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Reduced specificity in emotion judgment in people with autism spectrum disorder

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ABSTRACT

There is a conflicting literature on facial emotion processing in autism spectrum disorder (ASD): both typical and atypical performance have been reported, and inconsistencies in the literature may stem from different processes examined (emotion judgment, face perception, fixations) as well as differences in participant populations. Here we conducted a detailed investigation of the ability to discriminate graded emotions shown in morphs of fear-happy faces, in a well-characterized high-functioning sample of participants with ASD and matched controls. Signal detection approaches were used in the analyses, and concurrent high-resolution eye-tracking was collected. Although people with ASD had typical thresholds for categorical fear and confidence judgments, their psychometric specificity to detect emotions across the entire range of intensities was reduced. However, fixation patterns onto the stimuli were typical and could not account for the reduced specificity of emotion judgment. Together, our results argue for a subtle and specific deficit in emotion perception in ASD that, from a signal detection perspective, is best understood as a reduced specificity due to increased noise in central processing of the face stimuli.

1. Introduction

People with autism spectrum disorder (ASD) demonstrate pervasive dysfunctions in social communication, but it has been elusive to find the underlying specific processing deficits. A number of impaired components of social communicative functioning have been reported, notably including impaired face processing and emotion recognition. Yet even this literature is discrepant. In particular, several studies find reliable, but weak, deficits in the ability to recognize emotions from facial expressions (Law Smith et al., 2010; Philip et al., 2010; Wallace et al., 2011; Kennedy and Adolphs, 2012), although others do not (Baron-Cohen et al., 1997; Adolphs et al., 2001; Neumann et al., 2006) (see (Harms et al., 2010) for a review). This discrepancy may be attributed to the known heterogeneity of ASD, the stimuli and tasks used in the various studies, as well as ceiling effects or the compensatory strategies by individuals with ASD. However, it has been argued that as long as the measures are sensitive enough, behaviorally- or biologically-based measures can almost invariably detect group differences in facial emotion recognition (Harms et al., 2010). Two major methodological approaches could enhance sensitivity to reveal group differences and avoid ceiling effects: one is to modify the task demand (e.g., using difficult or unfamiliar tasks), the other is to manipulate the stimuli, such as face morphing (Law Smith et al., 2010; Wallace et al., 2011).

Impaired face perception or emotion recognition might also arise from atypical fixations onto faces, which have been reported in many studies, but again in a rather heterogeneous literature. For instance, it has been shown that adults with ASD have an increased tendency to saccade away from the eye region of faces when information is present in those regions (Spezio et al., 2007), but instead have an increased preference to fixate the location of the mouth (Neumann et al., 2006). During viewing naturalistic social videos, people with autism demonstrate abnormal patterns of social visual pursuit that are consistent with reduced saliency of eyes and increased saliency of mouths, bodies, and objects (Klin et al., 2002). When viewing static faces, people with autism view non-feature areas of the faces significantly more often but core feature areas of the faces (e.g., eyes and mouth) significantly less often than controls (Pelphrey et al., 2002) and they have piecemeal rather than configural strategies (Dawson et al., 2005). Similarly, some research suggests that people with ASD demonstrate active avoidance of fixating the eyes in faces, which in turn influences recognition performance of emotions (Kliemann et al., 2010), whereas other research suggests that children with ASD demonstrate gaze indifference

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and passive insensitivity to the social signals in others' eyes at the time of initial diagnosis (Moriuchi et al., 2017). The atypical facial fixations are complemented by neuronal evidence of abnormal processing of information from the eye region of faces in blood-oxygen-level dependent (BOLD) fMRI (Kliemann et al., 2012) and single-neuron responses in the amygdala (Rutishauser et al., 2013). A recent study using comprehensive modeling with a large number of natural scene images showed that people with ASD not only have reduced saliency representation of faces, but show reduced saliency for many semantic-level attributes of visual stimuli (Wang et al., 2015).

On the other hand, however, many other studies have shown apparently normal social orienting and attention to facial features in people with ASD (see (Guillon et al., 2014) for a recent review). For example, infants who later develop autism show an equally strong face orienting response (Elsabbagh et al., 2013) and adults with ASD can have fixation dwell times onto faces that are largely typical (Kuhn et al., 2010; Nakano et al., 2010). In several studies, young children and adolescents with ASD show typical patterns of attention to eyes and mouth (de Wit et al., 2008; Falck-Ytter et al., 2010; McPartland et al., 2011). The latter study is particularly relevant, since it found typical fixation patterns despite impaired face recognition ability (McPartland et al., 2011). Taken together, these findings not only point to the need to resolve discrepancies in the literature, but also (and relatedly) to the need to distinguish between the various processes that contribute to facial emotion processing, so that we can better understand which specific components characterize ASD.

In this study, we used a two-alternative forced-choice task with a gradient of morphed faces along the fear-happy dimension to investigate the sensitivity and specificity with which people are able to distinguish emotions in facial expressions. Concurrent eye tracking provided important comparison data. Using morphed stimuli allowed us to parametrically control the intensity of the stimuli and to assess emotion discrimination at a fine-grained level. We not only examined eye movements with respect to stimulus levels (i.e., emotion intensity and ambiguity levels), but also with respect to behavioral judgment. We also quantified the fixation noise, and investigated whether such noise could predict the correctness of emotion judgment. Although we found remarkably similar eye movement patterns between participants with ASD and controls, as well as normal thresholds to report fear and normal confidence in judgments of emotions, participants with ASD showed reduced specificity to emotions.

