fifty-six participants (M_{age}= 37.45 years, SD_{age}= 11.08 years) completed Experiment 2. Of the 12 individuals who described their sex as male, 9 described their gender identity as male, 2 identified as non-binary and 1 identified as female. Of the 44 individuals who described their sex as female, 38 described their gender identity as female, 4 identified as non-binary, and 2 preferred not to say.

6.4.2 Measures

6.4.2.1 University of California, Los Angeles Loneliness Scale (UCLA 20-item)

To assess the frequency and intensity of experiences of loneliness, all participants completed the twenty-item UCLA Loneliness Scale (UCLA 20-item; Russell, 1996). The UCLA 20-item scale measures emotions and experiences associated with various aspects of loneliness (e.g., intimate, relational or collective). This scale has previously been demonstrated to reflect experiences of loneliness in autistic individuals accurately alongside high levels of internal consistency (Cronbach's alpha = 0.90) (Grace et al., 2023). Research has also suggested that autistic adults score, on average, 18% higher than non-autistic individuals on this scale (Russell, 2020). The scale consists of 20 items, and participants rate how well each statement describes their experiences on a 4-point scale, from 1 (Never) to 4 (Always). 9 items are reverse scored. Total UCLA 20-item scores range from 20 to 80. Higher scores indicate higher levels of loneliness.

6.4.2.2 University of California, Los Angeles Loneliness Scale (UCLA 3-item)

Grace et al. (2022, 2023) reported that the UCLA 20-item scale has only been used in ~five studies with autistic adults. Therefore, we included two loneliness scales recommended by the UK government. The Office for National Statistics (2018) suggests using both direct and indirect measures to assess loneliness in the general adult population as national indicators.

The three-item UCLA Loneliness Scale (UCLA 3-item; Hughes et al., 2004) has been recommended as an indirect measure of loneliness (Office for National Statistics, 2018). Until now, with the exception of a study by Jackson et al. (2018) only the original UCLA-20 questionnaire has been used with autistic samples. We decided to include both the UCLA-20 and UCLA 3-item questionnaires in this study to determine if the shorter UCLA 3-item version is equally as accurate at measuring loneliness in autistic individuals.

Participants completed the UCLA 3-item scale (Hughes et al., 2004). The scale consists of three questions: "How often do you feel that you lack companionship?", "How often do you

feel left out?" and "How often do you feel isolated from others?". These questions measure three dimensions of loneliness: relational connectedness, social connectedness, and self-perceived isolation (Hughes et al., 2004). Participants rate how well they related to each item on a 3-point scale, from 1 (Hardly ever) to 3 (Often). Total scores ranged from 3 (indicating less frequent loneliness) to 9 (indicating more frequent loneliness). There is no recommended cut-off score for which a person would definitely be considered lonely (Hughes et al., 2004; Office for National Statistics, 2018).

Previous work by Jackson et al. (2018) demonstrated that overall levels of loneliness in autistic post-secondary students, as measured by the total UCLA 3-item score, were significantly associated with the number and satisfaction level of close friendships. Most importantly, lifetime suicidal behaviours were positively associated with levels of loneliness (Jackson et al., 2018).

6.4.2.3 ONS single-item measure of loneliness

This single-item self-report measure asks respondents, "How often do you feel lonely?" on a 5-point scale. Higher scores indicate higher levels of self-perceived loneliness. As recommended by The Office for National Statistics (2018) the UCLA 3-item scale questions were completed before this direct measure of loneliness.

6.4.3 Statistical procedures

Again, we split the sample into two face recognition subgroups based on CFMT scores using the same criterion as Experiment 1. The poor face recognition group (N = 15, M_{age} = 37.87, SD_{age} = 12.74) included those who scored less than 65% on both versions of the CFMT (M = 50.28, SD = 10.09). The good face recognition group (N = 41, M_{age} = 37.29, SD_{age} = 10.58) included those who achieved a score of 65% or more on one or both variants (M = 76.00, SD = 8.95).

Differences between subgroup responses on the loneliness measures were assessed through independent samples *t*-tests ($\alpha = 0.05$, two-tailed). Correlations were assessed by computing Pearson correlation coefficients ($\alpha = 0.05$, two-tailed).

6.4.4 Ethics

Ethical clearance was granted by the Departmental Ethics Committee for Psychological Sciences, Birkbeck, University of London and the experiment was conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent before taking part.

