RUNNING HEAD: EMOTION RECOGNITION IN AUTISTIC ADULTS

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Speed and Accuracy of Emotion Recognition in Autistic Adults: The Role of Stimulus Type, Response Format and Emotion

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Data are accessible at OSF link: https://osf.io/ndbfs/

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Abstract

Emotion recognition difficulties are considered to contribute to social-communicative problems for autistic individuals. Prior research has been dominated by a focus on forced-choice recognition response accuracy for static face presentations of basic emotions, often involving small samples. Using free-report and multiple-choice response formats, we compared emotion recognition in IQ-matched autistic ($N = 63$) and nonautistic ($N = 67$) adult samples using 12 face emotion stimuli presented in three different stimulus formats (static, dynamic, social) that varied the degree of accompanying contextual information. Percent agreement with normative recognition responses (usually labeled 'recognition accuracy') was slightly lower for autistic adults. Both groups displayed marked inter-individual variability and, although there was considerable overlap between groups, a very small subset of autistic individuals recorded lower percent agreement than any of the nonautistic sample. Overall, autistic individuals were significantly slower to respond and less confident. Although stimulus type, response format and emotion affected percent agreement, latency and confidence, their interactions with group were nonsignificant and the associated effect sizes extremely small. The findings challenge notions that autistic adults have core deficits in emotion recognition and are more likely than nonautistic adults to be overwhelmed by increasingly dynamic or complex emotion stimuli and to experience difficulties recognizing specific emotions. Suggested research priorities include clarifying whether longer recognition latencies reflect fundamental processing limitations or adjustable strategic influences, probing age-related changes in emotion recognition across adulthood and identifying the links between difficulties highlighted by traditional emotion recognition paradigms and real-world social functioning.

Lay Summary. It is generally considered that autistic individuals are less accurate than nonautistic individuals at recognizing other people's facial emotions. Using a wide array of emotions presented in various contexts, this study suggests that autistic individuals are, on average, only slightly less accurate but at the same time somewhat slower when classifying others' emotions. However, there was considerable overlap between the two groups, and great variability between individuals. The differences between groups prevailed regardless of how stimuli were presented, the response required or the particular emotion.

Keywords. emotion recognition; autistic adults; accuracy, latency, confidence

Speed and Accuracy of Emotion Recognition in Autistic Adults: The Role of Stimulus Type, Response Format and Emotion

Accurate and timely recognition of emotion expressions is critical in social interactions (Wallace et al., 2011). Given that one feature of autism is difficulty associated with social communication and interaction (DSM-5; American Psychiatric Association, 2013), interest in whether such difficulties are underpinned by problems recognizing facial emotion expressions is unsurprising. Despite extensive research, inconsistent findings abound. Conclusions from meta-analyses and reviews vary: some argue for general emotion recognition impairments that increase with age (Lozier et al., 2014), some suggest pervasive impairments that do not vary with age (Uljarević & Hamilton, 2013), some highlight variability reflecting individual and paradigm differences (Nuske et al., 2013), and others argue that differences may only become apparent when emotion processing becomes difficult (e.g., Harms et al., 2010; Nuske et al., 2013). We compared emotion recognition in autistic and nonautistic adults, focusing on three conditions that have been linked to inconsistent findings: type of stimulus presentation, response format and emotion.

Stimulus Type

Static images (photographs) have been the dominant mode of stimulus presentation, despite not being typical of how emotional expressions are encountered in real-life interactions. An alternative to static images is to present moving images of faces that are considered to provide a more ecologically valid evaluation of emotion recognition (Enticott et al., 2014). Such stimuli might range from a simple depiction of the face emotional expression being formed by the target individual to the individual displaying the expression in a life-like social interaction that provides an additional array of contextual cues. In the present study such stimuli are labeled as dynamic and social stimulus types, respectively. That emotion recognition should be enhanced when stimuli include contextual cues typically associated with real-life expressions is intuitively appealing. Nevertheless, there are contradictory findings regarding the effect of stimulus type (e.g., Ambadar et al., 2005; Enticott et al., 2014).

Van de Cruys et al.'s (2014) predictive coding account of autism suggests that autistic individuals may have difficulty processing face emotions displayed as dynamic stimuli (moving images) or embedded in social contexts. They argued that effective processing in real-world contexts demands learning to assign lesser weight to violations in expectations (i.e., prediction errors) that are detected—or learning that the same social rule applies across stimulus input variations. Failing to do so will reduce the likelihood of achieving a generalized representation of emotional expressions. This account suggests that autistic individuals' emotion recognition might be hindered by the variable contextual information contained in more complex stimuli. It is unclear, however, whether—when compared with nonautistic individuals— autistic adults' emotion recognition might be rendered less accurate, slower or perhaps both, as few studies have measured recognition latency (Uljarević & Hamilton, 2013).

Response Format

Forced-choice response formats (e.g., multiple-choice) have been dominant in emotion recognition research (Lozier et al., 2014; Uljarević & Hamilton, 2013). Multiple-choice formats lack ecological validity because most real-life interactions do not provide the luxury of scanning a list of possible responses. Indeed, nonautistic individuals' performance on the Reading the Mind in the Eyes test—a test requiring recognition of emotion expressions[1]—is worse when free-report rather than multiple-choice responses are required (Betz et al., 2019; Cassells & Birch, 2014). Cassells and Birch (2014) suggested that multiple-choice formats permit compensatory process of elimination strategies. Betz et al. (2019) argued that multiple-choice word options provide contextual information that cues relevant conceptual knowledge, permitting observers to draw inferences about the displayed emotion not elicited by the stimulus itself. If dependence on such strategies differs for autistic and nonautistic individuals, group differences in emotion recognition may be obscured (or perhaps exaggerated) with multiple-choice options. Further, apart from expecting slower responding when individuals must compose free-report responses rather than simply clicking on a response option, an interaction between group and response format on latency might emerge if autistic and nonautistic groups differ in their dependence on such cues or strategies. Thus, investigation of emotion recognition using a free-report format should be informative about autistic-nonautistic group differences.

Emotion

Findings regarding whether autism-related difficulties in emotion recognition are emotion-specific are also contradictory. Although many studies have focused on the six purported ‘basic’ emotions—happy, sad, anger, fear, disgust, surprise (cf. Ekman et al., 1969)—methodological variations are common, with different subsets of emotions used, different intensities of emotional expression and so on. Although some suggest that emotion recognition difficulties in autistic individuals may be specific rather than general (e.g., Ashwin et al., 2006; Song & Hakoda, 2018), meta-analyses have suggested pervasive impaired recognition of basic emotions in autistic adults, with the possible exception of ‘happy’ at least when presented as a static stimulus (Lozier et al., 2014; Uljarević & Hamilton, 2013). The outcome for emotions outside the basic six (e.g., more subtle states such as ashamed, bored, disappointed, hostile, hurt, jealous, upset, worried, often referred to as ‘complex’ emotions) is unclear. Although some (Harms et al., 2010) assert that group differences are more likely for complex emotions, support for this perspective is not yet available from meta-analyses. Nor is it possible to assert whether autism-related processing difficulties for specific emotions might be reflected in recognition accuracy or latency. Given these inconsistent findings, we supplemented the six basic emotions with six of what are commonly referred to as ‘complex’ emotions. This methodological decision neither reflects a commitment to a particular conceptualization of basic and complex emotions nor to the view that processing of face emotion stimuli by autistic individuals is more (or less) likely to be specialized for particular emotions. There is now an extensive literature documenting the controversies about whether particular emotions should be classified as ‘basic’ emotions and even about what constitutes an emotion: for one recent overview, see Ortony (2022). Rather, our inclusion of multiple stimuli from the ‘basic’ and ‘complex’ categories was designed to permit group comparisons across stimuli that typically are associated with stronger versus weaker recognition performance while allowing comparison with extant autism research dominated by ‘basic’ emotions.

To summarize, we examined autistic and nonautistic adults’ recognition of face emotions across response formats and stimulus types. We targeted autistic (and nonautistic) adults with verbal IQs above 85 given the likelihood that lower verbal ability is likely to compromise both accuracy and speed of both free-report and multiple-choice responding. (A single nonautistic comparison group cannot of course establish that any processing difficulties observed in the autistic sample are unique to autism, an issue we return to in the Discussion.)