2. Methods

2.1. Participants

Eighteen high-functioning participants with ASD (15 male) were recruited from our laboratory's registry. All ASD participants met DSM-V/ICD-10 diagnostic criteria for autism spectrum disorder, and met the cutoff scores for ASD on the Autism Diagnostic Observation Schedule-2 (ADOS-2) revised scoring system for Module 4 (Hus and Lord, 2014), and the Autism Diagnostic Interview-Revised (ADI-R) (LeCouteur et al., 1989; Lord et al., 1994) or Social Communication Questionnaire (SCQ) (Rutter et al., 2003) when an informant was available. The ADOS-2 was scored according to the latest algorithm, and we also derived severity scores for exploratory correlation analyses (social affect (SA): 12.1 ± 4.22 (mean ± SD), restricted and repetitive behavior (RRB): 3.13 ± 1.36, severity score for social affect (CSS SA): 8.00 ± 1.71; severity score for restricted and repetitive behavior (CSS RRB): 7.13 ± 1.36, severity score for social affect plus restricted and repetitive behavior (CSS All): 7.88 ± 1.54). The ASD group had a full-scale IQ (FSIQ) of 105 ± 13.3 (from the Wechsler Abbreviated Scale of Intelligence-2), a mean age of 30.8 ± 7.40 years, a mean Autism Spectrum Quotient (AQ) of 29.3 ± 8.28, a mean SRS-2 Adult Self Report (SRS-A-SR) of 84.6 ± 21.5, and a mean Benton score of 46.1 ± 3.89 (Benton scores 41–54 are in the normal range). ADOS item scores were not available for two participants, so we were unable to utilize the revised scoring system. But these individuals' original ADOS algorithm scores all met the cutoff scores for ASD.

Fifteen neurologically and psychiatrically healthy participants with no family history of ASD (11 male) were recruited as controls. Controls had a comparable FSIQ of 107 ± 8.69 (two-tailed *t*-test, $P = 0.74$) and a comparable mean age of 35.1 ± 11.4 years ($P = 0.20$), but a lower AQ (17.7 ± 4.29, $P = 4.62 \times 10^{-5}$) and SRS-A-SR (51.0 ± 30.3, $P = 0.0039$) as expected. Controls were also matched on gender, race and education.

Participants gave written informed consent and the experiments were approved by the Caltech Institutional Review Board. All participants had normal or corrected-to-normal visual acuity. No enrolled participants were excluded for any reasons and all data are reported.

2.2. Stimuli and task

We asked participants to discriminate between two emotions, fear and happiness because these emotions are distinguished by particular facial features (Smith et al., 2005). We selected faces of four individuals (2 female) each posing fear and happiness expressions from the STOIC database (Roy et al., 2007), which are expressing highly recognizable emotions. Selected faces served as anchors, and were unambiguous exemplars of fearful and happy emotions as evaluated with normative rating data provided by the creators. To generate the morphed expression continua for this experiment, we interpolated pixel value and location between fearful exemplar faces and happy exemplar faces using a piece-wise cubic-spline transformation over a Delaunay tessellation of manually selected control points. We created 5 levels of fear-happy morphs, ranging from 30% fear/70% happy to 70% fear/30% happy in steps of 10% (Fig. 1**B**). Low-level image properties were equalized using the SHINE toolbox (Willenbockel et al., 2010) (The toolbox features functions for specifying the (rotational average of the) Fourier amplitude spectra, for normalizing and scaling mean luminance and contrast, and for exact histogram specification optimized for perceptual visual quality).

In each trial, a face was presented for 1 s followed by a question prompt asking participants to make the best guess of the facial emotion (Fig. 1**A**). After stimulus offset, participants had 2 s to respond, otherwise the trial was aborted and discarded. Participants were instructed to respond as quickly as possible, but only after stimulus offset. No feedback message was displayed and the order of faces was completely randomized for each participant. An inter-trial-interval (ITI) displaying a central fixation cross was jittered randomly with a uniform distribution between 1 to 2 s. Participants practiced 5 trials before the experiment to familiarize themselves with the task.

A subset of the participants (11 participants with ASD and 11 controls) also performed confidence ratings (Fig. 1**A**)—after emotion judgment and a 500 ms blank screen, participants were asked to indicate their confidence by pushing the button '1' for 'very sure', '2' for 'sure' or '3' for 'unsure'. This question also had 2 s to respond.

2.3. Behavioral analysis

We fitted a logistic function to obtain smooth psychometric curves (Fig. 1**C**):

$$P(x) = \frac{P_{\text{inf}}}{1 + e^{-\alpha(x - x_{half})}}$$

where P is the percentage of trials judging faces as fear, x is the morph level, P_{inf} is the value when x approaches infinity (the curve's maximum value), x_{half} is the symmetric inflection point (the curve's midpoint), and α is the steepness of the curve. P_{inf}, x_{half}, and α were fitted from the observed data (P and x). Flatter curves (smaller α) suggest that participants were less sensitive to the change in emotion intensity since they made similar judgments given different morph levels, and vice versa for steeper curves (larger α). We derived these parameters for