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Indistinguishable behavioural and neural correlates of perceptual self-other distinction in autistic and neurotypical adults

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ABSTRACT

Previous research has suggested that self-bias (i.e., enhanced cognitive processing of self- versus other-relevant information) may be atypical in autism spectrum conditions (ASC), perhaps due to difficulties with self-other distinction. However, empirical evidence for this is inconsistent, and the neural basis of processing differences remains unknown. We present two experiments that aimed to test perceptual self-bias and familiarity effects in ASC using a perceptual-association task. Participants were asked to distinguish face/label associations of the self from those of other people of differing levels of familiarity (i.e., friend *vs* stranger). Experiment 1 took an individual differences approach by testing whether behavioural self-bias is associated with the number of autistic traits in a neurotypical adult sample ($N = 59$). Experiment 2 took a case–control approach by testing whether behavioural self-bias and associated ERP responses differ between neurotypical ($N = 27$) and autistic ($N = 30$) adults. Across both experiments, behavioural results showed that participants experienced a self-bias (self > friend and stranger) and a familiarity effect (e.g., friend > stranger); neither effect was affected by the number of autistic traits or autism diagnosis. In Experiment 2, analysis of N1, N2, and P3 ERP components revealed a typical self-bias in both groups (self distinct from friend and stranger), and only the autistic group showed evidence of a familiarity effect (N2 more negative-going for stranger than friend). The findings are discussed in relation to self-other distinction ability, and the relevance of other neuropsychological and psychiatric conditions such as anxiety and alexithymia are also considered.

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1. Neural correlates of perceptual self-other distinction in autistic and neurotypical adults

Research often finds *self-biases* in cognition – the phenomena whereby people show enhanced cognitive processing for information processed in relation to the self, than for information processed in relation to someone else, or in other ways. Such self-bias provides an index of self-other distinction, as it enables us to test the extent to which the self is processed differentially compared to others. Self-biases have been observed to be diminished in adults and children with autism spectrum conditions (ASC) compared to neurotypical people in the domain of memory (Burrows et al., 2017; Grisdale et al., 2014; Henderson et al., 2009; Lombardo et al., 2007). However, in the perceptual domain, research suggests that self-bias effects may be typical in ASC. For example, Williams et al. (2018) used the perceptual shape association task (Sui et al., 2012) and found that autistic adults ($N = 22$), like neurotypical adults ($N = 21$), showed enhanced performance (i.e., faster RT and higher accuracy) for self-relevant matches compared to other-relevant matches. Importantly, there was no between-group difference in the speed and accuracy of responses, and unlike findings in the memory domain (e.g., Henderson et al., 2009), individual differences in the number of autistic traits were unrelated to the magnitude of self-bias effects in either this case–control sample, or in a larger sample of neurotypical participants ($N = 124$; Williams et al., 2018; see also Amodeo et al., 2021). Further evidence of typical self perceptual processing in ASC has been found using more complex (unfamiliar) face stimuli paired with self and other labels (Zhao et al., 2018). Together, these findings suggest that atypicalities in self-referential processing are not domain-general in autism.

The finding that self-relevant processing may be typical in ASC only under certain conditions might reflect the notion that autistic individuals are better able to compensate for their diminished self-referential cognition in certain domains, and/or when task difficulty is reduced (Bowler et al., 2015). Tasks that tap memory processes are likely to be more cognitively demanding than those that tap lower-level perception, and furthermore the neural basis of these processes are different (Quesque & Brass, 2019). Another factor that has been shown to reduce the difficulty of other processing is to relate information to familiar (e.g., self or mother) rather than unfamiliar (e.g., stranger) others. In the perceptual shape association task described above (Sui et al., 2012), responses were faster and more accurate for shapes that have been associated with familiar than unfamiliar other labels. Indeed, some researchers have reported that familiar others are processed comparably to the self due to the high degree of overlap in their representations (Ketay et al., 2019). Importantly, Williams et al. (2018) replicated the familiarity effect on perceptual performance in autistic adults, and no difference was found between autistic and neurotypical groups. In this paper, we consider that the purest index of self-other distinction (i.e., the ability to distinguish representations of the self from those of others) involves comparing processing for self and familiar others since they are both familiar to the self (unlike famous/unfamiliar others) and only differ on personal relevance. In contrast, the purest index of familiarity involves comparing processing for familiar and unfamiliar others (i.e., friend *vs* stranger) since they are both distinct from the self and differ on familiarity.

To date, very little is known about the real-time neural correlates that underlie self- and familiarity-biases in autism, though such investigations will undoubtedly enhance our understanding of the underlying mechanisms. Finding that neural responses differ (i.e., either by different amplitudes or latencies of ERP effects) between autistic and neurotypical people, despite undiminished behavioural responding, would suggest that autistic people experience atypicalities in their early perceptual processing, but may recruit additional processes to compensate for this in their behavioural expression of self-other processing. Alternatively, finding that neural responses during self-referential tasks do not differ between autistic and neurotypical people would support the notion that self-bias and familiarity effects are undiminished in ASC from the perceptual level in the earliest moments of processing (e.g., Williams et al., 2018; Zhao et al., 2018).

In this paper, we address these questions by extending previous studies in the perceptual domain using a face-label task that distinguishes self- and other-relevant processing, and testing the extent to which effects of self-reference and familiarity are altered in neurotypical adults with a higher number of autistic traits (Experiment 1) or in autistic adults (Experiment 2). In Experiment 2, we complement the standard behavioural data collected in these tasks by recording temporally sensitive event-related potentials (ERPs) in response to face-name pairings to examine the real-time mechanisms that underlie self- and other-relevant processing in autism and neurotypical adults. This allowed us to test for real-time evidence of difficulties with self-other distinction that might not be evident at a behavioural level.

1.1. *Neural underpinnings of perceptual self-bias in ASC: evidence from EEG*

A growing body of research has examined self-other processing in neurotypical adults using ERPs (see Knyazev, 2013 for a review). This work typically manipulates the consistency of self-reference with auditory, visual or sensory experiences (e.g., own name/face pairings, Cygan et al., 2014; self/other touch, Deschrijver, Wiersema, & Brass, 2016; self/other perspective-taking, Ferguson, Brunsdon, & Bradford, 2018; shape and self/other-relevant label associations, Sui et al., 2023), and has converged on showing modulation of the P3 ERP component when processing self-relevant compared to other-relevant information, suggesting that this component indexes the distinction between self and other perspectives. There is mixed evidence on whether P3 is influenced by the familiarity of the other, with some studies showing no difference in P3 between self- and close-other names (both elicit a P3 that is larger than unfamiliar-other names; Tacikowski et al., 2014), and others showing attenuated P3 modulation for self-other conflicts that involve a less versus more similar other (Ferguson et al., 2018). Very little research has examined the neural underpinnings of self-reference and familiarity in ASC, therefore it remains unclear whether neural indices of self and other processing differ in autism despite typical behavioural responses.

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Two recent ERP studies have compared self- and other-referential processing between autistic and neurotypical people in the visual domain (Cygan et al., 2014; Nowicka et al., 2016). Among neurotypical participants, ERPs showed an enhanced P3 in response to participants' own face/name stimuli compared to both close- and unfamiliar-other relevant stimuli, as well as preferential processing (i.e., enhanced P3 amplitude) for close others compared to unfamiliar others. These patterns reflect the expected self-bias and familiarity-bias in neurotypical people. In contrast, autistic participants showed the typical P3 effect for self-relative to unfamiliar-other stimuli, but no difference in P3 amplitude between self- and close-other stimuli (i.e., both own and close-other stimuli elicited a higher P3 amplitude). These patterns suggest that at a neural level, autistic people experience an atypical self-reference effect on perception (i.e., attention is not preferentially allocated for the self-*versus* familiar-others), but a typical familiarity effect (i.e., familiar self and other stimuli are processed preferentially to unfamiliar-other stimuli).

One other study used an *auditory* oddball task to compare neural responses to self-other processing between autistic and neurotypical people (Nijhof et al., 2022). They found that while neurotypical adults elicited an enhanced late parietal positivity (similar to P3) to self-relevant stimuli (i.e., auditory presentation of their own name) relative to other-relevant stimuli (close- and unfamiliar names did not differ), autistic adults did not distinguish the self from either close- or unfamiliar-other stimuli on the late parietal positivity component. Both groups showed evidence of a familiarity effect on the early N1 component (i.e., higher amplitudes for self and close-other *vs* unfamiliar-other) (see also Schwartz et al., 2020). These patterns are consistent with findings in the visual domain, showing that the neural responses to self-relevant information may be atypical in autism, but familiarity is typical (Cygan et al., 2014; Nowicka et al., 2016).

Despite autistic adults showing general similarities in response to self-relevant and familiar stimuli, P3 responses in autistic participants to self-relevant stimuli were only enhanced relative to unfamiliar-others in the visual tasks (Cygan et al., 2014; Nowicka et al., 2016), but in auditory tasks, either did not differ (Nijhof et al., 2018) or were significantly reduced relative to neurotypical participants (Schwartz et al., 2020). The discrepant findings might reflect differences in modality and task demands between studies (Nijhof et al., 2018). In Cygan et al.'s (2014) and Nowicka et al.'s (2016) visual tasks, the processing of self-relevant stimuli was task *relevant,* in that participants were required to press a key in response to seeing self-relevant stimuli. In contrast, the processing of self-relevant stimuli was task *irrelevant* in Nijhof et al.'s (2018) and Schwartz et al.'s (2020) auditory tasks; participants were not required to respond to self-relevant stimuli, and attending to it would impede rather than support task performance (Nijhof et al., 2018). This suggests that autistic adults do not automatically distinguish familiar (e.g., self and familiar-other) from unfamiliar (unfamiliar-other) stimuli in the same way as neurotypical people. Providing explicit instructions to attend to specific stimuli, may prompt autistic participants to compensate for this atypicality.

The possibility that autistic people use different self-related attentional mechanisms has been tested recently using the attentional blink paradigm. Nijhof et al. (2022) found that the attentional blink (i.e., difficulty detecting the second of two target stimuli presented in close temporal succession) is reduced when the second target was the participant's own name compared to a close other (self-bias) or an unfamiliar other name (i.e., a familiarity effect), and did not differ in magnitude between ASC and neurotypical adults. This suggests that the attentional self-bias is typical in ASC. This self-bias was reflected in higher N2 amplitude (alongside an increased N2 and P3 for the familiarity effect), which also did not differ between ASC and neurotypical adults. Since previous studies that showed atypical ERP correlates of self-bias in ASC (Cygan et al., 2014; Nijhod et al., 2018; Nowicka et al., 2016) all did so at later stages of cognitive processing (late P3/late parietal positivity), it may be that early-stage self-referential cognition is typical in ASC (Nijhof & Bird, 2019; Nijhof et al., 2022; Williams et al., 2018), with atypicalities only appearing at later stages (Nijhof et al., 2022).