6.4.5 Results

6.4.5.1 UCLA 20-item scale

Overall, the UCLA 20-item scores were in the average range ($M = 56.39$, $SD = 9.70$). Subgroup analysis revealed that the poor face recognition group scored higher ($M = 59.40$, $SD = 7.25$) on the UCLA than the good face recognition group ($M = 55.29$, $SD = 10.31$). See **Figure 6.3**. However, this difference was non-significant, [t (35.575) = 1.664, $p = 0.105$, $d = 0.427$]. The difference was close to significance at the one-tailed point ($p = 0.052$) which will be explored further in the **6.5 General Discussion** section. Note, for these comparisons, it was necessary to correct the degrees of freedom because the variance between subgroups was not equal [F (1,54) = 4.609, $p = 0.036$].

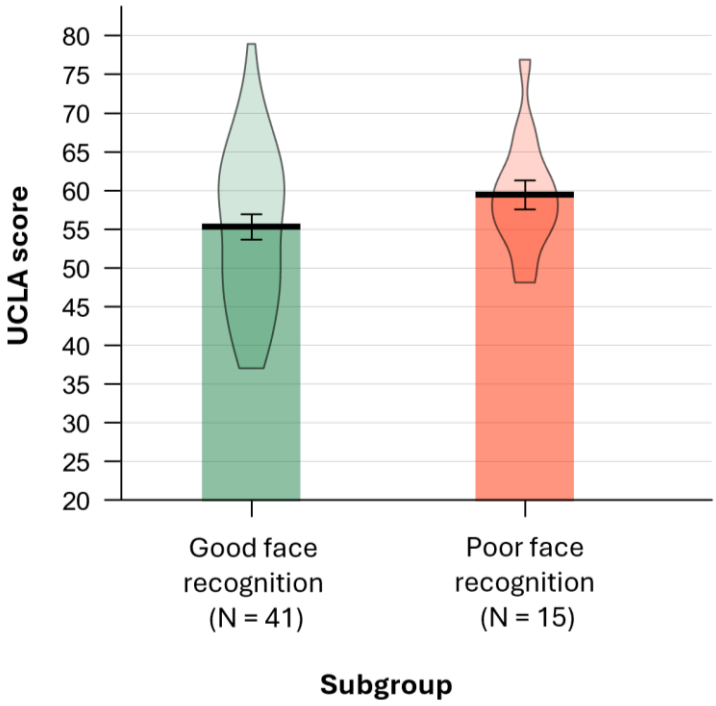

Figure 6.3 Mean scores on UCLA 20-item between good face recognition and poor face recognition subgroups. Bars depict mean scores. Distribution plots illustrate the spread of scores within each group. Error bars ±1SE.

6.4.5.2 UCLA 3-item scale

Similarly, on the UCLA 3-item, the poor face recognition group scored slightly higher (M = 7.07, SD = 1.75) than the good face recognition group (M = 6.98, SD = 1.80). However, this difference was non-significant [t (54) = 0.169, p = 0.866, d = 0.051].

6.4.5.3 ONS single-item measure of loneliness

The ONS single-item measure of loneliness also showed no significant group differences between the poor (M = 3.60, SD = 1.30) and good (M = 3.59, SD = 1.16) face recognition groups [t (54) = - 0.040, p = 0.968, d = 0.042].

Furthermore, our exploratory correlational analyses revealed that all three loneliness measures were positively correlated with one another in our sample (N = 56). As seen in **Table 6.6**, these data suggest that all measures index the same construct and that the UCLA 20-item and UCLA 3-item scales align with autistic adults' subjective experiences of

loneliness. Furthermore, this confirms that the UCLA 3-item version provides a good approximation of performance on the longer UCLA 20-item version. Consequently, as recommended by the Office for National Statistics (2018) for the general population, using the UCLA 3-item and the ONS single-item measure may also be advantageous to assess loneliness in the adult autistic population.

Table 6.6 Mean performance of the autistic sample on the loneliness measures employed in Experiment 2, along with their respective correlations.

Variable	**M *(SD)***	**1**	**2**	**3**
1. UCLA 20-item	56.39 *(9.70)*	-		
2. UCLA 3-item	7.00 *(1.77)*	0.727***	-	
3. ONS single-item	3.59 *(1.19)*	0.647***	0.831***	-

Note. ***$p < 0.001$.

6.5 Discussion

In the present study, we conducted two experiments to examine to what extent face recognition problems impact the social anxiety and/or loneliness of autistic people. It is now well-established that a subgroup within the autistic population exhibit severe lifelong face recognition problems (Gehdu et al., 2022; Hedley et al., 2011; Kamensek et al., 2023; Minio-Paluello et al., 2020; Stantić et al., 2021). However, there is less appreciation that these difficulties, where observed, have important psychosocial consequences. The present results suggest that autistic individuals with poor face recognition experience greater social anxiety than those with average or above-average face recognition. Strikingly, more than half our sample felt that poor face recognition hampered their social interaction, while over a third thought that poor face recognition had undermined their efforts to make friends.