Participants completed tasks involving (a) static (photographs), dynamic (moving images) and social stimuli (dynamic stimuli varying in the degree of contextual information), and (b) multiple trials for six basic and six complex emotions. Participants provided both free-report and multiple-choice responses. Dependent measures were agreement with normative recognition responses (traditionally labeled emotion recognition accuracy), response latency and confidence. As noted earlier, it is difficult to predict whether group differences will be reflected in accuracy, response latency or both. Meta-analyses have ignored latency as a dependent variable because it is seldom recorded or reported. Yet, slower recognition of others' emotions obviously has important theoretical and applied implications. Some recent studies suggest that autistic-nonautistic group differences in latency might be expected. For example, Loth et al. (2018) reported poorer recognition accuracy and longer latencies for autistic adolescents and adults when asked to indicate which of three static images of basic and complex emotions matched a previously viewed target word. In a similar vein, Drimalla et al. (2021) reported slightly lower accuracy and longer latencies for autistic adults when required to choose which of two multiple-choice options corresponded to basic emotion stimuli displayed as static images. Whether these patterns replicate under free-report conditions and across different types of stimulus presentation is unknown.

Method

Participants

The autistic sample comprised 63 volunteers (46 male, 17 female), aged 18–66 years (*M* = 31.1 *SD* = 13) diagnosed with autism spectrum disorder by a multidisciplinary team or medical professional using the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR [APA, 2000] or DSM-5 [APA, 2013]) and registered on an Australian university research participation database. Wechsler Abbreviated Scale of Intelligence-Second Edition (WASI-II; Wechsler, 2011) Verbal Comprehension Index (VCI) and Full-Scale IQ (FSIQ) scores spanned 85–143 (*M* = 104.44, *SD* = 12.71, 95% *CI* [101.30, 107.58]) and 85–138 (*M* = 107.05, *SD* = 12.26, 95% *CI* [104.02, 110.08]), respectively. The non-autistic sample included 67 individuals enrolled in transition or undergraduate programs (20 male, 47 female), aged 18–65 years (*M*= 23.8 *SD* = 8.9) without an ASD diagnosis and with VCI scores (only VCI sub-tests administered) ranging from 85–136 (*M* = 106.57, *SD* = 11.44, 95% *CI* [103.83, 109.31]. The groups did not differ significantly in VCI, t (128) = 1.00, p= .318, but the nonautistic group contained a larger proportion of female participants, $\chi^2(1) = 24.21$, $p < .001$, and was younger overall, t (109.26) = 3.73, $p < .001$. Participants' primary language was English.

Design

The design was a 2 (Group: autistic, nonautistic) × 2 (Response Format: free-report, multiple-choice) × 3 (Stimulus Type: static, dynamic, social) × 12 (Emotion: afraid, angry, ashamed, disappointed, disgusted, frustrated, happy, hurt, jealous, sad, surprised, worried) mixed design. Stimulus type, response format and emotion were within-subjects' factors. Dependent measures were percent agreement with normative recognition responses (usually labeled emotion recognition accuracy), response latency and confidence. We targeted as large a sample of autistic adults as would commit to a 3–5 hour testing session. Unfortunately, sample size estimates based on meta-analysis outcomes (e.g., Griffiths et al., 2019; Uljarević & Hamilton's, 2013) and approaches within GPower and R-packages (to our knowledge) do not accommodate designs including a between-subjects factor and three within-subjects factors.

Following each social stimulus response, participants also provided a short description of how they might respond to the target individual after observing their emotional expression. Those data, together with extensive metacognition analyses involving within-individual and between-group relationships between recognition response confidence and percent agreement are part of a large study on "Emotion Recognition, Empathic Reactions and Metacognitions in Autistic Adults" and are not reported here because of word limits.

Materials

Stimuli were from the EU-Emotion Stimulus Set database (O'Reilly et al., 2012, 2016) which spans 20 emotions portrayed by a diverse group of actors. We used the high intensity versions of 12 emotions (the 6 'basic' emotions and another 6 chosen at random), displayed as static images (photographs), dynamic video clips (a video of the person making the facial expression), and contextual social scenes, without vocalizations. Recognition scores from O'Reilly et al.'s (2016) validation studies for these stimuli appear in Supplementary Table S1.[2]

Participants completed three emotion recognition tasks (static, dynamic, social) for each emotion delivered online (via Qualtrics) in randomized order on the same 15-inch Apple Macbook Pro (connected to a usb/wireless mouse).

Response Format

For static stimuli, participants viewed each stimulus and typed a single-word free-report response below it to describe the emotion the target was feeling, followed by a confidence rating. Then, they selected the target's emotion from four multiple-choice options. After viewing the short clips of dynamic and social stimuli, participants proceeded to a subsequent screen where the free-report question was presented, followed by the confidence question; the multiple-choice options then appeared on a separate screen and they selected the target's emotion from the four multiple-choice options.

The free-report always preceded the multiple-choice response. Although forced-report formats predominate in emotion recognition research, free-report responses may provide a more ecologically valid reflection of emotion recognition. Our priority was obtaining as large a sample as possible under free-report that was uncontaminated by a previous multiple-choice response. Given the negligible prospect of securing sufficient autistic participants to achieve that objective when only half of the participants provided their free-report first, we elected not to counterbalance response formats, conceding that interpretation of multiple-choice patterns would be difficult.

Multiple-choice options for each item included the target emotion and three foils randomly selected from a pool of 60 options that included the other 11 emotions and 49 emotions that were not too similar to the target emotions (Supplementary Table S2).

Stimulus Type

Trials for each stimulus type were completed in a block, with block presentation order counterbalanced. The static task presented photos of a face (shoulders up) whereas the dynamic task presented short video clips of a person (shoulders up) moving their face into configurations depicting the target emotions. For both the static and dynamic stimulus types there were 4 trials for each emotion (i.e., 48 trials), with presentation order within each type randomized. In the social stimulus task, participants were presented with 4–7 (*Mdn* = 7)[3] video clips of an interaction between the target and one or more people or objects that provided informative contextual information, with participants indicating the emotion of the person in the interaction specified as the target individual. Stimulus presentation order was randomized.

The following URLs provide two examples of each task:

- Static: https://qualtrics.flinders.edu.au/jfe/form/SV_9pqp0YDttUmdts1
- Dynamic: https://qualtrics.flinders.edu.au/jfe/form/SV_8vafpqESU40Iyu9
- Social: https://qualtrics.flinders.edu.au/jfe/form/SV_9oad9qroRmS3yrr

Emotion

The 12 emotions used were the six 'basic' emotions (afraid, angry, disgusted, happy, sad, surprised) and six emotions (ashamed, disappointed, frustrated, hurt, jealous, worried) commonly classified as complex emotions.

Measures

Following Barrett et al. (2019), we use the label percent agreement rather than recognition accuracy because 'accuracy' assessment is based on subjective judgments that provide an index of normative interpretations of emotional expressions rather than on some objective index of a specific facial emotional configuration. In other words, the reference point for an 'accurate' response is the typical response that observers provide to a particular emotion stimulus. O'Reilly et al. (2016) describe the methods used to classify the 'accurate' multiple-choice responses for the various face emotion configurations used.

Percent Agreement

For free-report scoring, synonyms for the 12 emotions were identified using four online thesaurus and/or dictionary platforms. Responses were coded as matching the normative response if they used the appropriate emotion term or an appropriate synonym. (See Supplementary Table S3 for the number of appropriate synonyms coded.) Non-synonym responses were presented to three judges who were asked to imagine that they were looking at someone's face and had to describe their emotion. For each emotion, they classified the responses based on closeness in meaning, scoring 3 (strict: label means exactly the same as the target emotion), 2 (lax: similar meaning, but not exactly the same), 1 (boundary: plausible alternative but not really a synonym) or 0 (incorrect: not at all like the emotion). If one judge's rating differed from the others, majority rule was applied; when all judges differed, the average (rounded) rating was used. See Table 1 for examples; all coding classifications available at https://osf.io/ndbfs/.

Thus, if a participant received scores of 1, 3, 0, and 2 on the 4 trials for the static presentations of 'angry', they received 6 of a possible 12 for that cell of the design and their free-report percent agreement score was 50% (i.e., 6/12). Or if a participant received scores of 1, 3, 0, 2, 3, and 3 on the 6 trials for the social presentations of 'angry', they received 12 of a possible 18 for that cell of the design and their free-report percent agreement score was 66.67%. For multiple-choice responses, selection of the target emotion (the normative recognition response) on each trial = 1 and a foil selection = 0; thus, a participant who selected the target response on 3 of the 4 trials for the static presentation of 'angry' received a percent agreement score of 75% for that cell.

An independent rater coded a subset of free-report responses (*n*= 2,200) across the three emotion recognition tasks; author MG independently scored the same subset; inter-rater reliability was indexed by Cohen's kappa (k = .89), with coefficients exceeding .80 generally considered to indicate strong agreement. The independent rater then scored the remaining responses (*n*= 19,900). To ensure reliability remained high, author MG scored another random subset (*n*= 1,115) of responses (k = .83).

