The psychophysiology of narrower face processing in autism spectrum conditions
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Faces are encountered across a huge range of visual conditions, including differences in light, distance and visibility. To accurately detect all faces under all these conditions, the face detection system must be suitably generalized. However, in autism spectrum conditions (ASCs), the typical generalization of perceptual learning is narrower. Here, we tested the generalization of the face detection system in a sample of adults with ASCs and a matched control group without ASCs. We recorded electroencephalography while participants viewed images of actual faces, face-like objects and non-face-like objects. Analysis of the N170 event-related potential component, which is related to the early stages of face detection, showed that the two participant groups were comparable in the activation of the N170 to actual faces and face-like objects, but that the typical control group showed an increased N170 for non-face-like objects over the group with ASCs. This indicates that the face detection system is less generalized (narrower) in ASCs than in typical development. We propose that the reduced social interest characteristic of ASCs is associated with a narrower face detection system that is less reliable in detecting all the faces in the environment. NeuroReport 23:395-399
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Among the social deficits that are characteristic of autism spectrum conditions (ASCs) [1], face perception has been a particularly strong focus of research since the finding that, unlike their typically developing peers, adolescents with ASC show greater memory for the lower parts of the face, including the mouth, than the upper parts, including the eyes [2]. Subsequent research has found deficits in ASCs for the recognition of facial emotion and identity [3] along with differences in the pattern of viewing of face components [4].

The N170 event-related potential (ERP) component provides a measure of the neural basis of face processing. It is a negative-going wave that is derived from scalp-recorded electroencephalography (EEG) that is maximal over lateral occipitoparietal sites between 130 and 200 ms after the presentation of a stimulus [5]. Its utility as an index of early face processing emerges from research showing that it is larger to human faces than to other stimuli [6].

Given the deficits in face perception in ASC and the relationship of the N170 with face processing, a reduced N170 to faces may be expected in ASC. Yet, N170 studies in ASC have shown inconsistent results. The first paper to describe an investigation of the N170 in ASC reported no difference in the amplitude of the N170 to faces between adults with ASC and typical controls [7]. In addition, no difference was found between ASC and typical control groups in the amplitude of the N170 or its magnetic analogue, the M170, to faces in several subsequent studies [8-10]. The studies that have found a difference in the amplitude of the N170 to faces between people with ASC and typically developing controls have found this difference only when the task demands are high [11,12] or when faces are presented upside down [13].

This inconsistency was emphasized in a review of the literature on face processing in ASC (Jemel et al. [14], p. 98, italics added). However, the authors noted that ‘individuals with ASC show typical, and even larger, face-object N170 differences’ than typical controls. That is, when compared with typical controls, individuals with ASC may show no reduction of the N170 to faces, but may show a reduction of the N170 to other objects, which creates a larger difference between the categories of faces and other objects in ASC than in typical development.

This assertion was not directly tested in previous N170 studies of ASC. However, such a hypothesis has a basis in recent results reported by our group and others regarding the properties of the N170 and also in current theories of perception in ASC. First, recent research has shown that although the N170/M170 is largest to human faces, it is not restricted to faces. Rather, it generalizes across all objects depending on how face-like they are. That is, the component is larger to objects that are perceived as being face-like than objects that are perceived as non-face-like [15,16]. Second, there is evidence that the typical generalization of perceptual learning is narrower in ASC. That is, individuals with ASC are less likely to remember...
aspects of a group of stimuli that are common to the group but are more likely to remember those aspects that are unique to individual examples [17].

Hence, if face perception is narrower in ASC, the N170 will generalize less to non-face objects such that the amplitude of the N170 will be reduced to non-face objects. The current study tests this prediction by investigating the degree to which the N170 generalizes to non-face objects in ASC. Specifically, we hypothesized that the N170 will generalize less in ASC; thus, the difference in the amplitude of the N170 between the ASC and the typical control groups will increase as the stimuli become less face-like.

Methods
Participants
This study was approved by the Psychology Research Ethics Committee at the University of Cambridge and consent was obtained from all participants. All participants were men and right-handed. Participants in the ASC group were diagnosed with Asperger syndrome according to international criteria [1] by a clinical psychologist or psychiatrist experienced in the diagnosis of ASC. Exclusion criteria for all participants were an uncorrected impairment in eyesight or hand movement, a personal or a family history of any psychological or genetic disorder apart from an ASC or a period of unconsciousness in the last 5 years. In addition, participants with a self or a family history of ASC were excluded from the control group.