6.5.1 Social interaction anxiety

The development of social anxiety in autism likely reflects the interplay of many factors (Spain et al., 2018) – poor face recognition may be just one part of this complex story. Crucially, however, our findings show that face recognition problems account for unique variance above and beyond the presence of co-occurring alexithymia and ADHD.

In our analyses, we found that both alexithymia and ADHD correlated independently with social anxiety. However, when entered into a multiple regression with face recognition ability, ADHD but not alexithymia accounted for a significant proportion of unique variance. This is especially interesting in the context of the strong correlation we see between ADHD and alexithymia (see **Chapter 4**). The correlation between alexithymia and social interaction anxiety has been widely discussed (Bird & Cook, 2013; Pickard et al., 2020) but it raises the question of whether this relationship is primarily driven by the presence of ADHD traits. Due to time constraints, we chose not to administer Part B of the ASRS which would have allowed us to classify participants into specific clinical ADHD subtypes (primarily hyperactive and impulsive ADHD, primarily inattentive ADHD and combined type ADHD). Research indicates that levels of social interaction anxiety can vary significantly among ADHD subtypes (Bishop et al., 2019; Koyuncu et al., 2015, 2019) including in the presence of alexithymia (Edel et al., 2010; Kiraz et al., 2020). Therefore, the association between alexithymia, ADHD and social interaction anxiety remains relevant. Future research should utilise more comprehensive diagnostic tools for ADHD to better understand these relationships, particularly in the context of face recognition problems among autistic individuals.

In keeping with previous research (Tsantani et al., 2021), we split our sample into those who scored less than 65% on both versions of the CFMT and those who did not. Eighteen participants met this criterion for poor face recognition. Interestingly, however, more than twice this number felt that poor face recognition hindered their social interaction. It is possible that CFMT scores sometimes over-estimate participants' face recognition ability (

see Burns et al., 2023). Alternatively, relatively mild face recognition problems may be sufficient to induce or exacerbate social interaction difficulties in some autistic individuals.

At the beginning of our study, we hypothesised that poor face recognition might lead to increased social anxiety in autistic individuals. Although the quantitative results suggest a possible association, they do not prove causality. However, the qualitative reports are significant in this context as many quotes in **Table 6.5** accord well with the proposed causal relationship.

6.5.2 Loneliness

We did not find an association between poor face recognition and loneliness. This null effect of group is very hard to interpret. Given some of the comments made by participants in Experiment 1 (see **Table 6.5**) there may well be an effect there, but we simply did not have enough statistical power to detect it. Notably, the mean group difference on the UCLA 20-item version approached significance (p = 0.052, one-tailed).

In addition, it may be that the questionnaires we employed are not well-suited to measuring loneliness in autistic individuals. This may have reduced the effect size. As demonstrated in an evaluation study by Grace et al. (2023) autistic adults felt that items on the UCLA scale (alongside other measures of loneliness) failed to capture the nuances of their experiences. Grace et al. (2023) reported that widely used loneliness scales do not account for camouflaging, a behaviour where autistic individuals mask their true selves to meet social expectations (J. Cook et al., 2021). This oversight might lead autistic participants to respond differently depending on whether they are considering their authentic behaviour or their camouflaged behaviour. Specifically, on UCLA, item 9 asks, “How often do you feel outgoing and friendly?” autistic participants might answer “often” or “always” when reflecting on their camouflaged behaviours but “rarely” or “never” when thinking about their non-camouflaged behaviour (Grace et al., 2023). Therefore, we may not have found a significant association

between face recognition difficulties and loneliness as our main loneliness measure, the UCLA may not accurately capture experiences of autistic loneliness.

Alternatively, face recognition ability may have minimal or no impact on loneliness in autistic individuals. It is possible that other factors contribute more significantly to their feelings of loneliness, such that variations in face recognition ability have little influence, as they may already experience high levels of loneliness (i.e., a ceiling effect).

6.6 Chapter summary

Autistic individuals with poor face recognition experience higher levels of social interaction anxiety than those with average or above-average face recognition. Notably, over half of our sample reported that poor face recognition hindered their social interactions, and more than a third felt it impacted their ability to make friends. Although a similar trend was observed with measures of loneliness, this effect did not research statistical significance.

