Seeing face-like objects: an event-related potential study

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The N170 event-related potential component is larger to faces than to other objects but also varies in amplitude between non-face objects. This study investigated the hypotheses that these differences are related to the perceived face-likeness of the objects. Event-related potentials were recorded from 18 participants who classified objects as 'face like' or 'non-face like'. Images of actual faces were also presented. The N170 was larger (more negative) to objects classified as face like than to those classified as non-face like. These data suggest that the amplitude of the N170 to objects is affected by the face-likeness of the objects. *NeuroReport* 00:000–000 © 2009 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Introduction

The N170 event-related potential (ERP) is recorded as a negative going wave maximal between 130 and 200 ms poststimulus onset at bilateral parietal sites and is associated with the detection of faces [1]. It is more negative to human faces than to cars, chairs, hands and animal faces [2], houses, Greebles, and shoes [3].

Interestingly, there is also variation in the amplitude of the N170 among these non-face object categories [4]. Cars have been found to elicit larger N170 amplitudes than other non-face objects [3,5], a finding that has been explained by Rossion and Jacques [4] as being, in part, because of the visual similarity between faces and cars. This assertion is given further weight by the finding that amongst non-face objects, the next largest N170 is elicited by houses and then by Greebles, which also share some superficial similarity with faces by having a small number of parts in a common configuration [3].

This literature suggests that the N170 amplitude is not simply a categorical measure that indicates a difference between faces and all other object categories. Instead, these results indicate that the N170 may be sensitive to the face-likeness of non-face objects. George *et al.* [6] investigated this further by presenting upright and inverted Mooney faces to participants and asking them to indicate whether they thought the image was a face or not. They found that the N170 was larger to stimuli that were seen by participants as a face. However, by providing participants with only two options ('face' or 'no face'), this design could not address the further hypothesis that non-face objects themselves may produce a different N170 amplitude dependent on their face-likeness.

Outside the ERP literature there is also evidence that the cortical source of the N170 component is sensitive to face-like objects. Source localization of the N170 suggests that it emanates from the superior temporal sulcus [7]. Taking single unit recordings from the superior temporal sulcus in macaque monkeys, Tsao *et al.* [8] found a region in which 97% of the cells were face selective. With such a high rate of face selectivity, the authors reviewed the rare images that activated the cells despite not being faces. They found that these images were 'clocks and round fruits, which share a common shape attribute with faces' (p. 673).

This study investigates the theory that the N170 amplitude is sensitive to the perceived face-likeness of non-face objects rather than differentiating only between faces and non-face object categories. This was tested by measuring the N170 amplitude in response to a range of objects and averaging them according to the subjective category assigned to them by participants: 'face-like object' or 'non-face-like object'; also included in the experiment were images of actual faces. If the hypothesis is correct, then the N170 amplitude should be significantly different between objects categorized as face like and those categorized as non-face like.

Methods

Participants

Electroencephalography was recorded from 18 participants with no history of psychological illness. Data from

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three participants was unavailable for analysis because of excessive movement artefact. The 15 participants (six male) who had data available for analysis had a mean age of 29 (SD = 6.8) years. All were right handed, had normal or corrected-to-normal vision, and gave written informed consent before participating.

Stimuli

Stimuli consisted of 240 images. Of these, 80 were faces from the 'Karolinska Directed Emotional Faces' DVD [9]. All faces were a front portrait view and had a neutral expression. Another 80 stimuli were images of objects that might be thought to look like faces, taken from the book 'Faces' [10], which were scanned in color at 600 dpi. The final 80 stimuli were images taken from Photo Clip Art by Hemera (*www.hemera.com*). All 240 images were edited in Photoshop CS3 (*www.adobe.com*), transformed to grayscale, mounted on a white background, equated for average luminance and contrast, and resized to 5×7 cm. After this, the stimuli were not grouped prior to their presentation.

Procedure

Participants were seated in a darkened room approximately 60 cm from the monitor on which the images (subtending $5.1 \times 7.3^{\circ}$ of visual angle) were presented for 500 ms. The interstimulus interval was randomized between 2900 and 3000 ms. The stimuli were randomly ordered and presented to participants in three blocks with a brief rest in between each. The total testing time was approximately 15 min. The stimulus train is described in Fig. 1.

Participants were instructed to press one button on the response pad if the stimulus was a face, another button if the stimulus was an object that looked similar to a face, and a final button if the stimulus was an object that did not look like a face. The order of buttons and the hand used was counterbalanced across participants. A practice trial of 10 stimuli was shown to participants following the instructions.