Of the 14 ASC and 15 control participants recruited for this study, 10 ASC and 13 controls provided at least 50% of the trials for averaging and were included in the final analysis. This final sample was matched on age (ASC $M = 30.61$ years, $SD = 6.2$; control $M = 29.54$ years, $SD = 4.81$) and full-scale intelligence quotient (FSIQ) (ASC $M = 115.2$, $SD = 14.13$; control $M = 118.17$, $SD = 14.57$; both $P > 0.6$). On the Autism Spectrum Quotient [19], where higher scores reflect a greater number of autistic-like traits, the ASC group scored significantly higher ($M = 34.1$, $SD = 7.08$) than the typical control group ($M = 14.33$, $SD = 6.92$, $t(12) = 7.57$, $P < 0.001$).

Stimuli
Stimuli consisted of faces, face-like objects, non-face-like objects and flowers. Faces were 50 front view images of neutral faces, taken from the Karolinska Directed Emotional Faces DVD [20]. Face-like objects and non-face-like objects were the 50 most consistently rated face-like and non-face-like objects, respectively, from the set used in our previous study of face-like objects in a different sample of typically developing adults [15]. The face-like objects were taken from the book Faces [21] and the non-face-like objects were taken from Photo Clip Art by Hemera (www.hemera.com). To increase the number of epochs in each category during averaging, each of the stimuli was shown twice. Flowers were 60 images from Photo Clip Art by Hemera (www.hemera.com). All stimuli were converted into greyscale, presented on a white background, equated for average luminance and contrast and resized to $5 \times 7$ cm using Adobe Photoshop (www.adobe.com). Stimuli were presented in a pseudorandom order to avoid immediate repetitions of stimuli. An example stimulus train is shown in Fig. 1.

Procedure
Testing took place in a darkened room with participants seated 60 cm from the monitor on which the stimuli were presented. Continuous EEG was recorded from 32 electrodes, arranged according to the 10–20 system and amplified using a Synamps amplifier (Compumedics Neuroscan, Charlotte, North Carolina, USA), which sampled the analogue signal at 1000 Hz with an analogue bandpass filter between 0.1 and 100 Hz. Reference was assigned to the tip of the nose with ground at FPZ. Vertical and horizontal eye movements were recorded in bipolar channels with electrodes 1 cm above and below the left eye and lateral to the outer canthus of each eye. Impedances were maintained below 5 kΩ.

Stimuli subtended approximately $5.1 \times 7.3$° of the visual angle and were presented for 500 ms. The interstimulus interval was randomized between 1200 and 1400 ms. Participants were instructed to press a response button with the index finger of their left or right hand when they saw a picture of a flower. The hand used was counterbalanced across participants. After a practice trial of 10 stimuli, the total testing time was approximately 15 min.

Electrophysiological analysis
The continuous EEG was visually assessed before epoching and major sections of artefacts were excluded from further analysis. Artefacts due to eye blinks were corrected using a subtraction method [22]. The continuous EEG was then epoched for the window between 100 ms before the onset of the stimulus and 300 ms after the onset of the stimulus, baseline corrected for the prestimulus interval and low-pass filtered at 20 Hz (12 dB). The N170 was analysed at the sites at which it was maximal: P7 in the left hemisphere and P8 in the right hemisphere. The mean amplitude of the N170 component was calculated for the interval between 130 and 190 ms and the peak latency was calculated for the minimum value within this interval.

Statistical analysis
The analysis consisted of a mixed three-way analysis of variance with hemisphere (left, right), stimulus category (faces, face-like objects, non-face-like objects) and group (ASC, typical control) as factors and the mean amplitude and peak latency as outcome measures. In post-hoc comparisons, all $P$ values were Bonferroni corrected.
Fig. 1

Example stimulus train used in Experiment 2 including faces (a), face-like objects (b), non-face-like objects (c) and flowers (d). Images from FACES © 2000 by Francois Robert are used with permission of Chronicle Books, San Francisco. Visit www.ChronicleBooks.com.