Chapter 7: General Discussion

This thesis explored the significant variability in face processing abilities among autistic individuals, focusing on four key areas: face learning mechanisms in facial identity recognition, autistic individuals' insights into their relative face processing abilities, the role of alexithymia in facial expression recognition and the psychosocial impact of living with face recognition difficulties. These areas are discussed in Chapters 3 to 6 and will be summarised below.

Chapter 3

The study described in this chapter addressed whether face identity recognition difficulties in autism stem from deficits in face learning (Ipser et al., 2016) or issues in perceptual encoding. Using our Oddball task, we tested whether autistic individuals struggled to group ambient images by the identity of the people depicted.

Across two experiments, we found that autistic participants were less accurate in grouping ambient images by identity. Consistent with recent findings (Stantić et al., 2021) these results indicate that autistic individuals perform poorly on face identification tasks with minimal memory demands, suggestive of impaired face encoding. It has previously been shown that autistic people derive less benefit from facial variability when learning new facial identities (Ipser et al., 2016). The present findings suggest that this may well reflect poor perceptual input into learning mechanisms, not atypical perceptual learning per se.

It is important to note that in this study, the same group of autistic participants completed Experiments 2 and 3, while different groups of non-autistic controls completed these experiments. This was necessary because we were unable to recruit the same 60 controls for Experiment 3. This feature raises the possibility that the autistic participants benefited from practice effects in Experiment 3, while the non-autistic controls did not. However, the pattern of results seen in the third experiment was very similar to that seen in the second.

Indeed, the effect size seen in Experiment 3 (d = 0.777) was numerically larger than that seen in Experiment 2 (d = 0.661). Given that the non-autistic participants achieved higher levels of accuracy than the autistic participants, it seems unlikely that differential practice effects can account for the group difference observed.

Chapter 4

We examined the relationship between PI20 scores and CFMT performance. There have been debates about whether individuals have the necessary insight into their relative face recognition ability to provide meaningful responses to self-report measures (Arizpe et al., 2019; Bobak et al., 2019; Burns et al., 2023; Matsuyoshi & Watanabe, 2021). Evidence shows that PI20 scores in non-autistic participants strongly correlate with objective measures of face recognition (Gray et al., 2017; P. Shah, Gaule, et al., 2015; P. Shah, Sowden, et al., 2015; Tsantani et al., 2021) but findings within the autistic population have been inconsistent (Minio-Paluello et al., 2020; Stantić et al., 2021).

Our study assessed the relationship between PI20 scores and CFMT performance in autistic individuals while exploring how factors like autism severity, non-verbal intelligence, and co-occurring conditions such as alexithymia and ADHD might predict face recognition performance.

Using non-autistic comparison data from Tsantani et al. (2021) we found a significant correlation between PI20 scores and CFMT performance in autistic adults, contrary to recent reports. Therefore, suggesting that autistic individuals can accurately assess their face recognition abilities, validating the use of PI20 to screen for face recognition difficulties in this population. However, we found little or no association between CFMT performance and non-verbal intelligence, autism severity, or co-occurring alexithymia and ADHD.

It remains possible that insight into face recognition difficulties, specifically the correlation between PI20 and CFMT scores, varies with cognitive abilities or IQ. The PI20's high verbal demands could make it unsuitable for individuals with intellectual disabilities, leading to less

reliable self-reports of face recognition difficulties. Our autistic sample had average non-verbal ability, as all participants met the MRT cut-off, limiting our ability to examine how cognitive ability modulates the PI20-CFMT relationship. Given Walker et al. (2023) found a positive correlation between face memory and intellectual functioning, lower cognitive ability may impair self-awareness, leading to over-or underestimation of difficulties and weakening the PI20-CFMT correlation. Conversely, higher cognitive ability may enhance metacognitive skills, improving self-assessment accuracy and strengthening this relationship. However, while cognitive ability likely influences insight into face recognition difficulties, this relationship may be further moderated by autistic traits, co-occurring conditions and individual differences in metacognition.

It is important that future research ascertain if or how other measures of meta-cognitive performance relate to participants' responses on the PI20. For example, estimates such as meta c and meta d inferred from type-II signal detection tasks (Fleming & Lau, 2014; Maniscalco & Lau, 2012) may offer additional insights. Here, meta c reflects an individual's stable confidence bias (i.e., whether they are generally overconfident or underconfident), while meta d captures trial-to-trial fluctuations in confidence and assesses whether these variations correspond to the accuracy of perceptual decisions, thereby indicating the usefulness of confidence as a signal. For example, one might hypothesise that the PI20 scores of those with a higher meta c ought to correspond more closely to objective face recognition performance. It might also be interesting to examine how autistic and non-autistic individuals acquire insight into their relative face recognition abilities (e.g., What kinds of face recognition errors are salient? What have individuals been told about face recognition in autism?).