Latency and Confidence

Latency was recorded to the nearest 0.01s from stimulus onset to response completion for free-report responses in the static condition. In the dynamic and social conditions, free-report latency was recorded to the nearest 0.01s from the appearance of the free-report response question to response completion. For multiple-choice responses, latency was recorded to the nearest 0.01s from appearance of the multiple-choice response question to response completion. Confidence in free-report and multiple-choice responses was assessed immediately after each participant's response; participants were presented with an 11-point scale ranging from 0% to 100% and asked to select their level of confidence that the answer was accurate.

Procedure

The study was approved by the Social and Behavioural Ethics Committee of Flinders University. Participants were tested at home or the university and received a cash honorarium in recognition of the lengthy time commitment. Autistic participants' WASI-II measures were accessed from our research participant database; nonautistic participants completed WASI-II verbal subtests prior to the emotion recognition tasks. At the beginning of each task (i.e., static, dynamic, social), the experimenter read aloud the instructions on the laptop screen and ensured participants understood requirements. Participants entered demographic information, provided a single rating of their confidence in their ability to accurately recognize others' emotion and completed two practice trials for that task. Participants were reminded before each task to respond as quickly and accurately as they could; this instruction also appeared on the screen prior to each trial.

Results

We conducted separate 2 (Group: autistic, nonautistic) × 3 (Stimulus Type: static, dynamic, social scenes) × 2 (Response Format: multiple-choice, free-report) × 12 (Emotion: afraid, angry, ashamed, disappointed, disgusted, frustrated, happy, hurt, jealous, sad, surprised, worried) ANOVAs on percent agreement, latency and confidence, with stimulus type, response format and emotion as within-subjects factors.

The alpha level was 0.05. Following Lakens (2013), effect sizes are reported both as partial eta squared (η_p^2) and generalized eta squared (η_G^2), with approximate guidelines for small, medium and large effects guided by generalized eta squared (η_G^2) values of 0.01, 0.06, and 0.14, respectively. With the 12-level repeated measure emotion variable (main effect and interactions) involved in analyses of all dependent variables, violations of sphericity were detected; degrees of freedom were adjusted using the Greenhouse-Geisser correction. For each dependent variable there were significant two-and three-way interactions between the within-subjects variables (emotion, stimulus type and response format), with the source of the interaction generally involving different emotions. The interaction effect statistics are shown in Supplementary Materials Tables S5, S7 and S10 but, given the study's focus on autistic and nonautistic data patterns, they are not examined further.

Percent Agreement

A percent agreement score was calculated for each participant for each cell in the design as described earlier. Mean (and *SD*) percent agreement scores for all cells appear in Supplementary Table S4 and the ANOVA summary table appears in Supplementary Table S5. Overall percent agreement scores for each group are depicted in Figure 1 (top panel).

There were significant and large effects for response format, F (1, 128) = 2341.04, $p <$ .001, $\eta_p^2 = .95$, $\eta_G^2 = .18$, and emotion, F (8.67, 1109.63) = 161.35, $p < .001$, $\eta_p^2 = .56$, $\eta_G^2 =$ .23, and a weak effect for stimulus type, F (1.90, 243.72) = 97.45, $p < .001$, $\eta_p^2 = .43$, $\eta_G^2 =$ .05. Percent agreement was higher for multiple-choice (*M* = 81.91%, *SE* = 0.75, 95% CI [80.42, 83.41]) than free-report responses (*M* = 63.55%, *SE* = 0.62, 95% CI [62.32, 64.77]), and increased progressively for static (*M* = 67.06%, *SE* = 0.86, 95% CI [65.35, 68.77]), dynamic (*M* = 73.30%, *SE* = 0.79, 95% CI [71.73, 74.88]) and social stimulus presentations (*M* = 77.83%, *SE* = 0.74, 95% CI [76.37, 79.29]). Percent agreement varied across emotions but was relatively high for five of the six basic emotions, ranging from 70.56% to 88.56%; the complex emotions' agreement scores ranged from 51.48% to 70.59%.

The effect of group was significant, F (1, 128) = 9.98, p =.002, $\eta_p^2 = .07$, $\eta_G^2 = .01$, but the effect was very weak. Percent agreement was lower for the autistic (*M* = 70.64%, *SE* = 0.95, 95% CI [68.75, 72.52]) than the nonautistic (*M* = 74.83%, *SE* = 0.92, 95% CI [73.00, 76.65]) group. As Figure 1 highlights, despite the overall group difference, there was considerable overlap in the distributions of percent agreement for individuals in each group and marked inter-individual variability for both groups. There was, however, a small cluster of autistic individuals with lower percent agreement scores than any of the nonautistic sample.

Notably, group did not interact significantly with response format, stimulus type or emotion. Moreover, the effect sizes for these interactions were all extremely weak ($\eta_G^2 \leq .01$).

Response Latency

Mean response latency (to 0.01s) was calculated for each participant for each cell in the design; any mean more than 2.5 *SD* above or below the cell mean was adjusted to 2.5 *SD* from the mean (cf. Field, 2013). Overall latencies for each group are depicted in Figure 1 (bottom panel) and mean (and *SD*) latencies across cells are shown in Supplementary Table S6; the ANOVA summary table appears in Table S7.

There were significant effects for response format, F (1, 128) = 980.79, $p < .001$, η_p^2 = .89, η_G^2 = .20, stimulus type, F (1.91, 245.00) = 11.30, $p < .001$, η_p^2 = .08, η_G^2 = .01, and emotion, F (8.41, 1075.99) = 9.89, $p < .001$, η_p^2 = .07, η_G^2 = .01. Latencies were shorter for multiple-choice (*M* = 1.92, *SE* = 0.04, 95% CI [1.83, 2.00]) than free-report responses (*M* = 3.12, *SE* = 0.06, 95% CI [2.99, 3.25]). Latency was shortest for dynamic (*M* = 2.37, *SE* = 0.06, 95% CI [2.25, 2.49]), followed by social (*M* = 2.51, *SE* = 0.06, 95% CI [2.39, 2.63] and static stimuli (*M* = 2.67, *SE* = 0.07, 95% CI [2.54, 2.80]. Although latencies varied significantly across emotions, neither simple nor complex emotions were characterized by consistently shorter latencies.

There was a significant medium strength effect for group, F (1, 128) = 55.15, $p < .001$, η_p^2 = .30, η_G^2 = .09, with longer latencies for the autistic (*M* = 2.90, *SE* = 0.07, 95% CI [2.75, 3.04]) than the nonautistic group (*M* = 2.14, *SE* = 0.07, 95% CI [2.00, 2.28]). There was overlap in the response latency distributions for individuals in the two groups and marked inter-individual variability for both groups (see Figure 1, bottom panel). But there was a sizable cluster of autistic individuals with longer latencies than any of the nonautistic sample.

The effect of group was not moderated by either stimulus type or emotion, with effect sizes for these interactions extremely weak ($\eta_G^2 \leq .001$). There was a significant but extremely weak Response Format × Group interaction, F (1.00, 128) = 30.79, $p < .001$, η_p^2 = .19, $\eta_G^2 < .01$, reflecting a more marked latency reduction from free-report to multiple-choice for the autistic group (*M* = 3.60, *SE* = 0.09, 95% CI [3.42, 3.79], to *M* = 2.19, *SE* = 0.06, 95% CI [2.07, 2.31]) than the nonautistic group (*M* = 2.64, *SE* = 0.09, 95% CI [2.46, 2.81], to *M* = 1.65, *SE* = 0.06, 95% CI [1.53, 1.76]). This weak effect may reflect greater processing difficulties (e.g., accessing relevant conceptual knowledge), or perhaps less fluent keyboard typing, for autistic individuals when providing free-report responses. Note, however, that the proportionate latency reductions for the two groups were almost identical and the absolute latency values suggest that the nonautistic group was likely approaching the floor in the multiple-choice condition. We make no attempt to interpret the significant but weak three and four-way interactions involving group, particularly given the possible floor effect for the nonautistic group.

To check the possibility that longer latencies for autistic individuals might simply reflect occasional trials that resulted in error (perhaps reflecting momentary inattention, an idiosyncratic difficulty with a particular emotion, etc.), we compared latency for all ‘accurate’ trials completed by autistic and non-autistic participants. As shown in Supplementary Materials Table S8, latencies for accurate trials were significantly longer for autistic than nonautistic participants regardless of the subset of conditions considered. Note also that the data are not consistent with the possibility that slower autistic individuals were simply more cautious and hence more ‘accurate’ individuals given the correlation between overall latency and percent agreement negative and weak, r (61) = -.14, p = .27.