Electrophysiology

Electroencephalography was recorded from 32 electrodes using a modified Quickcap 10/10 system (Compumedics Neuroscan, Charlotte, North Carolina, USA) with reference at the tip of the nose and ground at Fpz. Vertical and horizontal eye movements were recorded in bipolar channels with electrodes above and below the left eye (vertical electrooculogram) and 1 cm from the outer canthus of each eye (horizontal electrooculogram). Impedances at all sites were maintained below 5 kΩ. The Synamps amplifier (Compumedics Neuroscan) sampled the analog signal at 1000 Hz with a bandpass filter between 0.1 and 100 Hz.

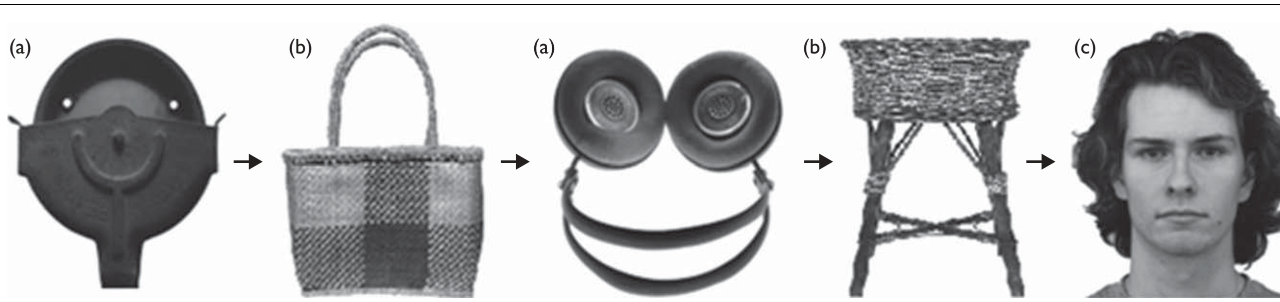
Offline, the artefact because of eye blinks was corrected using an eye movement subtraction algorithm [11]. Epochs were formed for the period from 100 ms before to 900 ms after the presentation of each stimulus and were baseline corrected against the prestimulus interval.

Importantly, epochs were averaged according to the category they were assigned by each participant. For stimuli classified as faces, an average of 79.13 epochs formed each participant's average. For stimuli classified as face-like objects, there was an average of 66.13 epochs and for stimuli classified as non-face-like objects, there was an average of 91.2 epochs. Average waveforms were low-pass filtered at 30 Hz (12 dB) using a zero-phase shift FIR filter.

Analysis

Between 70 and 130 ms after the onset of stimulus in the grand average waveforms, a positive potential was maximal over occipital sites. This was identified as the P1. Further, between 140 and 200 ms, a negative potential was maximal over parietal regions. This negativity was identified as the N170. Consistent with the N170 literature [4], analyses were conducted on peak latency and amplitude for the maximum value between 70 and 130 ms at electrodes O1 and O2 for the P1 and the minimum value between 140 and 200 ms at electrodes

Fig. 1



Stimulus train showing example stimuli from Faces (a), from Photo Clipart (b) and from the KDEF database (c). Images from FACES © 2000 by François Robert are used with permission of Chronicle Books, San Francisco. Visit ChronicleBooks.com.

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P7 and P8 for the N170. The average epochs for each participant were visually inspected to ensure that this point represented a true local maximum. These data were entered into a two-way repeated-measures analysis of variance (ANOVA) with subjective category (face, face-like object, and non-face-like object) and hemisphere (left – O1 or P7 and right – O2 or P8) as factors. The ANOVAs had Greenhouse—Geisser-adjusted degrees of freedom.