Chapter 5

This chapter investigated the role of alexithymia on facial expression recognition. In neurotypical populations, facial expressions are considered to be vital for understanding

others' emotions and intentions (Adolphs, 2002; Frith, 2009). Difficulties in interpreting facial expressions can impact social interactions and mentalizing skills in autistic individuals (Frith & Frith, 2006; Harms et al., 2010; Uljarevic & Hamilton, 2013). However, evidence shows that co-occurring alexithymia affects expression recognition in autistic samples (R. Cook et al., 2013; Keating, Fraser, et al., 2022; Oakley et al., 2016; Ola & Gullon-Scott, 2020). This raises the question of whether autism itself affects expression recognition independently of alexithymia (Keating, Fraser, et al., 2022).

Here, we explored whether the effects of autism and alexithymia on expression recognition vary with the types of stimuli, potentially revealing an overlooked independent effect of autism. We compared autistic participants (with and without high levels of alexithymia) and matched non-autistic controls in their ability to categorise facial expressions under two conditions: eyes-only (with a surgical mask occluding the mouth region) and whole face (without any occlusion).

High-alexithymic autistic participants correctly identified fewer expressions than non-autistic controls, while low-alexithymic autistic participants showed no impairment relative to non-autistic controls. This pattern was consistent across both conditions, with no evidence that autistic participants—whether with or without alexithymia—were disproportionately impaired when focusing solely on the eye region. These findings further support the view that impaired expression recognition in autistic individuals is attributable to co-occurring alexithymia, not autism per se (Bird & Cook, 2013; R. Cook et al., 2013).

Research by Jack et al. (2009) has demonstrated that cross-culturally, Westerners distribute their fixations evenly across the face, whereas Eastern observers consistently fixate on the eye-region. They suggest that by persistently fixating the eyes, Eastern observers sample ambiguous information, thus causing significant confusion. Therefore, although we observed no evidence that our autistic participants, with or without high levels of alexithymia, were disproportionately impaired when basing decisions on the eye-region alone, this may not hold true for racially minoritised autistic individuals in the UK. If we hypothesise that facial

expression recognition, in some part, may also be shaped by early cultural learnings, individuals with dual or multiple identities across both the West and East may exhibit differential face fixation patterns and biases regardless of autism and alexithymia. Therefore, it would be interesting to look at this in the future with autistic people from different cultures.

Work by Sowden et al. (2021) has demonstrated that both spatial and kinematic facial cues affect expression recognition accuracy in non-autistic individuals (see **Chapter 1** for a detailed outline of this work). In the autism literature, follow-up work by Keating et al. (2022) demonstrated that autistic participants required higher-intensity cues to accurately identify facial expressions, especially anger, compared to non-autistic individuals. These differences were attributed to autistic traits rather than alexithymia, as both groups were matched for levels of alexithymic traits. In the future, it would be interesting to expand our research by using dynamic facial expression stimuli, which could build on the robust group differences we observed with static stimuli.

Chapter 6

We explored whether face recognition difficulties impact social anxiety and loneliness in autistic individuals. Since those with developmental prosopagnosia (DP) often report high levels of social anxiety (Dalrymple et al., 2014; Yardley et al., 2008) we hypothesised that poor face recognition (where observed) might also contribute to higher levels of social anxiety and loneliness in autistic individuals, independent of co-occurring alexithymia and ADHD (Bird & Cook, 2013; Koyuncu et al., 2015, 2019; Pickard et al., 2020).

In our study, autistic participants were divided into two subgroups (good and poor face recognition) based on CFMT scores. We assessed social anxiety, mental wellbeing and loneliness and collected qualitative insights about face recognition difficulties through a bespoke survey.

In Experiment 1, we found that autistic participants with poor face recognition experienced higher social interaction anxiety compared to those with average or above-average face recognition. Over half reported that poor face recognition hindered their social interactions, and over a third felt it affected their ability to make friends. Poor face recognition was also linked to higher alexithymic and ADHD traits. However, Experiment 2 revealed no similar association between poor face recognition and increased loneliness. While nearly half felt inadequate due to face recognition difficulties, only a small fraction avoided social situations because of it. These findings are the first to suggest that autistic individuals with poor face recognition may experience persistent psychosocial challenges similar to those experienced by individuals with DP including increased social anxiety, depression, social isolation, loneliness and internalised feelings of inadequacy (R. Cook & Biotti, 2016; Dalrymple et al., 2014; Duchaine & Nakayama, 2006; Yardley et al., 2008).