1.2. *The current study*

The current study used a perceptual association task (Sui et al., 2012, 2023; Williams et al., 2018; Zhao et al., 2018) to test whether self-biases and familiarity-biases on perception are altered in ASC by exploring whether binding of information to the self elicits a similar ERP response between autistic and neurotypical adults. In contrast to the geometric shapes (e.g., Williams et al., 2018) or familiar face stimuli (Cygan et al., 2014; Nowicka et al., 2016) used in previous studies, the current study replicates the design used by Zhao et al. (2018) by using unfamiliar-faces that have been learned with a label for the self or other; participants' own faces or faces of known familiar-others were not used to minimise the influence of bottom-up familiarity or personal salience. Zhao et al. (2018) found that the self-reference effect of unfamiliar face processing was typical in autistic adults, however they did not test the familiarity effect. We extend this work by recording the real-time neural correlates of self and familiarity effects in autistic and neurotypical adults.

In Experiment 1, we tested whether behavioural indices of self-bias and familiarity effects are associated with the number of autistic traits in a sample of neurotypical adults. Experiment 2 took a case–control approach by testing whether behavioural and ERP indices of self-bias and familiarity effects differ between neurotypical and autistic adults. The current paper therefore adds to the previous literature by employing a more complex and ecologically-valid unfamiliar face-name task (building on the more simple and abstract geometric shape-name versions of this association task that have dominated this literature), and combining behavioural (e.g., Williams et al., 2018) and ERP (e.g., Cygan et al., 2014; Nijhof et al., 2018; Schwartz et al., 2020) evidence to test whether previous evidence for typical behavioural indices of self-bias and familiarity bias in autism are replicated in this more complex design. It also enables examination of both associations with autistic traits and group-level differences in self-bias and familiarity effects. By recording ERPs we aimed to test whether typical self-bias and familiarity effects are accompanied by comparable real-time neural responses. Finally, the combination of behaviour and ERPs enabled us to

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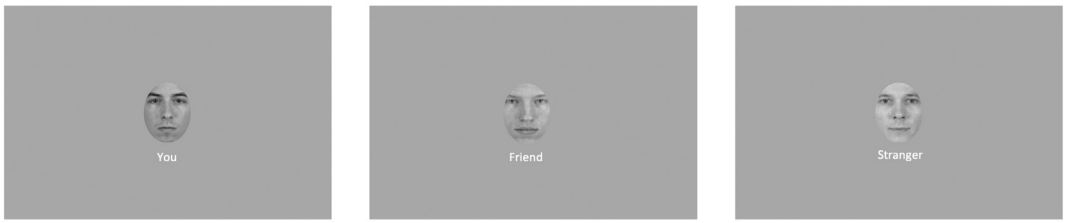

Fig. 1 – Illustration of learning phase slides. At the beginning of the experiment, each face-label match was presented for 20 sec.

examine spontaneous and controlled self- and familiarity-influences, and whether typical behavioural performance in autism might be driven by alternative mechanisms compared to neurotypical people (evident on neural measures).

In line with previous behavioural research using the perceptual association task, we predicted that the size of the self-bias and familiarity effects on behavioural measures would be unrelated to the number of autistic traits (Experiment 1) and would be undiminished in autistic adults compared to matched neurotypical adults (Experiment 2). Furthermore, we predicted that ERP measures would show an enhanced N1, N2, and P3 amplitude for self matches compared to both friend and stranger matches, which would also differ significantly (Self > friend > stranger). Based on the existing behavioural findings in the perceptual domain in ASC, we predicted that autistic and neurotypical groups would not differ in their neural responses, with both showing evidence of a self-bias and familiarity effect on ERP responses.

In both experiments, we report how we determined our sample size, all data exclusions, all inclusion/exclusion criteria, whether inclusion/exclusion criteria were established prior to data analysis, all manipulations, and all measures in the study.

2. Experiment 1: Method

2.1. Participants

We recruited a volunteer sample of 59 University of Kent undergraduate students. One participant was excluded from analysis because they scored below 33% accuracy (i.e., below chance-level, suggesting that they did not remember the trained face-label pairings) on the task, thus the final sample included 58 participants (13 male; 45 female) aged 18–27 (M = 19.22; SD = 1.45). An *a priori* power analysis using G*Power (Vinet & Zhedanov, 2010) revealed that 12 participants would be enough to detect a referent x trial type interaction with effect size 1.31 (Williams et al., 2018, Exp. 1) and power of .90. The larger sample size of n = 59 was recruited to enable correlation analyses of the self-bias and familiarity effects with individual differences in autistic traits. A *post-hoc* power analysis shows that this sample size achieved a power of .65 to detect a Pearson's correlation coefficient of r = .3 (alpha = .05, two-tailed) for the association between AQ and self-bias score.

Participants had normal or corrected-to-normal vision and self-reported no history of psychiatric or neurological conditions. All participants provided written informed consent and following completion of the experiment, participants were fully debriefed and received partial course credits for their participation. Ethical approval was provided by University of Kent Research Ethics Committee.

2.2. Design

This was a 3 (Referent: Self/Friend/Stranger) x 2 (Trial type: match/mismatch) within-subjects design.

2.3. Materials and procedure

Self-Referential Perceptual Matching Task: The task was created using Psychopy2 (Peirce et al., 2019). The *learning phase* (see Fig. 1) had the purpose of teaching participants about the identity of three neutral faces. Participants were presented sequentially with three faces (taken from Ma et al., 2015) for 20 s each. Each face had direct gaze, and non-face features (e.g., hair; ears) were removed using Microsoft Paint/Paint 3D. Simultaneously, a label (either "You", "Friend", or "Stranger") was presented below each face, in Calibri bold white font. Participants were instructed to "remember the three face-label matches". Importantly, the identity of each face (e.g., either you, friend, or stranger), and the order that each face-label match was presented in the learning phase was randomized across participants to avoid order effects.

Test phase: on each trial (see Fig. 2), there was a blank screen (500 msec) followed by a centrally positioned white fixation cross (500 msec), after which one of the three faces was presented (100 msec) above *either* the label that was previously

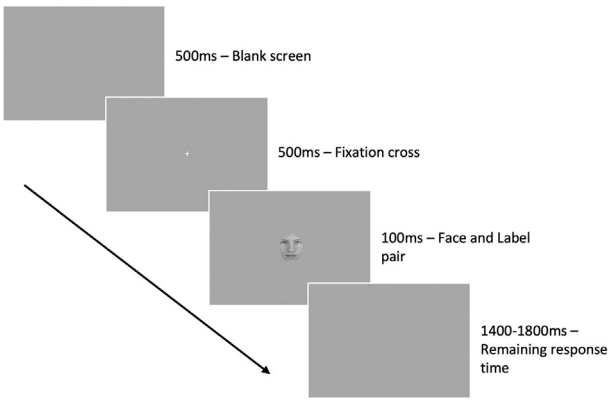

Fig. 2 – Illustration of an example trial in the test phase.

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associated with the face – a *match* (self-associated face + "You"; friend-associated face + "Friend"; stranger-associated face + "Stranger") – or one of the labels that was associated with one of the other two faces – a *mismatch* (self-associated face + "Friend" or "Stranger"; friend-associated face + "You" or "Stranger"; stranger-associated face + "You" or "Friend"). Participants were asked to respond as quickly and accurately as possible when the face-label pair presented was a match (by pressing key "c") or a mismatch (by pressing key "m"). The response window started from the onset of the face-label pair presentation and continued for a further 1400–1800 msec (randomised across trials). Performance feedback ("correct" or "incorrect") was presented centrally on screen (400 msec) after each of the 12 familiarisation trials at the start of each block. If participants scored below chance on the first set of 12 familiarisation trials, then they repeated the learning phase and the first set of familiarisation trials. The main task included three blocks, each containing 120 experimental trials presented in a random order (i.e., 360 experimental trials in total), including 60 match (20 for each of the three possible correct combinations) and 60 mismatch (10 for each of the six possible incorrect combinations) trials. No feedback was given on performance. The dependent variables were participants' mean RT and accuracy (proportion of correct responses) on match and mismatch trials for each referent. The task took approximately 15 min to complete.

Socio-emotional features: Two established measures were used to assess autistic traits (the 50-item Autism-spectrum Quotient (AQ); Baron-Cohen et al., 2001; Ashwood et al., 2016; $M = 19.55$; $SD = 7.05$) and camouflaging tendency (Camouflaging Autistic Traits Questionnaire (CAT-Q); Hull et al., 2019; $M = 98.12$; $SD = 23.11$); see Supplementary Materials. These measures were included to assess whether these socio-emotional features are associated with the size of the self-bias and familiarity-bias in this task. On the AQ, nine participants (~15%) scored above the screening cut-off (26 or above), and four participants (~7%) scored above the clinical cut-off (32 or above). Legal copyright restrictions prevent public archiving of these established measures, but they which can be obtained from the copyright holders in the cited references.

Bayesian Analysis: Bayesian analysis was also used to interpret the results (conducted using JASP .14.1; JASP Team, 2020), which enables a more graded interpretation than only using p values or effect sizes. This estimates the relative strength of the alternative hypothesis over the null hypothesis, or vice versa (e.g., Dienes, 2014; Rouder et al., 2009). For the Bayesian analyses, we adopted the default Cauchy priorsBayes factor (BF^{10}) < 1 is evidence supporting the null hypothesis (<.33 is firm evidence), and Bayes factors >3, >10, >30, and >100 are firm, strong, very strong, and decisive evidence supporting the alternative hypothesis respectively.

3. Experiment 1: Results

Data can be found on open science framework (https://osf.io/br98c/). Analyses were conducted using SPSS statistical software and drop-down menus, therefore analysis scripts are not available.

Trials were excluded from RT and accuracy analysis if the RT exceeded three standard deviations from the participant's overall mean or from the mean RT of the group overall (this excluded 13.98% of trials); trials were also excluded from the RT analysis if answered incorrectly. Two ANOVAs were conducted to analyse the effect of referent, and trial type on RT and accuracy using 3 (Referent: self/friend/stranger) x 2 (Trial type: match/mismatch) repeated measures ANOVAs. See Fig. 3.