Results

P1

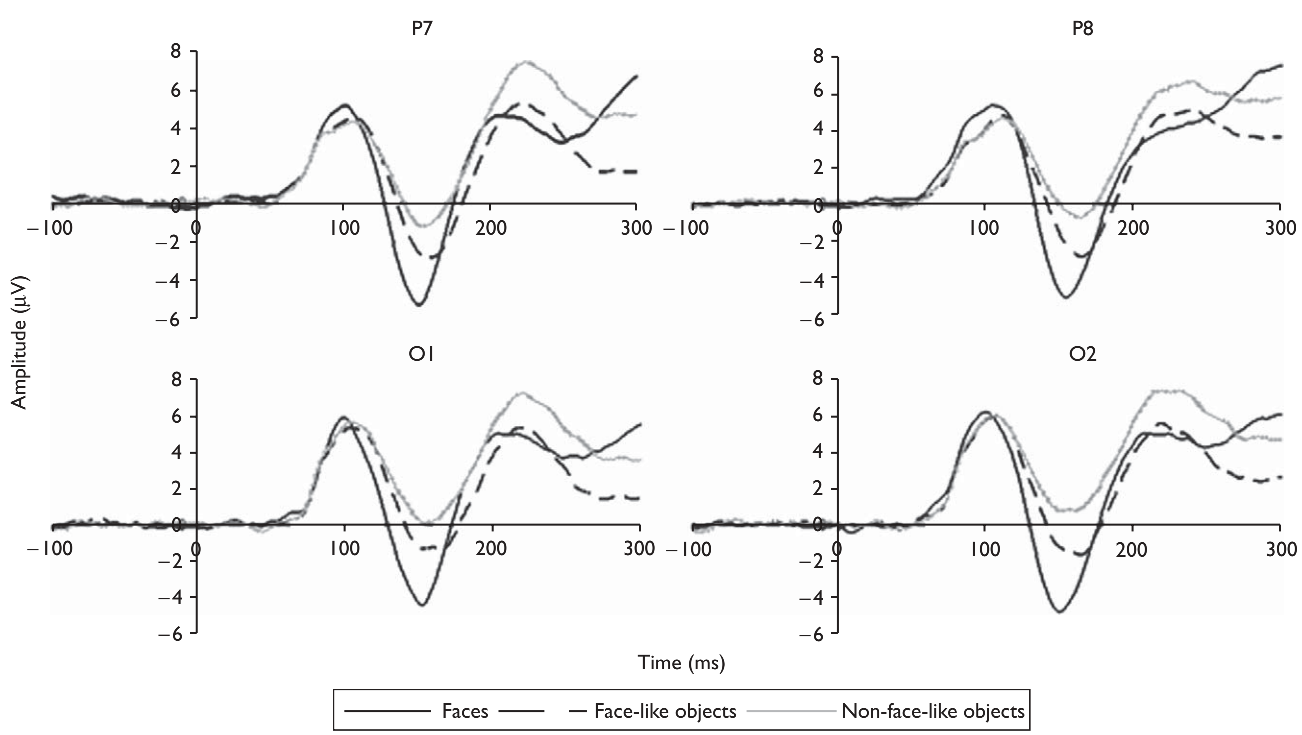
For the amplitude of the P1, the two-way interaction between hemisphere and subjective category was not significant [$F(1.85,25.7) = 0.58$, $P = 0.55$]. The main effect of hemisphere on the amplitude of the P1 was also not significant [$F(1,14) = 0.96$, $P = 0.34$]. An inspection of the grand average waveforms (shown in Fig. 2) suggested that the amplitude of the P1 may be larger for faces (mean = 6.66 μV, SD = 4.59) than for either face-like objects [mean = 5.89 μV, SD = 3.25] or non-face-like objects (mean = 6.65 μV, SD = 3.89). However, the main effect of subjective category on the amplitude of the P1 was not significant [$F(1.38,19.27) = 0.8$, $P = 0.42$].

The interaction between hemisphere and subjective category for the latency of the P1 was also not significant [$F(1.12,15.48) = 1.103$, $P = 0.34$] and neither was the main effect of hemisphere [$F(1,14) = 0.16$, $P = 0.69$]. As with the amplitude of the P1, an inspection of the grand mean waveforms suggested that the latency of the P1 may be earlier for actual faces (mean = 100.23 ms, SD = 9.58) than for either face-like objects (mean = 101.47 ms, SD = 8.52) or non-face-like objects (mean = 101.4 ms, SD = 8.12). However, the main effect of category on the latency of the P1 was also not significant [$F(16.1,63.31) = 0.25$, $P = 0.76$].

N170

For the amplitude of the N170, the two-way interaction between hemisphere and subjective category was not significant [$F(1.48,20.63) = 0.04$, $P = 0.92$]. The main effect of hemisphere was also not significant [$F(1,14) = 0.001$, $P = 0.98$]. However, consistent with the hypotheses, the main effect of subjective category on the amplitude of the N170 was significant [$F(1.78,24.97) = 25.08$, $P < 0.001$]. Exploring this effect with repeated measures *t*-tests showed that the amplitude of the N170 to faces [mean = −5.75 μV, SD = 4.64] was larger than to both face-like objects [mean = −3.75 μV, SD = 4.34, $t(1,14) = -4.45$, $P = 0.001$] and non-face-like objects [mean = −1.87 μV, SD = 2.9, $t(1,14) = -6.3$, $P < 001$]. Importantly, consistent with the hypothesis, there was a significant difference between face-like and non-face-like objects with a larger amplitude N170 to face-like objects [$t(1,14) = -3.33$, $P = 0.005$]. These results are shown in Fig. 2.