While this study offers qualitative insights into social interaction difficulties, social anxiety and loneliness related to poor face recognition, it does not account for the experiences of autistic individuals who do not communicate verbally. As noted by Grace et al. (2023) in their own work, our study also overlooks the loneliness experienced by autistic adults who rely on alternative communication methods like sign language and communication devices. Therefore, it remains unclear how face recognition difficulties may impact the psychosocial wellbeing of autistic individuals with different communication needs.

Furthermore, despite growing research on mental wellbeing in autistic adults, many widely used survey instruments have not been validated for this population (Nicolaidis et al., 2020). Consequently, constructs related to mental wellbeing, such as depression and anxiety, are often defined and validated based on neurotypical experiences. This has led to efforts in developing autism-specific measures, like those for suicidality (Cassidy et al., 2018) and quality of life (H. McConachie et al., 2018) as existing tools have been considered to inadequately capture the unique factors associated with being autistic (Grace et al., 2023).

Creating more sensitive measures of mental health for autistic adults requires establishing shared definitions of mental health constructs that accurately reflect autistic experiences and can be utilised by both clinicians and the autism community (Nicolaidis et al., 2020). The Delphi method has proven effective in this process, allowing autistic individuals to lead in defining key concepts and co-producing survey instruments that better measure their experiences. This methodology has been successfully applied to define constructs like autistic burnout (Higgins et al., 2021) and autistic post-traumatic stress disorder (Rumball et al., 2023). Therefore, when investigating the impact of face recognition difficulties on mental wellbeing, it is crucial to first establish a consensus on what constitutes as social interaction, social interaction anxiety, and loneliness in autism. Only then can new scales be developed or existing ones, like the UCLA, be appropriately adapted.

In the context of our work, differentiating between camouflaged behaviours in relation to face recognition problems is extremely important given that we know many individuals with DP often adopt particular behaviours to better navigate social interactions, by for example, using characteristic facial features, voices, clothing, hairstyles and walking gait to recognise others (R. Cook & Biotti, 2016). In our study, qualitative reports by autistic participants included a combination of behaviours used to navigate social interactions in similar ways to what has been reported by those with DP. For example, by paying close attention to a person's facial features and body as contextual cues to correctly identify different people in a social setting, needing the support of others during social interactions and needing to put on an act whilst socialising or avoiding socialisation all together (see **Table 6.5**).

However, could it be possible that autistic individuals with face recognition difficulties exhibit a particular type of autistic camouflaging that is distinct from i) autistic individuals without face recognition problems and/or ii) individuals with DP? If so, do these pose a particular set of social interaction challenges and subsequent psychosocial consequences of mental wellbeing compared to autistic individuals who camouflage but do so without the added barrier that comes with living with face recognition difficulties?

In the future, work exploring the psychosocial consequences of face recognition difficulties in autism should incorporate measures of social camouflaging. For example, The Camouflaging Autistic Traits Questionnaire (CAT-Q; Hull & Mandy, 2021), assesses camouflaging across three subcategories: compensation (techniques to navigate social difficulties linked to autism), masking (methods to conceal autistic traits or project a more neurotypical persona) and assimilation (approaches to blend in during social interactions) (Hull et al., 2019; Hull & Mandy, 2021). It may be possible that autistic individuals with poor face recognition exhibit a particular subcategory of camouflaging when trying to better navigate social interactions, compared to those with good face recognition.

7.1 Overarching themes and issues

7.1.1 Heterogeneity within the autistic population

Across our experiments, we consistently found strong evidence of heterogeneity in face recognition ability within our autistic samples. In **Chapter 3**, for example, some autistic participants struggled with the Oddball task, while others performed at near-perfect levels. Additionally, in the same study, 50% of our autistic sample (30 out of 60) scored above the PI20 cut-off for DP, consistent with previous research (Kamensek et al., 2023; Minio-Paluello et al., 2020; Stantić et al., 2021). In **Chapters 4 and 6**, we identified two face recognition subtypes based on CFMT scores; in **Chapter 4**, specifically, autistic individuals who scored above the PI20 cut-off had lower scores on both versions of the CFMT compared to those who scored below the PI20 cut-off. Furthermore, **Chapter 5** demonstrated that facial expression recognition ability varied as a function of alexithymic traits, aligning well with previous research (Bird & Cook, 2013; R. Cook et al., 2013).