Accuracy: There was a significant main effect of referent, $F(2, 114) = 34.34$, $p < .001$, $\eta_p^2 = .38$, $BF^{10} > 100$. Post-hoc paired samples t-tests revealed that accuracy followed a pattern of self > friend > stranger, whereby accuracy on self trials was higher than for friend, $t(57) = 4.42$, $p < .001$, $d = .58$, and stranger trials, $t(57) = 7.46$, $p < .001$, $d = .98$; accuracy was also higher for friend than stranger trials, $t(57) = 4.53$, $p < .001$, $d = .60$. There was no significant main effect of trial type, $F(1, 57) = .57$, $p = .46$, $\eta_p^2 = .01$, $BF^{10} > 100$.

The trial type × referent interaction was significant, $F(2, 114) = 22.32$, $p < .001$, $\eta_p^2 = .28$, $BF^{10} > 100$. Post-hoc paired samples t-tests revealed that accuracy followed a pattern of self > friend > stranger conflated over both match and mismatch trial types, with the difference between conditions as described above (all ts > 2.24, ps < .03).

RT: Analysis of RT revealed a significant main effect of trial type, $F(1, 57) = 298.75$, $p < .001$, $\eta_p^2 = .84$, $BF^{10} > 100$, whereby RT was faster on match than mismatch trials. There was also a main effect of referent, $F(2, 114) = 60.34$, $p < .001$, $\eta_p^2 = .51$, $BF^{10} > 100$. Post-hoc paired samples t-tests revealed that RT followed a pattern of self < friend < stranger, whereby RT for self trials was significantly faster than for friend, $t(57) = 8.35$, $p < .001$, $d = 1.10$, and stranger trials, $t(57) = 10.89$, $p < .001$, $d = 1.43$; RT was also significantly faster for friend than stranger trials, $t(57) = 2.63$, $p = .01$, $d = .35$.

There was a significant trial type × referent interaction, $F(2, 114) = 28.87$, $p < .001$, $\eta_p^2 = .34$, $BF^{10} > 100$. The referent effect was significant in match trials, $F(2, 114) = 59.34$, $p < .001$, $\eta_p^2 = .51$, $BF^{10} > 100$, and mismatch trials, $F(2, 114) = 10.52$, $p < .001$, $\eta_p^2 = .16$, $BF^{10} > 100$. Post-hoc paired samples t-tests revealed that in match trials, RT followed a pattern of self < friend < stranger, with the difference between conditions as described above (all ts > 3.01, ps < .004). In mismatch trials, RT followed a pattern of self < friend = stranger, whereby RT for self mismatches were significantly faster than for friend mismatches, $t(57) = 4.76$, $p < .001$, $d = .59$, and stranger mismatches, $t(57) = 3.10$, $p = .003$, $d = .41$; Friend mismatches did not significantly differ in RT from stranger mismatches, $t(57) = 1.41$, $p = .17$, $d = .19$.

3.1. Association analysis

We calculated a self-bias score for RT and accuracy by subtracting the RT/accuracy for self-relevant matches from the average combined RT/accuracy for familiar-other and unfamiliar-other matches. A Pearson's correlation revealed that there was no significant correlation between the size of the RT self-bias effect and AQ, $r(58) = -.15$, $p = .25$, $BF^{10} = .31$, or

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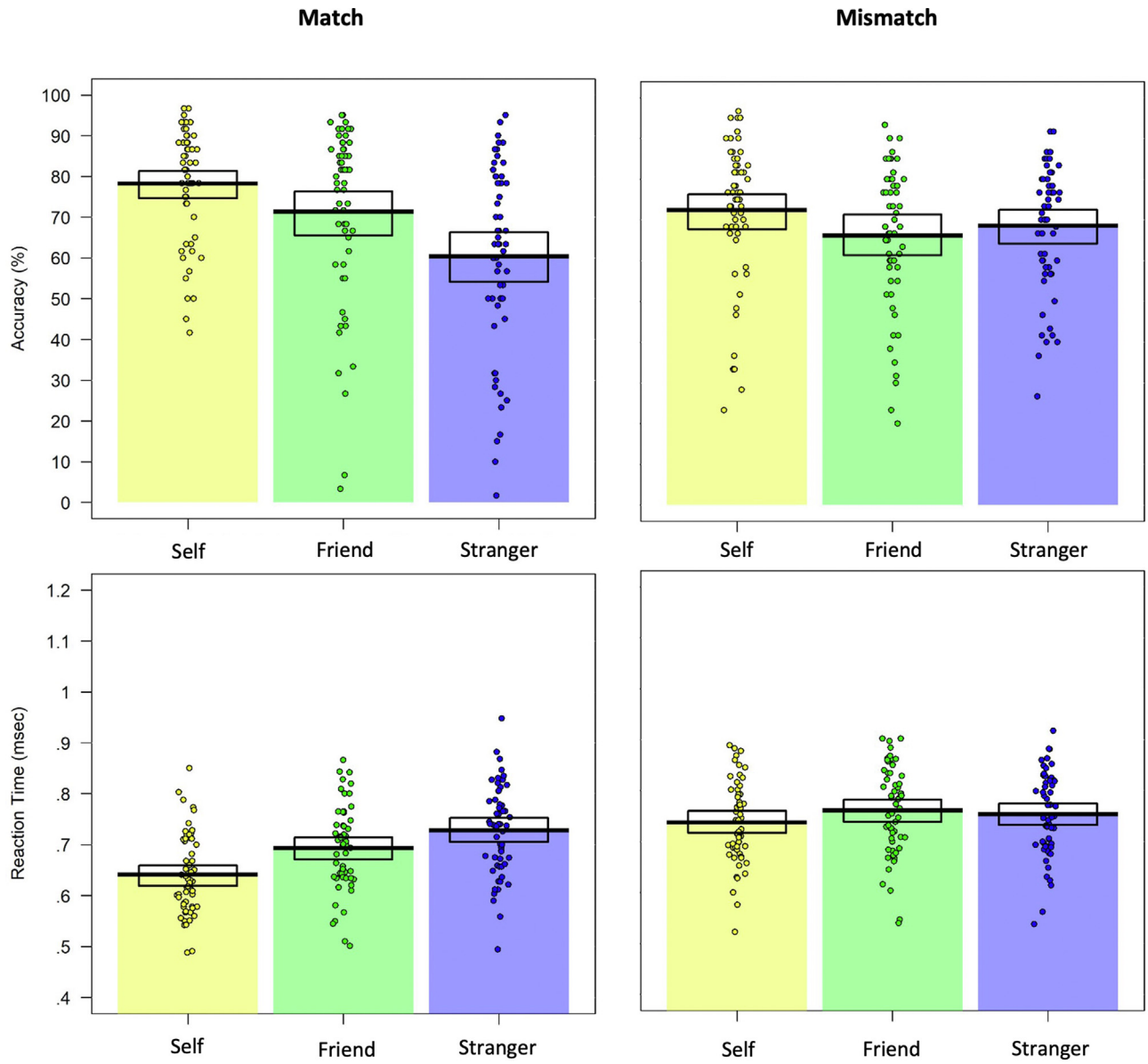

Fig. 3 – Accuracy and RT descriptive statistics for each referent in match (left panel) and mismatch (right panel) trials in Experiment 1. Boxed area represents 95% confidence interval.

CAT-Q, $r(58) = -.22$, $p = .09$, $BF^{10} = .69$, and no significant correlation between the size of the accuracy self-bias effect and AQ, $r(58) = -.005$, $p = .97$, $BF^{10} = .16$, or CAT-Q, $r(58) = .05$, $p = .69$, $BF^{10} = .18$.

We also ran exploratory (i.e., not pre-registered) correlations on the familiarity-effect for RT and accuracy, to examine whether socio-emotional features (including autistic traits) differentially influence the familiarity-effect and the self-bias effect. This was calculated by subtracting the average combined RT/accuracy for self and familiar-other matches from the unfamiliar-other matches. A Pearson's correlation revealed that there was no significant correlation between the size of the RT familiarity effect and AQ, $r(58) = .06$, $p = .64$, $BF^{10} = .18$, or CAT-Q, $r(58) = .01$, $p = .95$, $BF^{10} = .16$ and no significant correlation between the size of the accuracy familiarity effect and AQ, $r(58) = .03$, $p = .81$, $BF^{10} = .17$, or CAT-Q, $r(58) = .05$, $p = .69$, $BF^{10} = .18$.

3.2. *Summary*

In Experiment 1, we replicated both the self-bias effect and the familiarity effect on perception, using temporarily learned associations between (unfamiliar) faces and referent labels (self, friend, stranger). Participants were faster and more accurate when responding to a self-associated face compared to a friend-associated face, and even slower/less accurate when responding to a stranger-related face. Importantly, the self-bias effect was not associated with individual differences in autistic traits or camouflaging. The results are therefore consistent with our predictions and those reported for more

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abstract shape-label pairings (Williams et al., 2018, Experiment 1).

4. Experiment 2: Method

Methods and analysis for Experiment 2 were fully pre-registered on the Open Science Framework (https://osf.io/62w7n).

4.1. Participants

Participants were recruited from the Autism Research at Kent participant database, which includes autistic and neurotypical adults who have consented to being contacted to take part in research studies. The recruited sample included 27 neurotypical adults (16 male; 11 female) with no history of psychiatric or neurological conditions (self-report) and 30 adults with a clinical diagnosis of ASC (19 male; 12 female). One autistic participant was excluded from the analysis because they scored below 33% on the face-label task (see Table 1). The final sample of autistic participants (18 male; 12 female) either had a diagnosis of autistic disorder ($N = 6$), autism spectrum disorder ($N = 4$), Asperger's syndrome ($N = 10$) or not known ($N = 9$). We note that of the total participants who took part in this experiment, five autistic and three neurotypical were excluded from the ERP analyses due to poor quality of EEG data (resulting in a trial loss of >40%) or technical problems with EEG recording. Thus, the final ERP sample included 25 autistic participants and 24 neurotypical participants (see Table 3 in Supplementary Materials).

Participants completed the Wechsler Adult Intelligence Scale (WAIS-III or WAIS-IV; Wechsler, 1997; Wechsler, 2008) with a trained researcher, either after the main task, or in a separate testing session. Participant groups did not differ significantly on age, gender, or Intelligence Quotient (IQ; see Table 1 for group contrasts for the full score, verbal and performance scaled indices). To assess the current autistic characteristics, autistic participants were also assessed on module 4 of the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000) by a trained, research-reliable researcher, and videos were double coded by an additional trained, research-reliable researcher to ensure reliability of scoring (inter-rater reliability was found to be excellent with intraclass correlation of .89). Legal copyright restrictions prevent public archiving of the WAIS or ADOS, but they which can be obtained from the copyright holders in the cited references.