Confidence

Mean (and *SD*) confidence values across all cells are shown in Supplementary Table S9; the ANOVA summary table appears in Table S10. There were significant main effects for response format, F (1, 128) = 59.30, $p < .001$, $\eta_p^2 = .32$, $\eta_G^2 = .01$, stimulus type, F (1.85, 236.20) = 78.99, $p < .001$, $\eta_p^2 = .38$, $\eta_G^2 = .08$, and emotion, F (5.26, 673.71) = 102.72, $p < .001$, $\eta_p^2 = .45$. $\eta_G^2 = .05$. Confidence was higher for multiple-choice (*M* = 81.46%, *SE* = 1.08, 95% CI [79.32, 83.61]) than free-report responses (*M* = 78.05%, *SE* = 1.10, 95% CI [75.89, 80.22]), and rose progressively across static (*M* = 74.93%, *SE* = 1.25, 95% CI [72.46, 77.39]), dynamic (*M* = 78.83%, *SE* = 1.21, 95% CI [76.45, 81.22]) and social stimulus presentations (*M* = 85.52%, *SE* = 1.06, 95% CI [83.41, 87.62]). Confidence varied across emotions but was highest for the six basic emotions, ranging from 78.66% to 87.20%; the other emotions’ confidence scores ranged from 74.76% to 78.46%.

The main effect for group was significant, F (1, 128) = 19.05, p < .001, $\eta_p^2 = .13$, $\eta_G^2 = .09$, with the autistic group less confident (M = 75.10, SE = 1.53, 95% CI [72.07, 78.13]) than the nonautistic group (M = 84.41, SE = 1.49, 95% CI [81.47, 87.35]). The effect of group was not moderated by either stimulus type or response format, with both effect sizes extremely small ($\eta_G^2 < .003$). A very weak but significant interaction between emotion and group, F (5.26, 673.71) = 5.49, p < .001, $\eta_p^2 = .04$, $\eta_G^2 \leq .01$, reflected a trend to smaller group differences for the basic emotions happy, surprised and disgusted. We make no attempt to interpret the Stimulus Type × Emotion × Group interaction given the extremely small effect size and the involvement of the 12-level emotion variable.

Gender and Age Effects

The autistic sample contained a larger proportion of males than the nonautistic sample. To check whether the different ratios of males to females in each group might have influenced the findings, we conducted the main analyses on percent agreement, latency and confidence separately for male and female participants and compared the outcome patterns with those for the full dataset. Given the size of the minority cohorts, there are obvious power issues but a consideration of effect sizes guides interpretation. The full analysis outputs appear at https://osf.io/ndbfs/. For percent agreement, the effect of group was no longer significant for the female subset and the effect size was small; the interactions involving group matched the overall data. For latency, (a) the main effect of group was unchanged, (b) the effect of stimulus type for males was nonsignificant but the pattern of descriptive statistics and the effect size mirrored the overall pattern, and (c) the two-way interactions involving group were consistent with the overall patterns. For confidence, neither the effect of group nor the two-way interactions differed.

The autistic sample was also, on average, older than the nonautistic sample. Identifying any possible contribution of the age differences between groups is difficult. As Miller and

Chapman (2001) argued, with pre-existing groups (e.g., autistic and nonautistic), pre-treatment differences in variables such as age may reflect important differences associated with group membership. Consequently, controlling for age risks removing variance that is actually associated with the group factor and, consequently, controlling for such differences statistically is inappropriate (e.g., Chapman & Chapman, 1973; Miller & Chapman, 2001). Note, however, that in the autistic group, a weak and significant negative correlation with age was detected for percent agreement, r_s (61)= -.25, p = .045, although not for latency, r_s (61)= .21, p = .104. Thus, perhaps the group difference in percent agreement might have been even narrower with a more homogeneous younger autistic cohort.

Discussion

In this study we examined autistic and nonautistic adults' recognition of face emotions across response formats (free-report, multiple-choice), stimulus types (static images, moving or dynamic images, social stimuli) and an array of basic and complex emotions, focusing on degree of agreement with normative recognition responses, response latency and confidence. We highlight five findings. First, stimulus type had a modest impact on percent agreement and confidence and a weak effect on latency, with percent agreement enhanced by the additional cues and contextual information respectively provided by dynamic and social stimuli. Second, percent agreement and confidence were generally higher for those emotions typically labeled as basic. Third, response format exerted a strong impact, with multiple-choice responding associated with higher agreement, shorter latencies and higher confidence. Note, however, the extent to which the impact of the multiple-choice format reflected exploitation of cues provided by the prior free-report is unknown.

Fourth, percent agreement was slightly but significantly lower for the autistic group. It is important to emphasize, however, the considerable overlap in the distributions of percent agreement scores for each group and the marked inter-individual variability within both groups. Autistic individuals were also markedly slower and less confident than nonautistic individuals. Fifth, the inferential test outcomes and the associated effect sizes demonstrated that the comparative percent agreement and latency patterns for the two groups were unaffected by variations in stimulus type and emotion. And, although the latency difference between free-report and multiple-choice formats was larger for the autistic group, the effect size suggests a very weak effect that may simply have resulted from the nonautistic group nearing the floor.

Theoretical Implications

The study highlights several theoretical issues. First, the patterns across dependent measures do not support a conclusion of a core deficit in emotion recognition in autistic adults. The percent agreement data indicate substantial overlap between groups and considerable inter-individual variability, thus questioning whether face emotion processing difficulties are ubiquitous. Although the latency data might be interpreted as indicating less efficient processing of emotion expressions associated with autism, such a conclusion would be premature.

Our methodology was not designed to identify the speed-accuracy operating characteristics of either group (cf. Pachella, 1974). Consequently, we are unable to determine whether individuals in either group were processing and responding to emotion stimuli as rapidly as they could or just pursuing a different strategic approach. For example, perhaps autistic individuals simply adopted a more cautious approach such as carefully reflecting on their decisions before responding. Or perhaps their longer latencies reflect a predisposition towards a qualitatively different processing strategy characterized by deliberative and effortful processing rather than the intuitive and less effortful processing characteristic of nonautistic individuals (cf. Brosnan et al., 2016, 2017, although see Farmer et al., 2021). We address ways of clarifying this issue in the later section on future research directions.

Second, the absence of differential effects of stimulus type for the two groups is inconsistent with Van de Cruys et al.'s (2014) suggestion that autistic individuals may be hindered by being unable to ignore irrelevant cues associated with the variations in expressions of the same facial emotion displayed in dynamic or social contexts. These patterns obviously do not invalidate Van de Cruys et al.'s (2014) predictive coding account of autism, but—given there were multiple presentations of 12 different emotions—they suggest that greater stimulus complexity or variability is insufficient to undermine emotion recognition in autistic individuals.

Third, the absence of interactions between group and emotion for both percent agreement and latency is inconsistent with notions that autistic individuals' difficulties may be emotion-specific or confined to what are often referred to as complex emotions. However, given the considerable inter-individual variability observed in all conditions, we cannot rule out that such perspectives may apply for some sub-sets of individuals. But we must also remain cognizant of the possibility that, in an area dominated by small sample studies and limited stimulus sampling, emotion-specific patterns such as those reported in prior research may arise by chance.

Finally, although reluctant to read too much into the effect of response format on percent agreement, response latency and confidence given free-report always preceded multiple-choice, we acknowledge that its albeit weak interaction with group for latency suggests the possibility that contextual information provided by multiple-choice word options, as used in measures such as the Reading the Mind in the Eyes Test (cf. Betz et al., 2019; Cassells & Birch, 2014), provides cues that are especially helpful for autistic individuals. If so, researchers' reliance on multiple-choice response paradigms may underestimate autistic individuals' difficulties.

Methodological Issues

We note several issues that may have implications for the generality of our findings. First, the groups' gender compositions differed, with males and females in the majority in the autistic and nonautistic groups, respectively. Participant availability for our lengthy testing was limited and balancing gender (and age) was secondary to securing sizable samples. Although our posthoc comparisons of male and females' performance suggest the different gender compositions were not consequential, much larger samples would permit matching of gender compositions and adequately powered testing. A recent meta-analysis of face recognition difficulties in autistic individuals revealed their magnitude was unaffected by the proportion of males in study samples (Griffin et al., 2021). Whether this pattern will replicate for emotion processing is unknown.