This strong evidence of heterogeneity accords well with the view that autism is not a single, unitary condition but rather a neurodevelopmental condition with a spectrum of manifestations (Happé & Frith, 2020). Our findings suggest that differences in face

processing ability may contribute to one of these varied manifestations. A key strength of our within-group approach was the ability to explore the respective contributions of autism, alexithymia and ADHD to determine if and where autism may uniquely explain poor face recognition ability.

Importantly, we have found that certain subgroups within our autistic samples exhibit face recognition difficulties similar to those seen in DP (R. Cook & Biotti, 2016; Gray & Cook, 2018). This suggests that, like other neurodevelopmental conditions such as ADHD, which occur more frequently in the autistic population than in the general population, DP may also be a neurodevelopmental condition that commonly co-occurs with autism. Co-occurring DP could explain why some autistic individuals have poor face recognition abilities rather than autism per se. Our work on facial expression recognition should be extended to investigate whether co-occurring alexithymia, as opposed to DP, influences expression recognition in autism. Specifically, it may be important to examine how prosopagnosia might impact face encoding and how alexithymia may affect the interpretation of facial expressions and gestures, as well as how these factors might interact to shape overall expression recognition abilities.

7.1.2 Sample diversity and representativeness

We note that our database of autistic participants, like others which have been created through online sampling, tends to have a strong female participant bias (Rødgaard et al., 2022). For example, in a sample of 77 autistic participants, we have a 16:61 male-to-female ratio (~20% males). This may lead some to suggest that our sample is biased and unrepresentative, given that most of the autistic population is thought to identify as male (Ferri et al., 2018). However, our autistic and non-autistic samples were sex-matched; therefore, observed group effects are unlikely to have been influenced by participant sex. We recognise the need to replicate the present findings with a sample that better represents the wider autistic community. This challenge arises from potentially biased diagnostic

systems and societal barriers that have historically led to the underdiagnosis of autistic females (Lockwood Estrin et al., 2021; Rubenstein et al., 2015).

Additionally, our autistic sample lacked ethnic diversity, with around 93% of our participants identifying as White. Consequently, we used facial stimuli depicting White individuals to avoid attributing face processing difficulties to 'cross-race' effects, where perceptual difficulties arise when viewing types of faces with which they are less familiar (Furl et al., 2002; O'Toole et al., 2002; Sangrigoli et al., 2005). However, it remains unclear how well our findings generalise to faces of other ethnicities and more diverse autistic populations. As highlighted in **Chapter 5**, some researchers argue that face learning and recognition may be impacted by culture (Jack et al., 2009). Future research should include a broader range of participants who self-identify as autistic to ensure adequately powered and representative sample sizes, especially given the low and varied diagnosis rates across minoritised ethnic groups in the UK (Kandeh et al., 2020; Roman-Urrestarazu et al., 2021).

7.1.3 Measuring autistic traits

Throughout this project, we used the AQ questionnaire both to confirm group membership (autistic or non-autistic) and to assess autism severity within our autistic samples. While AQ scores played an important part in our selection of participants, it is important to note that all participants in the autistic group had a clinical diagnosis. This approach was sufficient to demonstrate that face recognition differences exist between the groups, as we recruited clinically diagnosed autistic individuals rather than comparing groups based on varying levels of autistic traits in the neurotypical population. However, we did not use the AQ questionnaire domain subscales to conduct more nuanced comparisons between autistic and non-autistic groups. Although using subscales is common in autism research (English et al., 2020) this method might overlook important distinctions among individuals with high AQ scores. For example, neurotypical individuals might differ qualitatively based on their scores on the 'attention to detail' subscale (Kitazoe et al., 2017). Additionally, AQ questionnaire items have been shown to function differently across different demographic groups, including

sex, gender and age, which raises concerns about the questionnaire's potential biases (Agelink van Rentergem et al., 2019; Belcher et al., 2023).

With these considerations in mind, future research aiming to explore specific autism characteristics, such as those potentially driving developmental differences in face recognition ability and sex differences, would benefit from employing additional measures beyond AQ subscales to gain a more comprehensive understanding of an individual's autistic profile.

7.1.4 Online research poses a potential risk to data integrity

As highlighted **in Chapter 2**, online recruitment has made it relatively easy to gather large samples across different regions while promoting more inclusive practices (Pellicano et al., 2023). However, these methods, particularly those offering participant incentives, tend to attract fraudulent participants (A. Jones et al., 2021; Teitcher et al., 2015). During our recruitment process, we encountered issues with similar email addresses, often differing by just a character, and received multiple emails from these seemingly distinct participants in quick succession. This led to concerns about individuals potentially completing experiments more than once under different names.