Participants provided written informed consent and were fully debriefed following completion of the experiment. They received £10 per hour of their participation, plus additional travel expenses. Ethical approval was provided by School of Psychology Research Ethics Committee at University of Kent.

4.2. Design

This was a 2 (Group: ASC/neurotypical) x 3 (Referent: Self/Friend/Stranger) x 2 (Trial type: match/mismatch) mixed design with repeated measures on the last two factors.

4.3. Materials and procedure

The materials and procedure for the self-referential perceptual matching task was identical to that outlined in Experiment 1.

Socio-emotional features: Participants completed the same questionnaire measures (the 50-item AQ, CAT-Q) as outlined in Experiment 1. In addition, participants completed two established measures to assess anxiety (Beck Anxiety Inventory (BAI); Beck et al., 1988), and alexithymia (Toronto Alexithymia Scale (TAS-20); Bagby et al., 1994); see Supplementary Materials. These measures were included to assess whether these socio-emotional features are associated with the size of the self-bias and familiarity-bias in this task. Legal copyright restrictions prevent public archiving of these established measures, but they which can be obtained from the copyright holders in the cited references.

Bayesian Analysis: Like Experiment 1, Bayesian analysis was also used to interpret the behavioural results (conducted using JASP .14.1; JASP Team, 2020).

4.4. EEG recording and analysis

A Brain Vision Quickmap amplifier system was used to record continuous EEG activity during the self-referential perceptual matching task. A 32-channel ActiCap was used to measure EEG over midline electrodes Fz, Cz, Pz, and Oz, over the left

Table 1 – Participant characteristics in Experiment 2. See Supplementary Materials for full details of each measure and scoring. Note: some tasks have missing data, so statistics are reported on maximal data for each task. IQ determined using Wechsler Adult Intelligence Scale (scaled scores); ADOS = Autism Diagnostic Observation Schedule; AQ = Autism-spectrum Quotient; TAS-20 = Toronto Alexithymia Scale; BAI = Beck Anxiety Inventory; CAT-Q = Camouflaging Autistic Traits Questionnaire.

	Autistic ($N = 29$; 18 male)				Neurotypical ($N = 27$; 16 male)				t	p	d
	Mean	SD	Range	N	Mean	SD	Range	N			
Age (years)	32.86	11.64	20–59	29	38.93	14.81	19–68	27	1.71	.09	.46
IQ: Full Scale	107.76	13.50	73–137	29	110.54	9.51	93–133	26	.87	.39	.24
IQ: Verbal	104.52	10.52	86–126	29	109.42	10.97	92–129	26	1.69	.09	.46
IQ: Performance	110.07	18.98	65–143	29	110.5	11.4	89–144	26	.10	.92	.03
ADOS: Total	8.33	5.76	1–21	18	–	–	–	–	–	–	–
AQ: Total	30.36	10.21	10–59	28	13.68	5.81	3–28	25	7.19	<.001	1.98
TAS-20: Total	58.36	19.01	5–84	28	43.18	10.89	28–65	22	3.33	.002	.95
BAI: Total	26.64	13.59	6–62	28	11.42	7.8	0–30	26	5.00	<.001	1.36
CAT-Q: Total	119.04	27.49	55–163	28	82.81	17.44	38–109	26	5.73	<.001	1.56

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hemisphere from electrodes Fp1, F3, F7, FC1, FC5, T7, C3, CP1, CP5, TP9, P3, P7, PO9, O1, and from the homologue electrodes over the right hemisphere. EEG data was referenced online to electrode FCz, and grounded to electrode AFz. EEG and EOG recordings were sampled at a rate of 500 Hz. Electrode impedances were kept at <25 KΩ.

Brain Vision Analyzer 2 software was used to pre-process the data before analysis. Offline, noisy or faulty electrodes were interpolated from surrounding channels (a maximum of 3 channels) and EEG data was re-referenced to the mean of right and left mastoids. EEG and EOG activity was then band-pass filtered (.1–30 Hz, notch filter at 50Hz), and data containing blinks was corrected using a semi-automatic ocular ICA correction approach (Brain Vision Analyzer 2.1). Next, EEG data was aligned to the onset of the visual stimuli (i.e., the face and label) and segmented into epochs from −200 msec to 1500 msec. Semi-automatic artifact detection was used to identify and discard segments with non-ocular artifacts (drifts, channel blockings, EEG activity exceeding ± 50 μV). Together, these procedures resulted in an average of 58 accepted segments per condition/participant. The remaining data was aligned to a -200-0 msec baseline period, then averaged per participant and condition.

Three ERP components were identified for analysis in our pre-registration: mean amplitude in the N1 (80–120 msec), N2 (200–260 msec) and P3 (250–600 msec; Comerchero & Polich, 1999; Polich, 2007; Polich & Kok, 1995) time-windows.[1] N1 is a negative-going component that peaks between 80 and 120 msec, and earlier over anterior than posterior regions. N1 is thought to reflect an early *involuntary* shift of attention to familiar stimuli (Holler et al., 2011; Tateuchi et al., 2012), particularly those in which people have a level of expertise/high degree of familiarity (Tanaka & Curran, 2001). N2 is a negative-going component that peaks between 200 and 350 msec primarily over anterior regions, but is also observed over posterior regions in visual attention paradigms (Folstein & Van Petten, 2007).

N2 is thought to reflect conflict monitoring and/or response inhibition mechanisms (Donkers & van Boxtel, 2004; Jolicœur et al., 2006; Kranczioch et al., 2007; Nijhof et al., 2022). The P3 is a positive-going component that peaks between 250 and 500 msec over central parietal electrode sites, and has been linked with self-referential processing and self-other distinction (see Introduction). In contrast to typical oddball effects on the P3, self-reference effects typically elicit larger P3 amplitudes for self-*compatible* conditions compared to self-*incompatible* conditions (Deschrijver et al., 2017).

Statistical analyses were run separately for midline and lateral electrode sites. Midline analyses included electrodes Fz, Cz, Pz and Oz. Lateral analyses were conducted on quadrant means involving the left anterior electrodes F3, F7, FC1, FC5; right anterior electrodes F4, F8, FC2, FC6; left posterior electrodes CP1, CP5, P3, P7, O1; and right posterior electrodes CP2, CP6, P4, P8, O2 (representing an Anterior–posterior x Hemisphere design).

5. Experiment 2: Results

Data can be found on open science framework (https://osf.io/br98c/). Analyses were conducted using SPSS statistical software and drop-down menus, therefore analysis scripts are not available.

5.1. *Behavioural analyses*

Trials were excluded from further analysis if the RT exceeded three standard deviations from the participant's overall mean or from the mean RT of the diagnosis group (this excluded 14.17% of trials in the neurotypical group, and 3.65% of trials in the autistic group); trials were also excluded from the RT analysis if answered incorrectly.[2] Two ANOVAs were conducted to analyse the effect of group, referent, and trial type on RT (ANOVA 1) and accuracy (ANOVA 2) using 2 (Group: autistic/neurotypical) × 3 (Referent: self/friend/stranger) x 2 (Trial type: match/mismatch) mixed ANOVAs with repeated measures on the last two factors. See Fig. 4.

Accuracy: All assumptions for the current analysis were met. Analysis revealed a significant main effect of trial type, $F(1, 54) = 6.45$, $p = .01$, $\eta_p^2 = .11$, $BF^{10} = 1.29$, whereby accuracy was higher for mismatches than matches. There was also a significant main effect of referent, $F(2, 108) = 17.92$, $p < .001$, $\eta_p^2 = .25$, $BF^{10} > 100$. Post-hoc paired samples t-tests revealed that accuracy followed a pattern of self > friend = stranger, whereby accuracy on self trials was higher than for friend, $t(55) = 4.54$, $p < .001$, $d = .61$, and stranger trials, $t(55) = 5.08$, $p < .001$, $d = .68$; however, accuracy did not differ between friend and stranger trials, $t(55) = .44$, $p = .66$, $d = .06$. There was no significant main effect of group, $F(1, 54) = .25$, $p = .62$, $\eta_p^2 = .01$, $BF^{10} = .43$, and no interaction between group x referent, $F(2, 108) = .35$, $p = .71$, $\eta_p^2 = 01$, $BF^{10} > 100$. However there were significant interactions between trial type x referent, $F(2, 108) = 35.01$, $p < .001$, $\eta_p^2 = .39$, $BF^{10} > 100$, trial type x group, $F(1, 54) = 5.67$, $p = .02$, $\eta_p^2 = .10$, $BF^{10} = .06$, both subsumed under a 3-way trial type x referent × group interaction, $F(2, 108) = 3.82$, $p = .03$, $\eta_p^2 = .07$, $BF^{10} > 100$.

Post-hoc tests investigated the 3-way effect by testing the group × referent interaction in each trial type separately. The group × referent interaction was not significant in match trials, $F(2, 108) = 1.10$, $p = .34$, $\eta_p^2 = .02$, $BF^{10} > 100$, but was significant in mismatch trials, $F(2, 108) = 5.40$, $p = .01$, $\eta_p^2 = .09$,

[1] Note that we pre-registered slightly different time windows for N1 (130–180 msec) N2 (250–320 msec), based on previous studies. However, visual inspection of grand average ERPs in our data showed that these time windows did not fit the N1 and N2 peaks elicited by our face-label stimuli. As such, the main results report adjusted time windows that fit our data, but analyses with the pre-registered time windows are reported in Supplementary Materials.

[2] We additionally pre-registered to exclude participants from analysis if their overall accuracy fell below 60%, based on the accuracy means reported in Williams et al.'s (2018, Experiment 1) shape-label version of this task. However, performance on our face-label version of the task was clearly more difficult, reflected by lower overall accuracy in both Experiments 1 and 2, therefore applying this exclusion criteria resulted in high data loss. We therefore report the data here without applying this accuracy cutoff criteria, but report the full pre-registered analysis In Supplementary Materials, showing that results were the same when this exclusion criteria was applied.