Results

N170

Across the groups and hemispheres, there was a significant main effect of stimulus category on the mean amplitude of the N170 \( F(2,42) = 45.16; P < 0.0001 \). This was further investigated using paired \( t \)-tests between each category. These showed that there were significant differences between each of the stimulus categories, with faces (\( M = 0.49 \) \( \mu \)V, SD = 3.49) producing a significantly larger (more negative) N170 than both face-like objects (\( M = 1.31 \) \( \mu \)V, SD = 3.01, \( t(122) = -2.81; P = 0.03 \)) and non-face-like objects (\( M = 3.03 \) \( \mu \)V, SD = 3.04, \( t(22) = -5.83; P < 0.0001 \), and face-like objects producing a significantly larger N170 than non-face-like objects \( t(122) = -5.36; P = 0.0001 \). The grand average waveforms are shown in Fig. 2.

There was also a significant interaction for the mean amplitude between stimulus category and participant group \( F(2,42) = 3.9; P = 0.02 \). This was determined using independent \( t \)-tests between the participant groups for each stimulus category. This showed that there were no significant differences between the ASC and the typical control groups for either faces \( t(142) = 0.66; P = 0.52 \) or face-like objects \( t(142) = 1.1; P = 0.31 \). However, there was a significant difference between the ASC (\( M = 4.84 \) \( \mu \)V, SD = 2.42) and the control group (\( M = 1.64 \) \( \mu \)V, SD = 2.79) in the amplitude of the N170 to non-face-like objects, in which the N170 was significantly smaller in the ASC group than the control group \( t(1,21) = 2.87; P = 0.01 \). This interaction is shown in Fig. 3. There were no other significant interactions or main effects for the mean amplitude or the peak latency of the N170.

Discussion

The current study investigated the generalization of face processing in ASC by recording the N170 ERP component to faces, face-like objects and non-face-like objects. Consistent with the hypothesis that generalization is reduced in ASC, there was a significant interaction between stimulus category and participant group such that the difference in the amplitude of the N170 between the ASC and the typical control groups was larger for non-face-like objects than for faces or face-like objects.

These results indicate that the face detection system in ASC is activated in response to actual faces but that this activation does not generalize to non-face objects to the same extent as it does in typical controls. In a review of perceptual generalization, Plaisted [17] argues that in ASC, categories are more narrowly defined, with sharper category boundaries. As demonstrated in Fig. 3, the results of this experiment show that the face detection system in ASC is indeed more narrowly defined, with a sharper boundary.

Faces are encountered across a large range of conditions. Differences in light, distance and orientation, not to mention the differences between faces themselves, all affect the physical properties of the face stimulus seen by a viewer. If the face processing system in ASC does not generalize across to all these instances of faces, then some faces will not be detected and the ability of individuals with ASC to react socially to their presence will be decreased. Hence, the reduced generalization of the face processing system indexed by the N170 in ASC is likely associated with the social difficulties seen in these conditions. Whether it is a cause or a consequence will be the subject of further research.

Another important question for future research is the developmental course of this difference in N170 activation. Johnson [23], p. 4) stated that 'the specificity of the N170 can be taken as an index of the degree of specialization of cortical processing for upright human faces'. Research on the developmental trajectory of cortical specialization in the typical population has shown that the structures implicated in the generation of the N170 in the fusiform gyrus become increasingly selective in their activation to faces from middle childhood [24]. It is possible that the current finding of excessively specialized N170 activation in ASC is related to the finding of a rapid maturation of the cortex in the first 2 years of life [25]. In addition to these between-group differences, several other effects were found for the N170 component. There was a main effect of stimulus category in which the N170...
was largest to faces and smallest to non-face-like objects. This is consistent with the results of our earlier study of face-like objects in the typical population [15]. By finding this same effect, the current results resolve an outstanding question from this earlier study. Because participants in this earlier study were directed to judge whether the objects were face-like or non-face-like, this conscious searching for the face-like properties of objects may have increased the difference in the N170 between face-like and non-face-like objects. However, in the current study, there was no such searching as participants were directed to press the response button when they saw a target flower. Thus, these results indicate that the difference in N170 activation due to the face-likeness of stimuli is due to the physical properties of the stimulus rather than priming from task instructions.

This study investigated the generalization of the early face processing system indexed by the N170 in ASC. By recording the N170 to three stimulus categories that
varied in their face-likeness, a greater specificity for the N170 in ASC was demonstrated. The typical control group showed a broad generalization of the N170 that decreased gradually from faces, across face-like objects to non-face-like objects. In contrast, the ASC group showed a narrower activation that was comparably activated to faces and face-like objects but did not generalize to non-face-like objects to the same degree as that shown by controls.

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Conflicts of interest
There are no conflicts of interest.

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