Second, a much larger autistic sample would enable investigation of other sampling issues. For example, the emotion stimuli were displayed by nonautistic individuals. Whether normative recognition responses for autistic and nonautistic individuals will vary when expressions are produced by autistic targets is unknown (cf. Edey et al., 2017; Keating & Cook, 2020). The contribution of alexithymia in our study is also unknown. Although alexithymia has been identified as an important predictor of emotion recognition (e.g., Cook et al., 2013), only recently has autistic and nonautistic individuals' emotion recognition been contrasted using other than static stimuli while controlling for alexithymia. It remains to be seen whether Keating et al.'s (2021) finding that, under such conditions, alexithymia was not predictive of emotion recognition accuracy replicates.

Third, large sample studies would also allow probing of the role of co-occurring conditions that may contribute to variability in emotion recognition in autistic samples: for example, higher levels of depression and anxiety (e.g., Nah et al., 2018) or the presence of sub-types that vary in terms of recognition of social signals, expressive aspects of social communication and the motivation for social interaction (cf. Uljarević et al., 2020). In other words, showing that particular emotion processing difficulties observed in autistic individuals are unique to autism and not observed in association with other psychological conditions that may co-exist with autism will be crucial for validating conclusions about emotion processing in autism.

Fourth, given our sampling of autistic individuals ruled out the potentially confounding impact of an intellectual disability on access to conceptually appropriate free-report responses, our findings cannot be generalized to autistic individuals with relatively low verbal or general ability.

Fifth, as already noted, free-report latencies included the time taken to type responses, thereby confounding processing and typing proficiency. Obvious solutions would be to record latency from the commencement of typing or perhaps use an independent measure of typing proficiency as a control. Unfortunately, neither approach would clarify the proportion of the 'typing time' that reflected a purely motor component versus ongoing cognitive processing (e.g., further reflection on the emotional state observed or its most appropriate label, starting to type and then thinking again and editing). However, the substantial mean latency difference and nonoverlapping confidence intervals for the two groups in the multiple-choice condition when only a button click was required suggests major contributions of processes other than typing proficiency. Nevertheless, more sophisticated methodologies will be required to resolve the relative contributions of these different components.

Future Directions

As already noted, it is unclear whether the latency patterns reflect a fundamental processing speed limitation underpinning autistic individuals' discrimination of emotions, greater caution or perhaps even a predisposition towards a different style of processing such as the deliberative and effortful processing style described by Brosnan et al., 2016b, 2017). An initial step in resolving these issues might involve constraining cautious responding or deliberative processing by limiting stimulus exposure durations or requiring responses prior to a variable deadline signal (cf., Brewer & Smith, 1990; Tracy et al., 2011). If autistic and nonautistic individuals attained similar and asymptotic percent agreement scores at an exposure duration or response deadline of, say, 1.5s, yet their response latencies in the absence of such constraints were 3.7s and 2.5s, respectively, then autistic individuals' longer latencies would reflect some kind of strategic influence such as withholding their selected response until they had double-checked their decision or using some form of deliberative processing strategy that is time-costly. If progressively shorter exposure durations or response deadlines increasingly differentiated the groups in terms of percent agreement, a non-adjustable processing limitation would be implicated. To date, the available evidence using such approaches—from small child and adolescent samples (Clark et al., 2008; Tracey et al., 2011)—is limited and contradictory.

A related question is whether autistic individuals' longer latencies might reflect time to decode emotion stimuli or the speed of generating the appropriate response. Recognition of others' expressions often does not require production of a word for the emotion observed. Given autistic adults may be impaired on semantic verbal fluency tasks (Spek et al., 2009), it will be important to examine the extent to which longer latencies might be attributable to speed of accessing verbal labels. It is also possible that the availability of much larger samples might reveal that autistic individuals of above-average verbal ability are able to access verbal labels more rapidly under both free-report and multiple-choice conditions.

Another worthwhile direction for future research would be the systematic charting, using cross-sectional and longitudinal studies, of age effects on percent agreement and latency in autistic individuals across adulthood. Lozier et al.'s (2014) meta-analysis highlighted larger group differences for autistic adults (age undifferentiated) than for adolescents and young children. Our data also hint at the possibility of magnified difficulties in older autistic adults.

Why emotion processing difficulties might be exacerbated in older adults who presumably have more experience of the social world than younger individuals is an interesting but unanswered question. The lifespan developmental literature should provide a fertile source for speculation about possible (nonsocial) cognitive declines or changes, neurophysiological changes and social-experiential influences from young adulthood onward that may shape the characteristics and efficiency of emotion processing. Gathering the relevant data across age points will obviously be demanding of both resources and access to samples.

The preceding issue signals another research imperative: understanding how difficulties observed on lab tasks translate into everyday social functioning. At present, we do not know how departures from normative interpretations of emotion stimuli detected in the lab translate into everyday emotion recognition problems—might 75% agreement with normative recognition responses indicate a problem, or maybe 65% or 50%? Might these values vary across emotions? And what might the consequences be of a delay of 0.5s, 0.75s or 1s in recognizing the emotion and might the implications vary depending on whether the individual is observing or engaged in the social interaction? Answering such questions will require paradigms that tap behaviors associated with recognition and responding in real-life interactions or perhaps in virtual reality settings. Those paradigms will have to accommodate variables such as co-occurring gestures, variations in prosody and other aspects of speech, familiar versus unfamiliar interaction partners, and so on. In other words, paradigms will need to grapple with the complexities of examining emotion processing in environments that capture the demands of real-life interactions.

Conclusion

When compared with nonautistic adults of similar verbal ability, emotion recognition in autistic adults was characterized by slightly lower percent agreement with normative responses, longer response latencies and lower confidence, although inter-individual variability was pronounced. However, the group patterns observed were stable across variations in the degree of contextual information accompanying stimulus presentation, free-report versus multiple choice response formats, and a large array of emotions. Taken together, the findings challenge the perspective that a core deficit in emotion recognition characterizes autistic adults. Whether different manipulations of these same independent variables produce converging findings remains to be seen.

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Footnotes

[1]Although the Reading the Mind in the Eyes test is often referred to as a test of Theory of Mind, researchers have questioned its convergent validity (e.g., Gernsbacher & Yergeau, 2019), highlighted robust relationships with emotion recognition performance (Henry et al., 2009) and argued that it more appropriately viewed as a test of emotion recognition (cf. Oakley et al., 2016).

[2]Raw data for the static condition provided by database manager, H. O'Reilly of the ASC-Inclusion Project: Autism Research Centre, University of Cambridge, UK. Email: heo24@medschl.cam.ac.uk

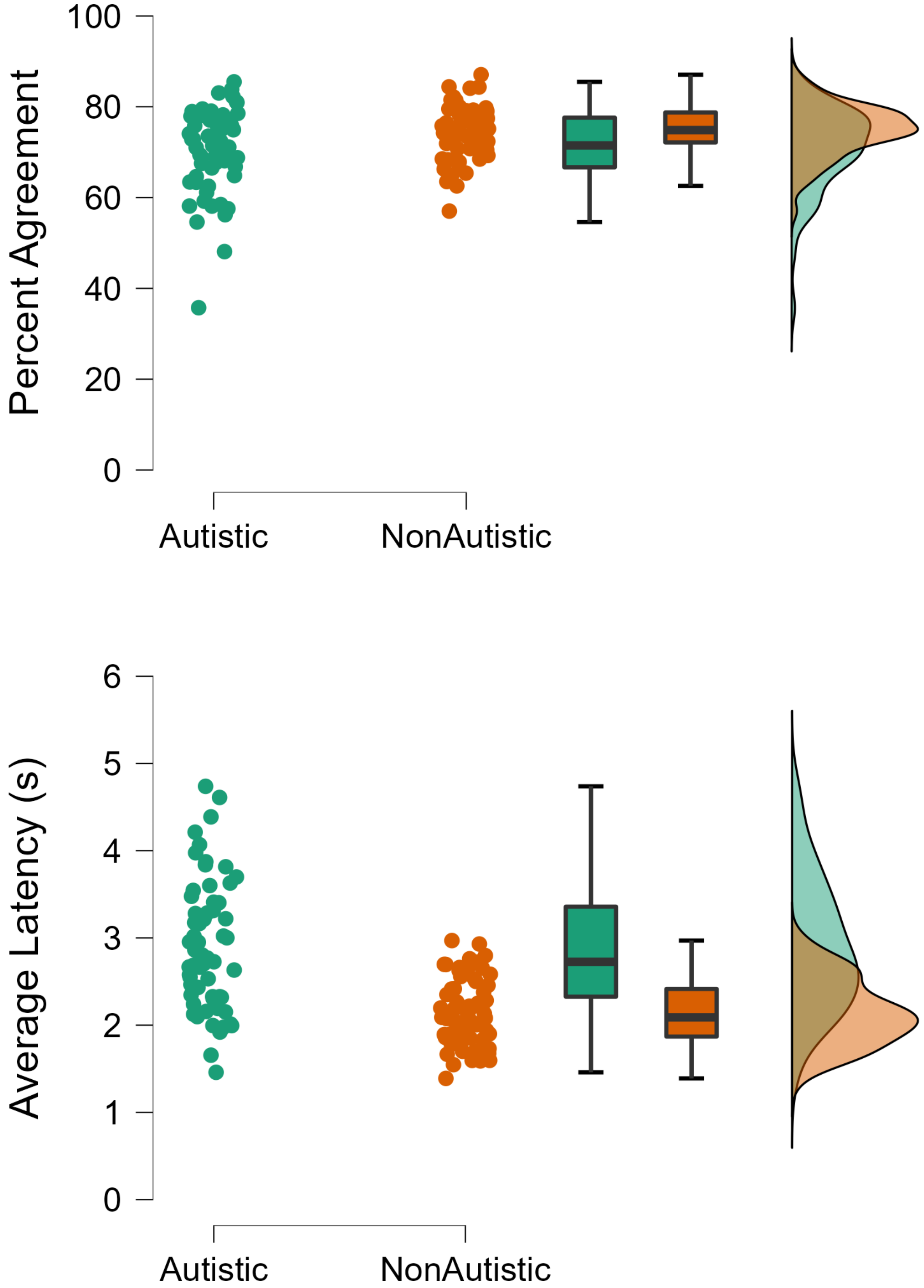
[3]To maximize trial numbers for the analyses of the social stimulus responses that participants indicated they would give to the target individual in response to their emotion expression, we included all social stimuli ($N = 74$) from the database for the 12 emotions, resulting in uneven social trial numbers across the 12 emotions.