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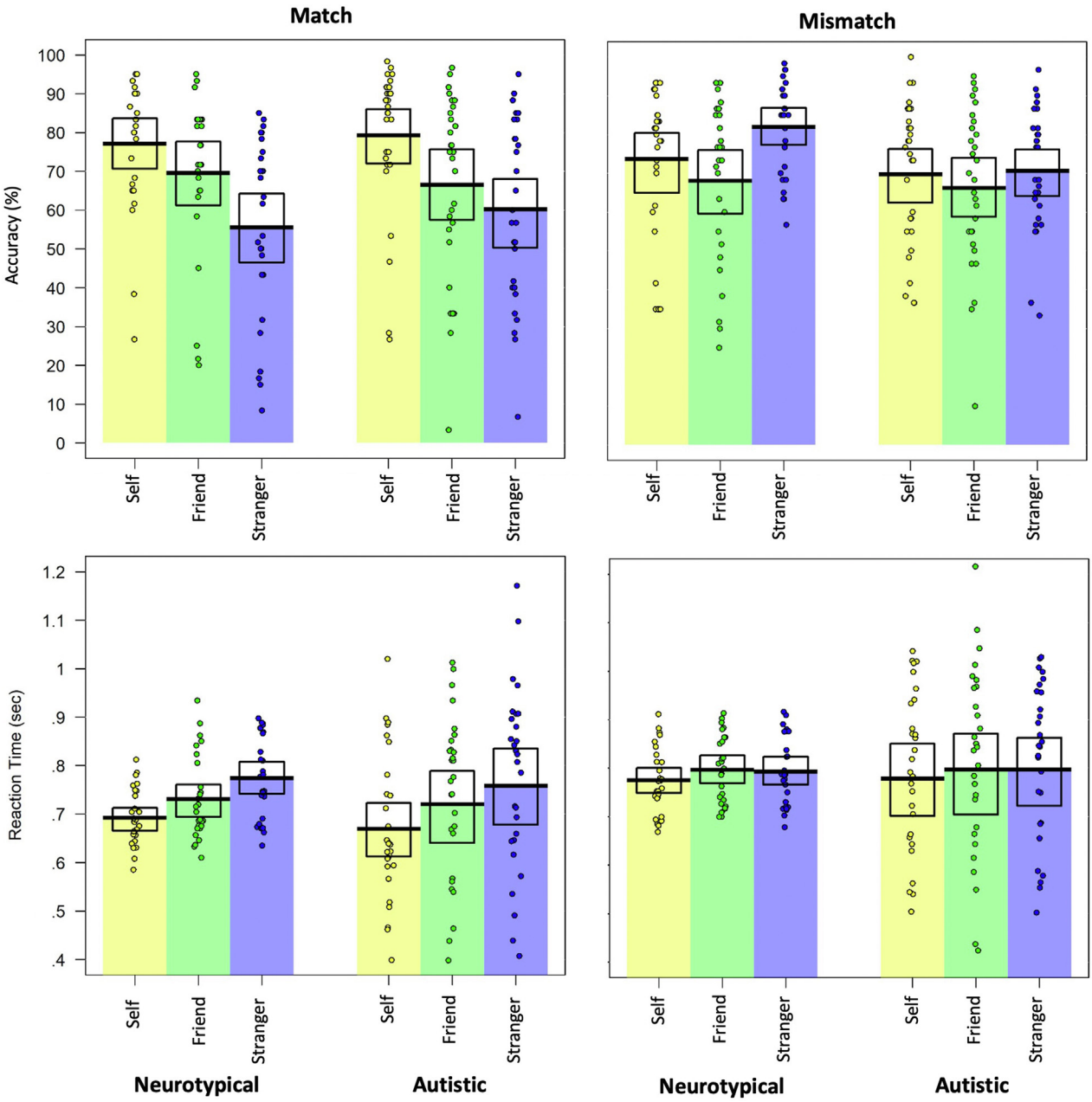

Fig. 4 – Accuracy and RT descriptive statistics in the neurotypical and ASC groups for each referent in match (left panel) and mismatch (right panel) trials in Experiment 2. Boxed area represents 95% confidence interval.

BF^{10} >100. Paired samples *t*-test revealed that in mismatch trials, accuracy in the neurotypical group followed a pattern of stranger > self > friend; accuracy was higher for stranger than self, $t(26) = 3.21$, $p = .003$, $d = .62$, and friend, $t(26) = 4.73$, $p < .001$, $d = .91$; accuracy was also higher for self than friend, $t(26) = 3.66$, $p = .001$, $d = .71$. In the autistic group, accuracy did not differ between self and friend, $t(28) = 1.87$, $p = .07$, $d = .35$, or self and stranger, $t(28) = .48$, $p = .66$, $d = .08$, but stranger was significantly higher than friend, $t(28) = 2.51$, $p = .02$, $d = .47$.

RT: Levene's test revealed that RT violated the homogeneity of variance assumption, so here we report significance tests with Greenhous-Geisser correction on dfs. Analysis revealed a significant main effect of trial type, $F(1, 54) = 99.21$, $p < .001$, $\eta_p^2 = .65$, BF^{10} >100, whereby matches were responded to more quickly than mismatches. There was also a significant main effect of referent, $F(2, 108) = 29.69$, $p < .001$, $\eta_p^2 = .36$, BF^{10} >100. Post-hoc paired samples *t*-tests revealed that RT followed a pattern of self < friend < stranger, whereby RT for self trials was significantly faster than for friend, $t(55) = 4.57$, $p < .001$, $d = .61$, and stranger trials, $t(55) = 7.68$, $p < .001$, $d = 1.03$; RT was also significantly faster for friend than stranger trials, $t(55) = 3.08$, $p = .003$, $d = .41$. There was no significant main effect of group, $F(1,54) = .04$, $p = .85$, $\eta_p^2 = .001$, $BF^{10} = .46$, and group did not interact with any of the other variables (Fs < 2.1, ps > .15).

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However, the referent x trial type interaction was significant, $F(2, 108) = 11.47$, $p < .001$, $\eta_p^2 = .18$, $BF^{10} > 100$. The referent effect was significant in match trials, $F(2, 108) = 24.51$, $p < .001$, $\eta_p^2 = .31$, $BF^{10} > 100$, and in mismatch trials, $F(2, 108) = 5.50$, $p = .01$, $\eta_p^2 = .09$, $BF^{10} > 100$. Post-hoc paired samples *t*-tests revealed that in match trials, RT followed a pattern of self < friend < stranger, with the difference between conditions as described above (all *ts* > 3.57, *ps* < .001). In mismatch trials, RT followed a pattern of self < friend = stranger, whereby, RTs for self were significantly faster than for friend, $t(55) = 2.64$, $p = .01$, $d = .35$, and stranger, $t(55) = 3.30$, $p = .002$, $d = .44$; friend did not significantly differ in RT from stranger, $t(55) = .25$, $p = .81$, $d = .03$.

5.2. *ERP effects*

Plots of the ERP waveforms in each group and condition are shown in Fig. 5 and topographies for the three ERP components of interest in Fig. 6. Note that due to space constraints, only significant ERP effects that involve group or condition are discussed in the text. Over lateral N1, N2 and P3, a 2 (Group: autistic/neurotypical) × 3 (Referent: self/friend/stranger) x 2 (Trial Type: match/mismatch) x 2 (Hemisphere: left/right) x 2 (Ant-Pos: anterior/posterior) mixed ANOVA was conducted with repeated measures on the last four factors. Over Midline N1, N2, P3, a (Group: autistic/neurotypical) × 3 (Referent: self/friend/stranger) x 2 (Trial Type: match/mismatch) x 4 (Electrode: Fz/Cz/Pz/Oz) mixed ANOVA was conducted with repeated measures on the last three factors.

Full statistical effects for each measure are summarised in Table D of the Supplementary Materials, and full data is available on the Open Science Framework (https://osf.io/br98c/).

Midline N1 (80–120 msec): Analysis revealed a referent × group interaction, $F(2, 92) = 3.36$, $p = .04$, $\eta_p^2 = .07$. Paired samples *t*-tests showed that in the autistic group, there was a more negative-going amplitude for stranger ($M = -1.02$, $SD = 2.26$) than friend ($M = -.40$, $SD = 1.91$), $t(23) = 2.63$, $p = .02$, $d = .54$. There were no other referent effects in either the neurotypical or autistic group (*ts* < 1.65, *ps* > .11). There was also a trial type × group interaction, $F(1, 46) = 4.20$, $p = .046$ $\eta_p^2 = .08$, however, follow-up analyses showed no between group difference in match, $t(46) = 1.13$, $p = .26$, $d = .33$, or mismatch, $t(46) = .10$, $p = .92$, $d = .03$, trials.

Lateral N1 (80–120 msec): Analysis revealed a significant main effect of referent, $F(2, 92) = 6.89$, $p = .002$, $\eta_p^2 = .13$, reflecting a less negative-going N1 amplitude for self ($M = -.05$, $SD = 1.23$) compared to both friend ($M = -.39$, $SD = 1.77$), $t(47) = 2.36$, $p = .02$, $d = .34$, and stranger ($M = -.57$, $SD = 1.77$), $t(47) = 3.34$, $p = .002$, $d = .48$, but there was no significant difference between friend and stranger, $t(47) = 1.40$, $p = .17$, $d = .20$. A trial type × group interaction, $F(1, 46) = 6.06$, $p = .02$, $\eta_p^2 = .12$, revealed that N1 amplitude was more negative-going in match than mismatch trials in the neurotypical (Match: $M = -.74$, $SD = 1.62$; Mismatch: $M = -.27$, $SD = 1.56$), $t(23) = 5.47$, $p < .001$, $d = 1.12$, but not the autistic (Match: $M = -.18$, $SD = 1.44$; Mismatch: $M = -.15$, $SD = 1.55$), $t(23) = .26$, $p = .80$, $d = .05$, group.

There were several two- and three-way interactions, which were subsumed under a hemisphere x Ant-Pos x trial type × referent interaction, $F(2, 92) = 20.37$, $p < .001$, $\eta_p^2 = .31$, which was broken down to look at the referent x trial type interaction in each quadrant separately. The referent x trial type interaction was significant in the right anterior quadrant, $F(2, 94) = 13.32$, $p < .001$, $\eta_p^2 = .22$. Paired samples *t*-tests showed no difference between referents in match trials, (*ts* < 1.02, *ps* > .31), but in mismatch trials, self ($M = 1.56$, $SD = 2.59$) elicited a less negative-going N1 amplitude than both friend ($M = -1.29$, $SD = 2.64$), $t(47) = 3.89$, $p < .001$, $d = .56$, and stranger ($M = -1.65$, $SD = 2.68$), $t(47) = 4.31$, $p < .001$, $d = .62$, and friend elicited a less negative-going N1 amplitude than stranger, $t(47) = 2.19$, $p = .03$, $d = .32$. The referent x trial type interaction was also significant in the left anterior quadrant, $F(2, 94) = 3.32$, $p = .04$, $\eta_p^2 = .07$, however none of the referent contrasts reached significance (*ts* < 1.88, *ps* > .07). The referent x trial type interaction was not significant in either of the posterior quadrants.