To address this, we continuously screened and removed individuals using the same email address under new names as our database grew. Despite these efforts, some similar email addresses may have gone unnoticed due to the high sign-up volume. Additionally, location-based limits on Gorilla Experiment Builder might not have prevented participants from outside the UK from joining. Furthermore, due to privacy concerns, we offered participants the option to receive reimbursement through direct bank transfer or through Amazon vouchers sent via email. However, this option meant it was harder to verify each participant's identity.

Despite these concerns, we continued to replicate some well-established effects. For instance, we observed significant correlations between TAS20 scores and both AQ scores

and social interaction anxiety scores, consistent with previous findings (Bird & Cook, 2013; Pickard et al., 2020). Additionally, our ADHD screener showed significant correlations with AQ scores (Hours et al., 2022; Leitner, 2014) and social interaction anxiety scores (Bishop et al., 2019; Koyuncu et al., 2015, 2019). In **Chapter 4**, the CFMT scores for our autistic sample were consistently lower than those of the non-autistic comparison group, in line with established literature (Gehdu et al., 2022; Hedley et al., 2011; Kamensek et al., 2023; Stantić et al., 2021). In **Chapter 5**, our findings regarding alexithymia as a key driver of poor facial expression recognition align well with existing literature (Bird & Cook, 2013; R. Cook et al., 2013). Therefore, despite potential concerns about minor deception among participants, the replication of these effects strongly supports the validity of our research.

7.1.5 Responsible research commitments to the autistic and neurodivergent communities

In the second year of this project, we established an advisory board to collaborate with members of the autistic community, recognising the importance of improving the accessibility to our research materials. This collaboration helped us to identify areas for improvement, such as making experimental instructions clearer and more coherent. Furthermore, the qualitative reports we collected in **Chapter 6** around the lived experiences of individuals struggling with face recognition difficulties demonstrated how valuable this kind of insight is.

It is imperative to acknowledge that the autistic community, including neurodivergent individuals from racialised and gender minoritised communities, have historically faced systematic harm, marginalisation and dehumanisation by the academic-industrial complex. For a comprehensive exploration, see Botha (2021) and Dawson & Fletcher-Watson (2022). Therefore, should our advisory board continue after this doctoral research project, we are keen to recruit autistic Lived Experience (LE) experts who are i) independent and impartial from our studies (our current advisors were invited to take part in our studies whilst also providing feedback on the research materials, this may have added some positive bias in their feedback), ii) are adequately reimbursed for their time accordingly and in line with

National Institute for Health and Care Research (NIHR) guidance and iii) who are able to provide LE expertise at a strategic level whereby their feedback on research aims, experiments and dissemination are embedded throughout the project cycle.

Future research on face processing in autism would greatly benefit from close collaboration with the autistic community in the ways described above. Such partnerships can integrate community-driven insights and strengths to create impactful translational support for autistic individuals who live with poor face recognition. The Centre for Research in Autism and Education (CRAE) at the University of London provides excellent examples of how embedded lived experience co-production can enhance autism research.

7.1.6 Commitment to Open Science

In accordance with Centre for Open Science (COS) recommendations, all data from this thesis, except the potentially identifiable qualitative data in **Chapter 6**, has been shared on the Open Science Framework (OSF). Our experimental paradigms for facial identity and expression recognition are also available on Gorilla Open Materials. The research articles arising from this body of work are all publicly available via the publishing journal or through institutional repositories.

7.2 Conclusion

This thesis aimed to understand the significant variability in face processing ability among autistic individuals. Using behavioural paradigms, we investigated the heterogeneity in facial identity and expression recognition ability in autistic individuals. Our findings suggest that difficulties in facial identity recognition in autism are likely due to poor perceptual input into learning mechanisms rather than atypical perceptual learning processes. We also found that autistic individuals, like non-autistic individuals, can accurately assess their face recognition abilities, validating the use of the PI20 questionnaire to screen for face recognition difficulties in this population. Furthermore, our work supports the view that impaired facial expression recognition in autistic individuals is attributable to high levels of co-occurring alexithymia

rather than autism per se. Lastly, our findings are the first to suggest that autistic individuals with poor face recognition may experience persistent psychosocial challenges similar to those faced by individuals with developmental prosopagnosia (DP). Overall, the work contained within this thesis confirms the presence of face processing problems in the autistic population and underscores the psychosocial consequences of those difficulties, where observed.

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