Table 1

Examples of Free-Report Emotion Recognition Scoring Classification

Emotion	Strict (3)	Lax (2)	Boundary (1)	Incorrect (0)
Afraid	Fearful	Alarmed	Discomfort	Amazed
	Scared	Horrified	Cautious	Happy
Worried	Concerned	Fearful	Melancholic	Disgusted
	Stressed	Uncertain	Ashamed	Curious

Figure 1. Raincloud plot showing the distributions of overall percent agreement (top panel) and average latency (bottom panel) for autistic and nonautistic participants



Supplementary Material

Table S1

Mean (& SD) Chance Corrected Recognition Scores (Percentage Correct) for High Intensity Basic and Complex Emotions from O'Reilly et al.'s (2016) Validation Study

	Stimulus Type					
	Static		Dynamic		Social	
Emotion	*M*	*SD*	*M*	*SD*	*M*	*SD*
Basic						
Afraid	57	20	78	13	94	5
Angry	46	32	69	14	72	13
Disgusted	53	19	82	23	82	10
Happy	94	6	82	13	66	25
Sad	81	12	80	10	67	31
Surprised	78	14	79	23	49	33
Complex						
Ashamed	41	26	59	26	75	14
Disappointed	15	10	55	13	66	13
Frustrated	38	18	75	12	96	4
Hurt	39	26	59	16	81	14
Jealous	11	13	14	17	44	31
Worried	53	18	63	15	77	20

Table S2

Pool of Emotions Used for Multiple-Choice Format

Target Emotions/States of Mind

Afraid	Disappointed	Happy	Sad
Angry	Disgusted	Hurt	Surprised
Ashamed	Frustrated	Jealous	Worried

Filler Emotions/States of Mind

Appreciated	Doubtful	Hopeful	Optimistic
Amazed	Dreading	Heartbroken	Pained
Awful	Desperate	Helpless	Passionate
Belligerent	Dismay	Hostile	Panicked
Bored	Eager	Inspired	Proud
Brave	Excited	Interested	Relieved
Bitter	Exhausted	Joking	Sympathetic
Certain	Exhilarated	Kind	Satisfied
Complacent	Flattered	Lonely	Sneaky
Confident	Grateful	Liberated	Suspicious
Dejected	Hatred	Nervous	Uncertain
Despair	Honoured	Offended	Unfriendly
			Weary

Table S3

Free-Report Emotion Recognition Coding Summary

Emotion	Number of Synonyms Coded	Number of Non-Synonym Responses Coded
Afraid	29	115
Angry	61	135
Ashamed	40	211
Disappointed	42	179
Disgusted	36	95
Frustrated	45	135
Happy	52	113
Hurt	30	173
Jealous	25	197
Sad	70	180
Surprised	34	127
Worried	80	166

Table S4

Means (& SDs) of Recognition Percent Agreement for Autistic and NonAutistic Groups Across Emotion, Stimulus Type and Response Format*

Emotion	Response Format	Static		Dynamic		Social	
		Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)
				Basic Emotions			
Afraid	FR	60.98 (24.63)	60.70 (24.65)	64.95 (23.34)	71.27 (20.12)	75.75 (18.97)	81.92 (13.82)
	MC	77.78 (26.98)	79.48 (24.59)	79.37 (22.24)	83.21 (20.13)	87.30 (17.64)	92.04 (11.73)
Angry	FR	62.57 (19.22)	66.29 (20.84)	68.39 (17.97)	73.38 (15.30)	76.87 (13.19)	79.82 (12.19)
	MC	69.84 (23.95)	75.75 (24.22)	81.35 (22.44)	85.45 (16.94)	89.12 (14.45)	91.47 (10.27)
Disgusted	FR	78.31 (26.54)	82.21 (18.46)	82.54 (19.38)	92.04 (13.33)	78.66 (17.23)	83.75 (11.58)
	MC	88.89 (19.97)	89.93 (16.89)	94.84 (12.83)	96.27 (10.88)	92.06 (15.51)	96.27 (8.11)
Happy	FR	96.03 (10.02)	98.26 (6.57)	85.85 (17.04)	85.45 (16.50)	72.11 (13.89)	73.28 (14.36)
	MC	92.46 (15.32)	95.90 (11.18)	94.84 (12.83)	93.66 (11.79)	87.30 (14.54)	87.63 (14.69)
Sad	FR	57.01 (24.33)	58.08 (24.32)	64.02 (24.99)	64.30 (18.85)	60.54 (15.80)	69.51 (16.03)
	MC	74.21 (26.17)	75.00 (26.11)	76.19 (26.35)	82.09 (18.87)	79.82 (16.75)	85.93 (15.23)
Surprised	FR	93.65 (16.17)	97.14 (8.28)	82.80 (16.39)	87.19 (15.65)	51.55 (22.57)	55.44 (13.89)
	MC	97.22 (7.92)	98.13 (6.62)	91.67 (14.89)	94.03 (11.59)	87.98 (12.36)	90.19 (10.61)
				Complex Emotions			
Ashamed	FR	43.52 (22.42)	44.78 (20.86)	44.05 (26.41)	54.48 (22.95)	64.55 (23.78)	71.14 (20.94)
	MC	65.08 (29.29)	67.16 (26.55)	71.83 (30.62)	79.85 (23.93)	83.67 (20.66)	86.99 (17.89)
Disappointed	FR	27.78 (20.52)	36.57 (20.87)	50.79 (22.34)	62.44 (24.16)	46.26 (18.13)	48.54 (14.07)
	MC	73.41 (25.74)	74.25 (26.10)	81.35 (22.44)	86.94 (19.15)	79.37 (18.46)	82.30 (12.94)
Frustrated	FR	29.50 (16.86)	31.84 (18.69)	52.25 (23.29)	59.20 (19.63)	86.11 (15.77)	93.41 (11.19)
	MC	62.30 (26.13)	69.78 (23.65)	79.76 (22.39)	87.69 (16.50)	98.02 (8.16)	96.27 (11.72)

Emotion	Response Format	Static		Dynamic		Social	
		Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)
Hurt	FR	50.79 (13.78)	56.34 (15.83)	54.50 (16.45)	57.46 (13.54)	60.39 (18.62)	68.30 (15.12)
	MC	65.87 (28.50)	74.63 (27.00)	73.41 (28.35)	77.61 (23.49)	81.18 (20.66)	87.42 (15.83)
Jealous	FR	26.46 (17.03)	29.35 (18.99)	28.17 (16.36)	33.58 (15.55)	56.75 (23.37)	59.95 (18.70)
	MC	48.02 (30.88)	55.22 (30.94)	51.19 (30.92)	64.18 (31.45)	80.56 (21.27)	84.33 (17.32)
Worried	FR	48.28 (23.10)	53.86 (23.76)	61.77 (23.41)	66.92 (20.72)	61.38 (21.29)	61.39 (19.82)
	MC	77.78 (20.14)	80.60 (22.95)	78.57 (24.53)	85.45 (18.02)	86.35 (16.78)	84.78 (16.36)

Note. MC = multiple-choice, FR = free-report

*Missing data points occurred for 0.12% and 1.04% of free report and multiple-choice responses, respectively, and were spread across both groups and all conditions. Missing responses were classified as no agreement (i.e., incorrect).