Midline N2 (200–260 msec): The analysis revealed referent x group and electrode × referent interactions which were subsumed under a three-way interaction between electrode x referent x group, $F(6, 276) = 2.90$, $p = .01$, $\eta_p^2 = .06$. The referent × group interaction was significant over electrodes Fz, $F(2, 92) = 3.95$, $p = .02$, $\eta_p^2 = .08$, and Cz, $F(2, 94) = 5.28$, $p = .01$, $\eta_p^2 = .10$, electrodes, but not Pz, $F(2, 92) = 3.04$, $p = .054$, $\eta_p^2 = .06$, or Oz, $F(2, 92) = .14$, $p = .87$, $\eta_p^2 = .003$ electrodes. Paired samples *t*-tests revealed that in the autistic group, there was a less negative-going N2 amplitude over Fz for self ($M = .62$, $SD = 3.28$) compared to both friend ($M = -.02$, $SD = 3.25$), $t(23) = 2.18$, $p = .04$, $d = .45$, and stranger ($M = -.71$, $SD = 3.51$), $t(24) = 3.56$, $p = .002$, $d = .73$, and a more negative-going N2 for stranger than friend, $t(23) = 2.12$, $p = .045$, $d = .43$; the referent effect was not significant over Fz electrode in the neurotypical group (*ts* < .50, *ps* > .62). Furthermore, in the autistic group, N2 amplitude was more negative-going over Cz electrode for stranger ($M = -.70$, $SD = 3.87$) compared to both self ($M = .50$, $SD = 3.62$), $t(23) = 3.54$, $p = .002$, $d = .72$, and friend ($M = -.03$, $SD = 3.63$), $t(23) = 2.60$, $p = .02$, $d = .53$; the referent effect was not significant over Cz in the neurotypical group (*ts* < 1.68, ps > .11).

Lateral N2 (200–260 msec): The analysis revealed a significant referent × group interaction, $F(2, 92) = 3.18$, $p = .046$, $\eta_p^2 = .07$, whereby the autistic group showed a more negative-going N2 amplitude for stranger ($M = .36$, $SD = 2.55$) than friend ($M = .84$, $SD = 2.22$), $t(23) = 2.80$, $p = .01$, $d = .57$; there were no other referent effects in the autistic (*ts* < 1.97, *ps* > .06) or neurotypical group (*ts* < 1.19, *ps* > .25).

There was also an Ant-Pos x referent interaction, $F(2, 92) = 34.77$, $p < .001$, $\eta_p^2 = .43$. Post-hoc tests showed a more negative-going N2 amplitude over the anterior region for stranger ($M = -.29$, $SD = 2.50$) than self ($M = .22$, $SD = 2.46$), $t(47) = 2.68$, $p = .014$, $d = .39$, and in the posterior region amplitude was more negative-going for self ($M = .77$, $SD = 2.57$) than friend ($M = 1.18$, $SD = 2.33$), $t(47) = 2.37$, $p = .02$, $d = .34$; there were no other referent effect in the anterior or posterior regions (*ts* < 2.01, *ps* > .05).

The Ant-Pos x trial type × group interaction was also significant, $F(1, 46) = 4.57$, $p = .04$, $\eta_p^2 = .09$, but the trial type × group interaction did not reach significance over the anterior, $F(1, 46) = .60$, $p = .44$, $\eta_p^2 = .01$, or posterior, $F(1, 46) = .68$, $p = .42$, $\eta_p^2 = .01$, regions.

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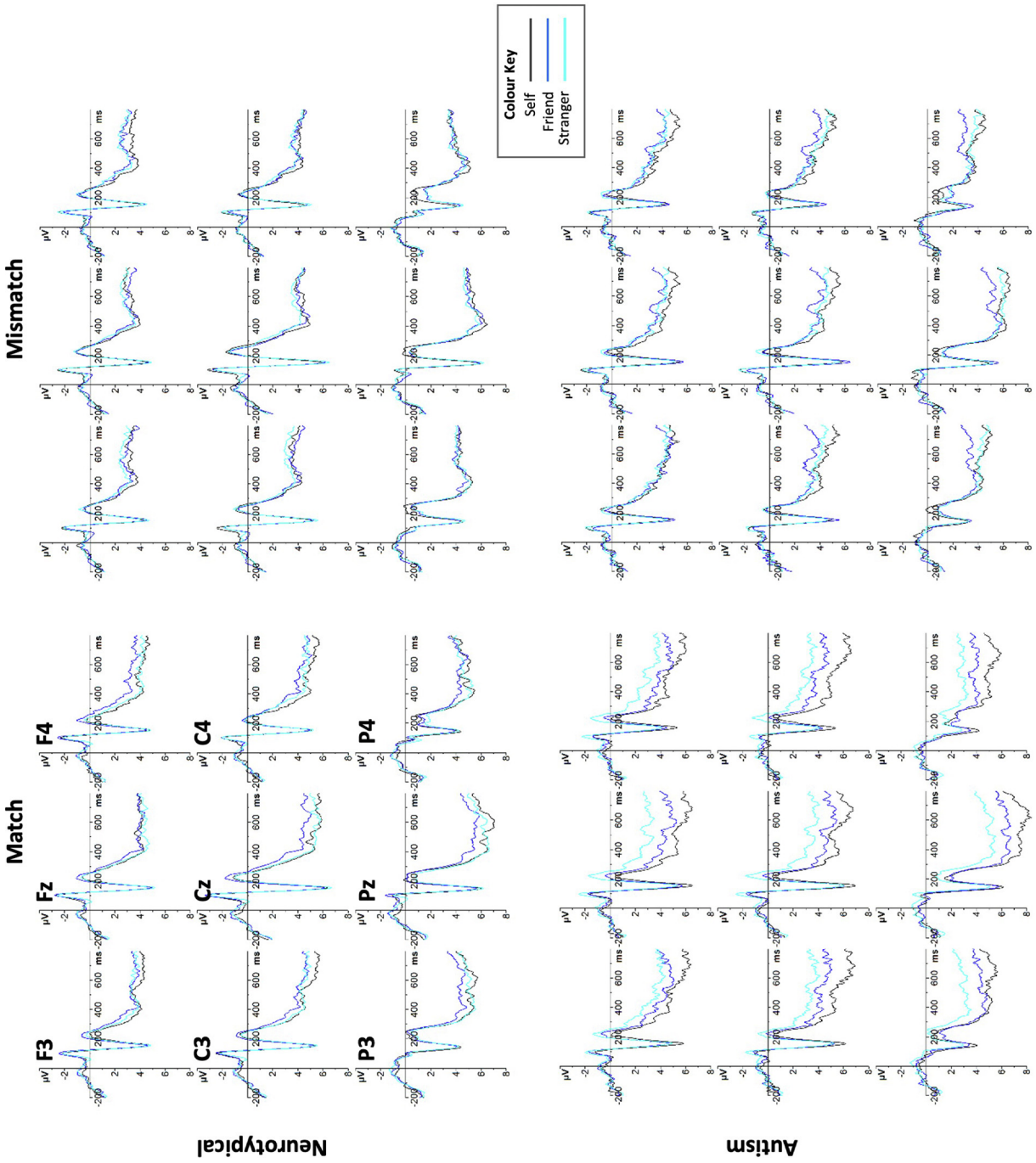

Fig. 5 – Grand average ERPs (over F3, Fz, F4, C3, Cz, C4, P3, Pz, P4) elicited by the face-label match (left panels) and mismatch (right panels) for self (black line), friend (dark blue line), and stranger (light blue line) in the neurotypical and ASC groups (see colour key).

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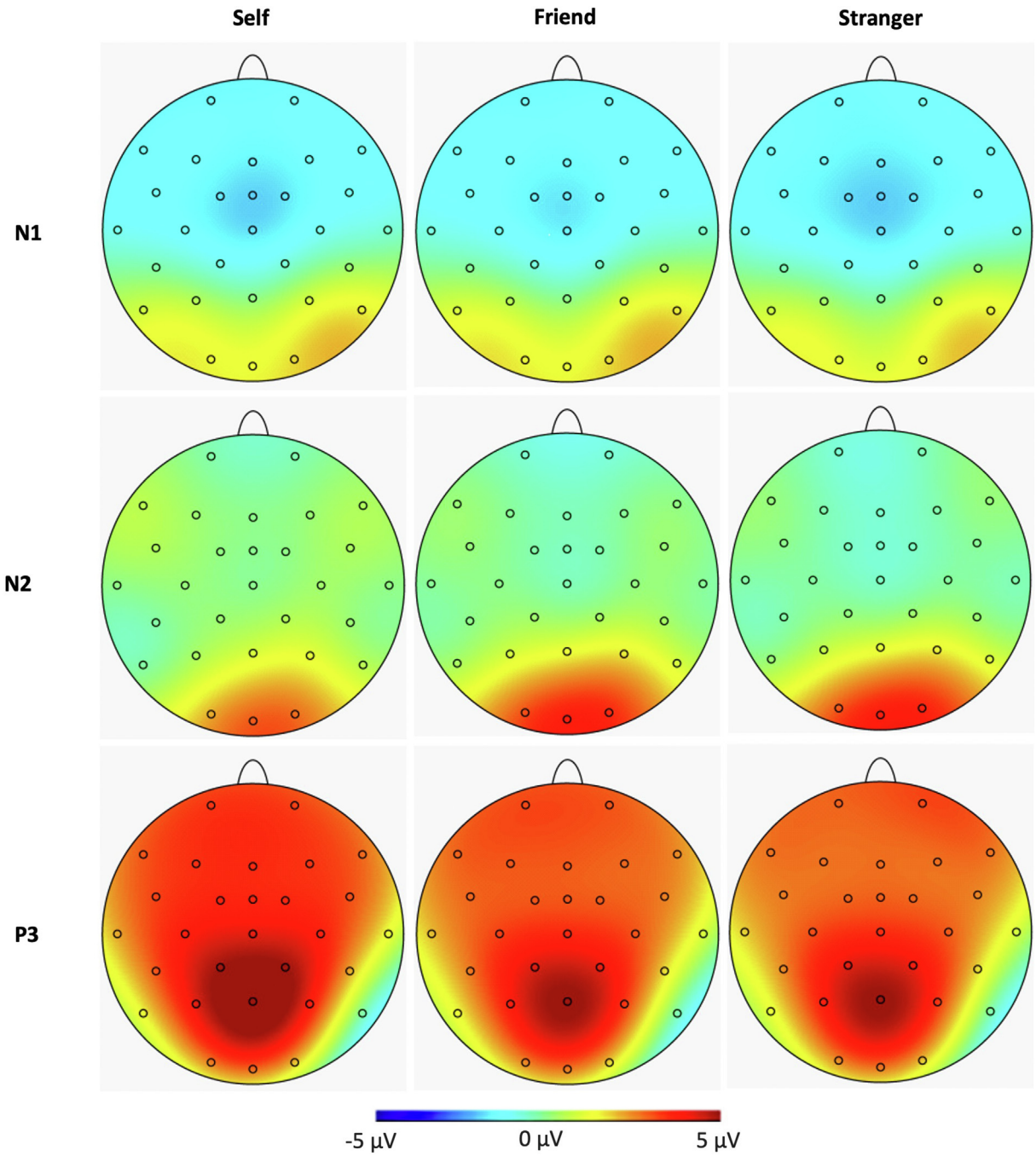

Fig. 6 – Topographic maps of the N1 (80–120 ms), N2 (200–260 ms), and P3 (250–600 ms) components averaged over match and mismatch trials across all participants, separately for the self, friend, and stranger conditions.