Table S5

Mixed ANOVA Outcomes for Recognition Percent Agreement

Source	*df*	Mean Square	*F*	*p*	η_p^2	η_G^2
Between-Subjects						
Group	1	41030.55	9.98	.002	.07	.011
Error	128	4110.09				
Within-Subjects						
Stimulus Type	1.90	95667.42	97.45	<.001	.43	.048
Error (Stimulus Type)	243.72	981.74				
Response Format	1	788563.86	2341.04	<.001	.95	.181
Error (Response Format)	128	336.84				
Emotion	8.67	120415.16	161.35	<.001	.56	.226
Error (Emotion)	1109.63	746.31				
Stimulus Type × Group	1.90	913.54	0.93	.392	.01	<.001
Response Format × Group	1.00	300.22	0.89	.347	.01	<.001
Emotion × Group	8.67	518.73	0.70	.708	.01	.001
Response Format × Stimulus Type	1.99	497.29	1.68	.189	.01	<.001
Error (Response Format × Stimulus Type)	254.21	296.14				
Response Format × Emotion	9.31	13553.28	47.15	<.001	.27	.034
Error (Response Format × Emotion)	1191.55	287.48				
Stimulus Type × Emotion	17.25	32043.40	73.32	<.001	.36	.134
Error (Stimulus Type × Emotion)	2208.43	437.02				
Response Format × Stimulus Type × Group	1.99	222.92	0.75	.471	.01	<.001
Response Format × Emotion × Group	9.31	299.04	1.04	.406	.01	<.001
Stimulus Type × Emotion × Group	17.25	501.54	1.15	.300	.01	.002

Source	*df*	Mean Square	*F*	*p*	η_p^2	η_G^2
Response Format × Stimulus Type × Emotion	17.13	5559.52	21.92	<.001	.15	.026
Response Format × Stimulus Type × Emotion × Group	17.13	247.97	0.98	.481	.01	.001
Error (Response Format × Stimulus Type × Emotion)	2192.59	253.59				

Table S6

Means (& SDs) of Response Latency (in s) for Autistic and NonAutistic Groups Across Emotion, Stimulus Type and Response Format

Emotion	Response Format	Static		Dynamic		Social	
		Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SDE*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)
				Basic Emotions			
Afraid	FR	4.01 (2.41)	2.72 (0.78)	3.59 (1.61)	2.57 (0.84)	3.15 (1.04)	2.55 (0.79)
	MC	2.19 (1.11)	1.45 (0.48)	1.98 (0.91)	1.50 (0.65)	2.30 (1.21)	1.62 (0.58)
Angry	FR	3.77 (1.68)	2.75 (0.79)	3.46 (1.57)	2.49 (0.80)	3.36 (1.25)	2.64 (1.17)
	MC	2.19 (1.07)	1.70 (1.08)	2.36 (2.14)	1.50 (0.58)	2.00 (0.77)	1.62 (0.76)
Disgusted	FR	4.77 (3.15)	3.01 (1.00)	3.42 (1.46)	2.46 (0.73)	3.50 (1.53)	2.57 (0.72)
	MC	2.91 (1.37)	2.28 (0.92)	1.92 (0.86)	1.53 (0.98)	2.07 (0.82)	1.93 (1.80)
Happy	FR	4.00 (1.69)	2.71 (0.76)	3.24 (1.27)	2.47 (0.78)	3.46 (1.47)	2.72 (1.08)
	MC	2.14 (1.28)	1.67 (1.26)	1.90 (0.79)	1.39 (0.42)	2.07 (0.83)	1.43 (0.42)
Sad	FR	4.11 (2.12)	2.82 (0.94)	3.65 (1.94)	2.68 (1.23)	3.41 (1.51)	3.20 (2.88)
	MC	2.09 (0.84)	1.75 (1.10)	2.09 (0.84)	1.75 (1.10)	2.29 (1.29)	1.55 (0.55)
Surprised	FR	3.73 (1.64)	2.90 (1.37)	3.49 (1.37)	2.74 (1.07)	3.48 (1.46)	2.65 (0.79)
	MC	2.13 (1.22)	1.73 (1.29)	2.02 (1.18)	1.58 (0.91)	2.16 (0.87)	1.57 (0.56)
				Complex Emotions			
Ashamed	FR	4.05 (2.03)	2.66 (0.73)	3.40 (1.44)	2.37 (0.61)	3.26 (1.24)	2.50 (0.74)
	MC	1.99 (0.70)	1.63 (0.71)	1.98 (0.89)	1.48 (0.59)	2.14 (0.87)	1.58 (0.75)
Disappointed	FR	3.88 (1.80)	2.70 (0.81)	3.59 (1.70)	2.54 (0.91)	3.27 (1.19)	2.55 (0.62)
	MC	2.28 (1.28)	1.65 (0.63)	1.88 (0.79)	1.46 (0.54)	2.16 (0.93)	1.63 (0.71)
Frustrated	FR	3.86 (1.72)	2.92 (1.18)	3.40 (1.23)	2.50 (0.86)	3.65 (1.62)	2.44 (0.79)
	MC	2.27 (1.06)	1.75 (1.15)	2.04 (1.12)	1.34 (0.39)	2.06 (1.07)	1.52 (0.63)

Emotion	Response Format	Static		Dynamic		Social	
		Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)
Hurt	FR	3.68 (1.96)	2.82 (1.42)	3.61 (1.57)	2.41 (0.77)	3.43 (1.49)	2.45 (0.70)
	MC	2.04 (0.83)	1.47 (0.46)	2.04 (0.94)	1.48 (0.74)	2.01 (0.83)	1.58 (0.76)
Jealous	FR	4.02 (2.25)	2.80 (0.86)	3.18 (1.18)	2.42 (0.63)	3.18 (1.14)	2.44 (0.82)
	MC	2.25 (1.03)	1.55 (0.57)	2.06 (1.03)	1.59 (0.63)	4.52 (2.98)	3.24 (0.99)
Worried	FR	3.76 (1.51)	2.80 (0.89)	3.58 (1.85)	2.43 (0.65)	3.29 (1.32)	2.52 (0.93)
	MC	2.16 (1.12)	1.60 (0.73)	1.93 (0.84)	1.36 (0.43)	2.08 (0.81)	1.80 (0.81)

Note. FR = free-report, MC = multiple-choice

Table S7

Mixed ANOVA Outcomes for Recognition Latency

Source	*df*	Mean Square	*F*	*p*	η_p^2	η_G^2
Between-Subjects						
Group	1	1328.09	55.15	<.001	.30	.091
Error	128	24.08				
Within-Subjects						
Stimulus Type	1.91	72.18	11.30	<.001	.08	.010
Error (Stimulus Type)	245.00	6.39				
Response Format	1.00	3388.09	980.79	<.001	.89	.204
Error (Response Format)	128.00	3.45				
Emotion	8.41	13.46	9.89	<.001	.07	.009
Error (Emotion)	1075.99	1.36				
Stimulus Type × Group	1.91	6.98	1.09	.337	.01	.001
Response Format × Group	1.00	106.37	30.79	<.001	.19	.008
Emotion × Group	8.41	1.06	0.78	.630	.01	<.001
Response Format × Stimulus Type	1.95	47.83	30.86	<.001	.19	.007
Error (Response Format × Stimulus Type)	249.26	1.55				
Response Format × Emotion	8.28	14.50	12.71	<.001	.09	.009
Error (Response Format × Emotion)	1060.14	1.14				
Stimulus Type × Emotion	14.25	15.24	10.19	<.001	.07	.016
Error (Stimulus Type × Emotion)	1824.48	1.50				
Response Format × Stimulus Type × Group	1.95	9.29	6.00	.003	.05	.001
Response Format × Emotion × Group	8.28	2.01	1.76	.077	.01	.001
Stimulus Type × Emotion × Group	14.25	2.34	1.56	.081	.01	.003