Midline P3 (250–600 msec): Analysis (see Fig. 7) revealed a significant effect of referent, $F(2, 92) = 3.50$, $p = .03$, $\eta_p^2 = .07$, whereby self ($M = 4.17$, $SD = 3.17$) trials elicited a larger amplitude than friend ($M = 3.66$, $SD = 3.05$), $t(47) = 2.19$, $p = .03$, $d = .32$, and stranger ($M = 3.57$, $SD = 2.42$), $t(47) = 2.15$, $p = .04$, $d = .31$, trials, but there was no difference in amplitude between friend and stranger trials, $t(47) = .38$, $p = .71$, $d = .06$. The significant interaction between referent x electrode showed that this self-bias effect on P3 was maximal over electrodes Cz and Pz. There was also a significant effect of trial type, $F(1, 46) = 10.62$, $p = .002$, $\eta_p^2 = .19$, with match trials eliciting larger amplitude ($M = 4.04$, $SD = 2.94$) than mismatch trials ($M = 3.56$, $SD = 2.61$).

There was also a trial type x referent × group interaction, $F(2, 92) = 3.45$, $p = .04$, $\eta_p^2 = .07$, which revealed that the referent × group interaction was only significant on match trials, $F(2, 92) = 4.67$, $p = .01$, $\eta_p^2 = .09$, and not on mismatch trials, $F(2, 92) = .26$, $p = .77$, $\eta_p^2 = .01$. Paired samples *t*-tests revealed that in the neurotypical group P3 amplitude did not differ between referents (ts < 1.88, ps > .07), but in the autistic group, amplitude was greater for self ($M = 5.06$, $SD = 3.94$) than both stranger ($M = 2.91$, $SD = 2.85$),

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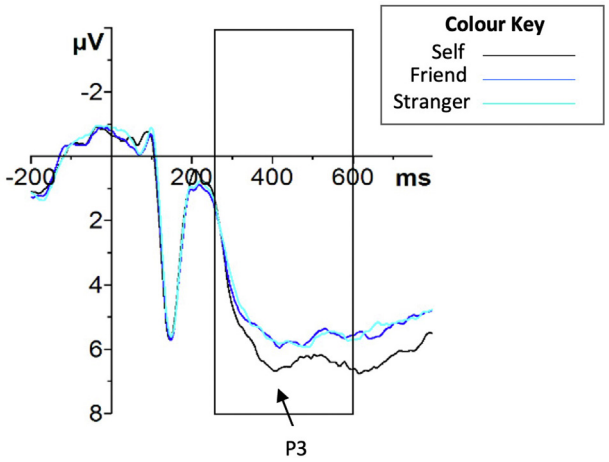

Fig. 7 – Grand average ERP waveform over Pz electrode, showing P3 amplitudes for each referent (see colour key).

$t(23) = 2.39$, $p = .03$, $d = .49$, and friend ($M = 4.23$, $SD = 3.78$), $t(23) = 2.22$, $p = .04$, $d = .45$; friend did not differ from stranger, $t(23) = 1.62$, $p = .12$, $d = .33$.

Lateral P3 (250–600 msec): Analysis revealed a significant effect of referent, $F(2, 92) = 3.90$, $p = .02$, $\eta_p^2 = .08$, whereby self ($M = 3.12$, $SD = 2.38$) trials elicited a larger P3 amplitude than both friend ($M = 2.70$, $SD = 2.39$), $t(47) = 2.19$, $p = .03$, $d = .32$, and stranger ($M = 2.64$, $SD = 2.04$), $t(47) = 2.46$, $p = .02$, $d = .36$, trials, but there was no difference in amplitude between friend and stranger trials, $t(47) = .31$, $p = .76$, $d = .05$. There was also a significant effect of trial type $F(1, 46) = 7.71$, $p = .01$, $\eta_p^2 = .14$, with match trials eliciting larger P3 amplitude ($M = 3.01$, $SD = 2.38$) than mismatch trials ($M = 2.63$, $SD = 2.00$).

5.3. *Association analyses*

The association between each of the self-bias and familiarity effect measures (i.e., RT, accuracy, and ERP amplitudes) and individual difference measures of autistic traits and camouflaging tendencies, was tested using a series of Pearson's correlations, as in Experiment 1. ERP measures were calculated for match trials only using the mean amplitude of N1, N2 or P3 over midline electrodes. Resulting statistical details are shown in Table 2.

None of the individual measures correlated with self-bias or familiarity effect on RT, or accuracy. N1 self-bias amplitude was negatively correlated with AQ, TAS-20, and CAT-Q, whereby participants with a greater self-bias on N1 had fewer autistic traits, lower alexithymia, and fewer camouflaging tendencies. N1 familiarity effect amplitude was negatively correlated with CAT-Q; participants with a greater familiarity effect on N1 had fewer camouflaging tendencies. Furthermore, N2 self-bias amplitude was negatively correlated with CAT-Q, and N2 familiarity effect amplitude was negatively correlated with BAI, showing that participants with a greater self-bias on N2 had fewer camouflaging tendencies and participants with a greater familiarity bias on N2 had lower levels of anxiety. Lastly, P3 self-bias and familiarity effect amplitude were negatively associated with BAI showing that participants with a greater self-bias and familiarity effect on P3 had lower levels of anxiety.

6. Discussion

The current study aimed to test whether perceptual self-bias and familiarity effects are undiminished in ASC (Williams et al., 2018; Zhao et al., 2018). Using a perceptual-association task (Sui et al., 2012), participants distinguished face/label associations relating to the self versus friend (familiar-other) versus stranger (unfamiliar-other). Experiment 1 took an individual differences approach by testing whether behavioural indices of self-bias and familiarity are associated with the number of autistic traits in neurotypical adults ($N = 58$). Experiment 2 took a case–control approach by testing whether behavioural and neural indices (measured using ERPs) of self-bias and familiarity differ between neurotypical ($N = 27$) and autistic ($N = 29$) adults.

Across both experiments, behavioural results showed that participants experienced both a self-bias and a familiarity effect. These effects were characterised by faster RT and higher accuracy for self-relevant stimuli compared to familiar-other (e.g., friend) and unfamiliar-other (e.g., stranger) stimuli, and faster RT and higher accuracy for familiar-other stimuli compared to unfamiliar-other stimuli (this familiarity effect was only significant on RTs in Experiment 2). Importantly, the number of autistic traits was unrelated to the magnitude of either the self-bias or the familiarity effect on RT or accuracy (in Experiments 1 and 2) and there was no between-group difference in the speed and accuracy of responses (Experiment 2).

Table 2 – Matrix displaying correlations between each self-bias and familiarity effect measure and cognitive predictors in the total sample.

	N	Self-Bias		Familiarity Effect		N	Self-Bias			Familiarity Effect		
		RT	Accuracy	RT	Accuracy		N1 amplitude	N2 amplitude	P3 amplitude	N1 amplitude	N2 amplitude	P3 amplitude
AQ	53	.10	.10	−.04	−.22	45	−.32*	−.22	−.25	−.19	−.18	−.11
TAS-20	50	−.08	−.03	−.04	−.11	43	−.39**	−.28	−.21	−.26	−.17	−.08
CAT-Q	54	.05	−.01	−.03	−.12	47	−.37**	−.29*	−.28	−.31*	−.26	−.17
BAI	54	−.05	.07	−.06	−.17	47	−.10	−.27	−.29*	−.28	−.39**	−.36*
ADOS (ASC group only)	18	.22	.30	−.05	−.16	15	.20	−.21	.02	.03	.004	−.12

*$p < .05$; **$p < .01$; ***$p < .001$.

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The findings largely support previous research that has reported typical behavioural self-bias, and hence self-other distinction, in the *perceptual domain* in ASC (Zhao et al., 2018; Williams et al., 2018), but are inconsistent with evidence from *other domains*, particularly memory, where self-bias is often diminished (Henderson et al., 2009; Lombardo et al., 2007; Burrows et al., 2017; Grisdale et al., 2014; but see Lind et al., 2020). This domain-level difference in self-reference might reflect differences in task difficulty across tasks – e.g., perceptual tasks that only require a first-order representation of self, as opposed to trait memory tasks that require a second-order representation of self (Williams et al., 2018) – or the different neural mechanisms that are engaged in the different domains. Our studies therefore additionally aimed to examine the real-time evidence of difficulties with self-other distinction that might not be evident at a behavioural level.

6.1. *Neural underpinnings of perceptual self-bias in ASC: evidence from ERPs*

In the N1 time window, we found evidence of a self-bias (i.e., N1 amplitude over lateral sites was more negative-going in the friend and stranger trials compared to the self) and a familiarity effect (i.e., N1 amplitude over anterior lateral sites was more negative-going in the stranger compared to friend trials) in both the neurotypical and autistic group, and the magnitude of these effects did not differ between groups. N1 is thought to reflect an early *involuntary* shift of attention to familiar stimuli (Haider et al., 1964; Höller et al., 2011; Luck et al., 2000; Tateuchi et al., 2012), particularly those in which people have a high degree of familiarity/expertise (Tanaka & Curran, 2001), and in the shape-association task, has been linked with the rate of information gathering during decisional processing (Sui et al., 2023). Therefore, the findings are in line with previous research in neurotypical people showing a distinction in N1 amplitudes in response to seeing familiar faces (Caharel et al., 2002; Marzi & Viggiano, 2007), and hearing familiar sounds (Kirmse et al., 2009), and names (Nijhof et al., 2018), compared to when seeing or hearing unfamiliar stimuli. The *self-bias* in ASC at this early stage of processing supports previous research which found that, like neurotypical participants, autistic participants distinguish between *hearing* one's own nameversus the name of an unfamiliar-other in this N1 time window (Nijhof et al., 2018); no research has found this typical early modulation of N1 reflecting a *self-bias* in ASC for *seeing* self versus other relevant stimuli, or indeed in any other modality. This provides strong evidence for spontaneous self-bias in ASC in the earliest moments of visual processing, even for temporarily learned associations between an unfamiliar face and self/other labels, suggesting that they are sensitive to these self-associations very quickly. We note that the direction of the self-other difference on the N1 in our study (i.e., self > other) is opposite to that seen in previous self-bias association studies that have used simple geometric shape stimuli (Sui et al., 2023) or auditory name stimuli in the absence of visual input (Nijhof et al., 2018). We attribute this difference to the more complex face stimuli used here, as well as the potential limitation of a processing conflict of matching an unfamiliar other's face with a self label; the key finding is that participants clearly distinguished self and others within 120 msec of the stimuli onset.

In the N2 time window, there was evidence of a self-bias in both groups - i.e., N2 amplitude differed between self and friend trials over posterior regions (which provides the strongest evidence of a self-bias) and between self and stranger trials over anterior regions. Furthermore, there was a familiarity effect (more negative-going for stranger than friend) on N2 in the autistic group only over midline and lateral sites. Since N2 is thought to reflect conflict monitoring and/or response inhibition mechanisms (Donkers & van Boxtel, 2004; Jolicœur et al., 2006; Kranczioch et al., 2007; Nijhof et al., 2022), we interpret these effects as reflecting the monitoring of conflict between the self and others of differing familiarity in our task, and/or the cognitive control required to inhibit incorrect responses. The finding that group differences emerged on the familiarity effect but not the self-bias might suggest that different types of conflict influence processing in each group. The observed self-bias on N2 is in line with Nijhof et al.'s (2022) research finding that the attentional blink (i.e., difficulty detecting the second of two target stimuli presented in close temporal succession) is reduced when the second target was the participant's own name compared to an unfamiliar person's name, or a familiar person's name, and was associated with increased N2 amplitudes in both ASC and neurotypical participants. As with the N1 component, the direction of this self-bias effect on the N2 component is opposite to that seen in the auditory domain in Nijhof et al. (2018)'s study, likely due to the unfamiliar face-name integration involved in the current task, which temporarily conflicts with own face-name schemas.

In the later P3 time window, there was a *self-bias* – whereby P3 amplitude was greater in the self compared to both the friend and stranger trials (which did not differ from each other). Previous research has shown modulation of the P3 ERP component in neurotypical people when processing self-relevant compared to other-relevant information, suggesting that this component indexes the distinction between self and other perspectives (e.g., own name/face pairings, Cygan et al., 2014; self/other touch, Deschrijver et al., 2017; self/other perspective-taking, Ferguson et al., 2018), and response selection (i.e., boundary separation; Sui et al., 2023). This self-bias in the P3 ERP component was observed in both neurotypical and autistic participants, and did not differ in magnitude between groups.

6.2. *Is self-bias typical in ASC?*

The difference between processing of self and familiar-other (i.e., self-bias) is thought to be the purest index of self-other distinction because both the self and close-other are familiar to the self (unlike self *vs* unfamiliar-others), therefore any difference in perception between the two is thought to result from personal relevance rather than familiarity. Across both behavioural and neural measures, we found strong evidence to support the effect of a self-bias on processing in both groups, despite the use of complex face stimuli that did not genuinely match the self-other label in any condition. That is, while face-label associations were clearly learned in this task, they also presented a major processing conflict in self and familiar other conditions since the depicted face was not of the self or a friend (i.e., the label matched the learned face, but

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conflicted with a known face). The fact that self-bias and familiarity effects were detected here using these unfamiliar stimuli demonstrates the strength of the associations that participants were able to encode and respond to.

Previous research has suggested that the *self-bias* effect is typical in ASC at the early N2 stage of processing (Nijhof et al., 2022), however, at the later P3 stage, there is a *familiarity* effect but no *self-bias* effect (Cygan et al., 2014; Nijhof et al., 2018, 2022; Nowicka et al., 2016). These findings suggest that seemingly typical behavioural indices of perceptual self-bias at the behavioural level in the associations task (e.g., Williams et al., 2018; Zhao et al., 2018) might be supported by different underlying mechanisms. In the current study (which also required only first-order self-representation), there was no between group difference in the magnitude of the *self-bias* effect at N1 or P3, and indeed, the influence of self-bias was evident within the earliest moments of processing (within 120 msec of stimuli onset). The findings therefore suggest that *self-bias* in the perceptual matching task is typical in ASC (Williams et al., 2018); although there is some evidence that different types of conflict might influence processing (i.e., familiarity only influenced N2 in the autistic group). It is unlikely that lack of between-group difference in behavioural and neural self-bias is caused by low sample size. The sample size in the current study (EEG: neurotypical = 24, ASC = 24) was comparable to or exceeded that used by Nijhof et al. (2018; NT = 21, ASC = 21), Cygan et al. (2014; NT = 23, ASC = 23) and Nowicka et al. (2016; NT = 15, ASC = 15), which suggests that we were sufficiently powered to detect a between group difference.

The current study addresses some of the key limitations of previous work, but also introduces some different potential confounds. Previous tasks (Cygan et al., 2014; Nijhof et al., 2018; Nowicka et al., 2016) used familiar stimuli that were personally salient (e.g., self/friend faces/names). These self, familiar- and unfamiliar-other stimuli are therefore likely to differ by: 1) levels of exposure (e.g., self face/name stimuli might have been exposed to the self more than familiar- and unfamiliar-other face/name stimuli), and consequently 2) pre-established status (e.g., conditioning to respond to own name more than the name of our friend). In contrast, the current study used unfamiliar face stimuli to minimise the influence of exposure/pre-established status (i.e., familiarity), and instead required participants to "bind" new stimuli to the *concept* of self/friend/stranger. This allowed us to test the effectiveness of this novel binding, rather than the strength of pre-established associations, however it also introduced a conflict of pairing an unfamiliar face with a familiar name which may have weakened familiarity effects. It might be that the initial binding of stimuli to the self is typical in ASC, but the strengthening of these associations over time is diminished, regardless of whether the task relies on first- or second-order representation of self. Further research is required to explore the ecological validity of matching a self or friend label to an unfamiliar face. Another potential limitation is that participants in the current study were explicitly instructed which stimuli to bind to each referent, and hence which stimuli are most important; under real-world conditions, people must make these judgements themselves. Therefore, difficulty in ASC might be deciphering which information to bind/up-regulate consolidation of; as such, difficulty might be more apparent in tasks using familiar stimuli because this relies on associations that they have previously formed themselves. Finally, the use of the AQ as a measure of autistic traits is valuable given increased discussions of autism as a dimensional concept that spans clinical and sub-clinical phenotypes (Happé & Frith, 2020), however the self-report measure itself may not be reliable given recent findings that it correlates poorly with clinical diagnosis (Ashwood et al., 2016), and the relatively low levels of autistic traits that it revealed in our samples.

6.3. *Individual variance and co-occurring factors that influence self-other distinction*

Differences in self-other distinction – and hence self-bias – have been associated with a number of more transient neuropsychological and psychiatric conditions, including depression, anxiety, stress, and post-traumatic stress disorder (Eddy, 2022; Lanius et al., 2020). In such cases, atypical self-other distinction is a symptom that has developed over time, often in response to environmental factors (Eddy, 2022). The cognitive profile that defines ASC – particularly difficulty with ToM and self-awareness – might make autistic people particularly susceptible to atypical self-other distinction: diminished ability to reflect on both the self and others would cause differences in distinguishing the self from others. In addition, environmental factors – e.g., societal pressures – are likely to contribute to atypical self-other distinction in ASC, as is observed in other conditions. For example, autistic people report feeling pressure to behave in a way that might appear neurotypical (Hull et al., 2017) – i.e., diminishing the distinction between their autistic and neurotypical traits. Over time, this could exacerbate any existing difference in self-other distinction ability. Therefore, we note that the extensive research on how self-other distinction differences might develop from environmental factors in neurotypical people should not be neglected when understanding the cognitive profile of autistic people.

In the current study, we conducted exploratory correlation analyses to examine how individuals' self-reported autistic traits, alexithymia, camouflaging tendencies, and anxiety levels impacted self and other processing in the perceptual matching task. Some evidence was found to suggest that clinically relevant characteristics - specifically alexithymia, camouflaging tendencies and anxiety - influenced the processing of self-bias and familiarity effects (i.e., on N1, N2, and P3). This is the first study to associate ERP self-bias and familiarity effect responses with these socio-emotional features. It is notable that alexithymia and anxiety commonly co-occur with other neuropsychiatric conditions that are associated with atypical self-other distinction and emotional/social difficulties – e.g., ADHD, eating disorders (Lavenne-Collot et al., 2023; Vuillier et al., 2020). More research is required to replicate these associations, and to investigate social-cognitive processing in autism whilst accounting for these co-occurring disorders/psychiatric problems (e.g., ADHD, eating disorders, body dysmorphia etc.).

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We note that variability in any cognitive ability – including self-other distinction – is a natural part of human diversity and should not be pathologized (Jaarsma & Welin, 2012). The current research aimed to identify differences in the cognitive profile of autistic people that might contribute to difficulty with key social abilities – e.g., ToM – that are known to influence mental health. Therefore, whilst research in neurotypical people suggests that self-other distinction ability varies with environmental factors, the extent to which individual effort/external intervention is required to support any cognitive ability may be dependent on the extent to which it would improve mental health (McPartland, 2019).

6.4. *Conclusion*

Overall, the current study replicates previous research by finding typical behavioural self-bias and familiarity effects in the perceptual association task in autistic adults (Williams et al., 2018; Zhao et al., 2018). ERP indices revealed the real-time processes that underlie these effects. Clear evidence of a self-bias was found in both groups, with self trials eliciting smaller N1 and N2 components and a larger P3 than familiar other ('friend') trials. This pattern shows that autistic adults can encode novel associations between faces and self/other labels and are influenced by learned self-biases in the earliest moments of processing (i.e., within 120 msec). Moreover, the typical behavioural perceptual self-bias appears to be driven by the same underlying real-time mechanisms between groups. There was also some evidence of a familiarity effect over N1 and N2 components, reflecting attention shifting and familiarity conflict, though this effect was weaker among neurotypical adults than autistic adults. Methodological factors, such as familiarity of the stimuli, are likely to account for the small neural response to familiarity and discrepancies with previous studies. Future research should examine the influence of co-occurring factors which may influence self-bias and familiarity effects in autistic and neurotypical people.

Open practices

The study in this article has earned Open Data, Open Materials and Preregistered badges for transparent practices. The data and materials used in this study are available at: https://osf.io/br98c/.

CRediT authorship contribution statement

Marchella Smith: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Heather J. Ferguson:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

None.

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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cortex.2024.03.012.

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