Source	*df*	Mean Square	*F*	*p*	η_P^2	η_G^2
Response Format × Stimulus Type × Emotion	14.25	14.13	11.14	<.001	.08	.015
Response Format × Stimulus Type × Emotion × Group	14.25	2.46	1.94	.018	.02	.003
Error (Response Format × Stimulus Type × Emotion)	1823.79	1.27				

Table S8

Latency (in s) of Accurate Trials (Strict Free Report Coding) for Autistic and NonAutistic Participants

	Autistic				NonAutistic				
Data Subset	*N Trials*	*M (SD)*	*Mdn*	Range	*N Trials*	*M (SD)*	*Mdn*	Range	Difference
Overall	13,705	2.68 (3.04)	2.05	0.32 – 66.94	15,603	2.03 (2.29)	1.65	0 – 69.07	*U* = -36.18, *p* <.001
Free-Report	5,057	3.55 (3.52)	2.75	0.86 – 66.94	5,978	2.62 (2.15)	2.25	0.80 – 65.71	*U* = -29.46, *p* <.001
Multiple-Choice	8,648	2.18 (2.60)	1.65	0.32 – 66.66	9,625	1.66 (2.30)	1.28	0 – 69.07	*U* = -34.71, *p* <.001
Static	3,477	2.86 (3.49)	2.15	0.32 – 66.94	3,921	2.12 (2.45)	1.70	0 – 57.08	*U* = -18.22, *p* <.001
Dynamic	3,797	2.54 (1.97)	2.87	0.44 – 59.59	4,420	1.90 (1.92)	1.60	0 – 52.94	*U* = -18.55, *p* <.001
Social	6,431	2.67 (2.88)	2.06	0.39 – 62.66	7,262	2.06 (2.40)	1.65	0.13 – 69.07	*U* = -25.16, *p* <.001
Basic	8,165	2.76 (3.33)	2.12	0.38 – 66.94	9,203	2.09 (2.39)	1.70	0 – 69.07	*U* = -27.55, *p* <.001
Complex	5,540	2.57 (2.56)	1.96	0.32 – 43.78	6,400	1.94 (2.14)	1.56	0.13 – 57.08	*U* = -23.52, *p* <.001

Note: Extreme latency values of 99.33, 112.22, 201.32 and 80.30, 89.28, 127.77 were removed from the autistic and nonautistic groups, respectively, although this did not affect the outcomes.

Table S9

Means (& SDs) of Recognition Confidence Ratings (ranging from 0-100) for the Autistic and NonAutistic Groups Across Emotion, Stimulus Type and Response Format

Emotion	Response Format	Static		Dynamic		Social	
		Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)
			Basic Emotions				
Afraid	FR	69.52 (19.54)	80.93 (12.20)	70.95 (18.07)	83.21 (11.96)	80.98 (14.84)	88.08 (11.74)
	MC	73.33 (20.59)	83.81 (12.70)	76.47 (17.81)	86.46 (11.86)	83.94 (15.88)	90.95 (10.90)
Angry	FR	67.82 (20.89)	78.25 (12.34)	71.71 (17.39)	82.39 (12.36)	82.77 (15.12)	89.87 (10.50)
	MC	69.33 (19.31)	83.17 (12.10)	74.21 (19.45)	84.93 (13.37)	85.90 (13.77)	91.19 (9.21)
Disgusted	FR	70.52 (14.64)	77.76 (9.07)	77.46 (17.72)	85.63 (12.09)	83.04 (14.58)	89.70 (11.30)
	MC	75.95 (19.51	85.49 (12.71)	83.37 (16.22)	91.49 (10.22)	85.42 (15.23)	92.09 (10.60)
Happy	FR	82.86 (18.13)	90.00 (10.62)	82.46 (15.53)	87.09 (12.03)	81.54 (14.74)	88.51 (11.28)
	MC	87.14 (15.46)	92.05 (10.15)	86.23 (14.96)	91.34 (10.59)	85.69 (14.88)	91.45 (10.75)
Sad	FR	66.35 (19.41)	77.91 (13.88)	71.51 (17.86)	81.94 (13.14)	77.66 (15.57)	85.97 (12.23)
	MC	71.63 (20.32)	80.90 (13.40)	74.80 (18.66)	86.53 (12.06)	79.59 (14.98)	89.17 (10.15)
Surprised	FR	77.90 (18.47)	85.78 (11.98)	77.78 (15.77)	85.41 (11.57)	82.95 (14.15)	89.53 (11.14)
	MC	83.37 (17.64)	90.37 (11.74)	82.86 (15.56)	89.18 (10.94)	85.81 (13.87)	90.21 (10.22)
			Complex Emotions				
Ashamed	FR	63.69 (21.87)	75.34 (12.81)	66.55 (18.72)	77.65 (15.25)	77.69 (15.81)	86.80 (11.71)
	MC	65.48 (22.29)	79.07 (13.41)	71.98 (19.61)	83.13 (13.77)	80.75 (16.22)	88.29 (11.59)
Disappointed	FR	62.94 (20.78)	74.22 (14.10)	69.68 (18.14)	82.09 (13.38)	75.96 (16.93)	84.69 (11.06)
	MC	66.23 (21.42)	78.25 (14.92)	75.16 (19.43)	86.75 (12.80)	80.05 (16.05)	86.82 (10.54)
Frustrated	FR	57.90 (22.11)	71.83 (14.49)	68.49 (18.86)	80.49 (13.06)	85.63 (13.40)	90.34 (12.51)
	MC	62.14 (21.97)	74.66 (14.83)	74.68 (19.74)	85.67 (12.59)	89.01 (12.62)	93.47 (10.81)

Emotion	Response Format	Static		Dynamic		Social	
		Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)	Autistic *M* (*SD*)	Non-Autistic *M* (*SD*)
Hurt	FR	65.71 (19.46)	79.10 (12.03)	67.94 (19.13)	82.99 (11.62)	79.21 (15.20)	87.08 (12.32)
	MC	69.40 (20.01)	82.39 (12.83)	71.47 (20.29)	83.81 (11.39)	82.27 (15.41)	90.19 (11.75)
Jealous	FR	63.97 (20.24)	74.22 (14.43)	66.43 (19.81)	78.40 (14.82)	79.84 (14.38)	86.98 (13.36)
	MC	62.58 (22.08)	74.25 (17.06)	64.76 (23.97)	77.01 (16.74)	81.79 (16.99)	86.87 (12.20)
Worried	FR	63.69 (20.47)	76.16 (13.54)	66.79 (18.44)	78.66 (13.86)	79.27 (15.79)	87.70 (12.05)
	MC	70.87 (18.53)	80.22 (12.86)	73.41 (17.91)	84.44 (12.37)	83.02 (15.18)	88.99 (11.94)

Note. FR = free-report, MC = multiple-choice

Table S10

Mixed ANOVA Outcomes for Recognition Confidence Ratings

Source	*df*	Mean Square	*F*	*p*	η_P^2	η_G^2
Between-Subjects						
Group	1	202749.03	19.05	<.001	.13	.086
Error	128	10643.59				
Within-Subjects						
Response Format	1	27140.95	59.30	<.001	.32	.012
Error (Response Format)	128	457.68				
Stimulus Type	1.85	96880.35	78.99	<.001	.38	.076
Error (Stimulus Type)	236.20	1226.55				
Emotion	5.26	22439.65	102.72	<.001	.45	.052
Error (Emotion)	673.71	218.45				
Response Format × Group	1	190.62	0.42	.520	.00	<.001
Stimulus Type × Group	1.85	3755.76	3.06	.053	.02	.003
Emotion × Group	5.26	1199.26	5.49	<.001	.04	.003
Response Format × Stimulus Type	1.90	482.85	6.35	.002	.05	<.001
Error (Response Format × Stimulus Type)	243.42	76.00				
Response Format × Emotion	8.83	459.42	12.66	<.001	.09	.002
Error (Response Format ×Emotion)	1130.62	36.30				
Stimulus Type × Emotion	13.25	4443.48	43.14	<.001	.25	.027
Error (Stimulus Type × Emotion)	1695.90	103.00				
Response Format × Stimulus Type × Group	1.90	41.25	0.54	.582	.00	<.001
Response Format × Emotion × Group	8.83	45.00	1.24	.267	.01	<.001
Stimulus Type × Emotion × Group	13.25	217.95	2.12	.010	.02	.001

Source	*df*	Mean Square	*F*	*p*	η_p^2	η_G^2
Response Format × Stimulus Type × Emotion	15.96	117.18	3.43	<.001	.03	<.001
Response Format × Stimulus Type × Emotion × Group	15.96	53.16	1.56	.070	.01	<.001
Error (Response Format × Stimulus Type × Emotion)	2043.37	34.18				