Fig. 2



Grand average waveforms at O1, O2, P7, and P8 for the three subjective categories.

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Similar to the amplitude of the N170, the interaction between hemisphere and subjective category for the latency of the N170 was not significant [$F(1.61,22.57) = 0.97$, $P = 0.38$] and neither was the main effect of hemisphere [$F(1,14) = 2.03$, $P = 0.18$]. Still consistent with the results for the amplitude of the N170, there was a main effect of category on the latency of the N170 [$F(1.38,19.29) = 6.66$, $P = 0.01$]. However, when this effect was explored further with paired *t*-tests, a different pattern of results was revealed. The N170 latency to faces [mean = 151.77 ms, SD = 5.45] was earlier than to face-like objects [mean = 159.3 ms, SD = 8.58, $t(1,14) = -3.54$, $P = 0.003$] and marginally significantly earlier than to non-face-like objects [mean = 157.1 ms, SD = 10.97, $t(1,14) = -2.0$, $P = 0.06$]. However, there was no significant difference between the two object categories [$t(1,14) = 1.6$, $P = 0.13$].

Discussion

Consistent with the hypothesis that the amplitude of the N170 is related to the perceived face-likeness of the stimuli, these results showed that N170 amplitude, across hemispheres, was significantly more negative to objects categorized as face-like than to objects categorized as non-face like. This suggests that the amplitude of the N170 to objects is related to the perceived face-likeness of the object.

The results also showed that the amplitude of the N170 was larger to stimuli categorized as faces than to the two object categories. However, this comparison was not the principle object of enquiry intended by this experiment. This supplementary result should be interpreted with caution as the face images were potentially more consistent in the variance of their physical properties than the two object categories [4]. Importantly, although this difference in physical variance could have affected the amplitude between faces and the two object categories, it would be unlikely to account for the difference between the face-like and non-face-like objects, as both these categories contained a variety of objects of differing shape and were thus consistently high in physical variance.

This difference between face-like and non-face-like objects was evident in the amplitude of the N170 but not in the latency, which is consistent with the N170 literature. Rossion *et al.* [3] found that when physical variance is controlled as it was in this comparison, differences in the latency of the N170 are evident only when stimuli are inverted. Again, the difference in the latency of the N170 between faces and the two object categories should be interpreted with caution because of the possible differences in physical variance in these comparisons. The effect of inversion on face-like objects would be an interesting subject for future research.

Although these category differences were found for the N170, the effect of face-likeness on the P1 was not as clear. Although the means showed a trend for a larger P1 to faces than to the two object categories, the ANOVA was not significant. In the electrophysiological literature on face processing, effects at the P1 stage are inconsistent. Although some studies have found differences between faces and non-face objects as early as the P1 stage [12–14], others have reported no difference in this earlier component while still finding a robust difference in the N170 as in the current study [15,16]. These findings warrant further study on the effect of face-likeness on the P1.

Another aspect of ERP research of face processing that has created inconsistent results is lateralization. In this study, no effect of hemisphere was found for either the P1 or the N170 across the subjective categories. This is consistent with several studies that have failed to find a significant difference between hemispheres [17,18] but is inconsistent with other studies that have found a greater N170 amplitude in the right hemisphere [2,19]. Scott and Nelson [20] propose that hemispheric differences in the amplitude of the N170 are associated with differences in the strategy used for face perception. Specifically, featural strategies result in a larger left hemisphere N170 and configural strategies result in a larger right hemisphere N170.

It is worth noting that participants were instructed to classify the images as faces, face-like objects, and non-face-like objects and hence were prepared to look for the face-likeness in the objects. However, considering the design of this experiment and the literature that preceded it, it is unlikely that this could account for the observed results. First, the task used here did not differentially affect the attention to the categories of actual face, face-like object, and non-face-like object as it was equally important to detect and classify all the stimuli. Hence, directed attention cannot explain the observed differences in the N170 amplitude. Second, the literature comparing faces with non-face-like objects, which prompted this study [3,5] used paradigms in which participants were not prepared to look for face-like aspects of objects. Despite this, these studies reported reliable differences between non-face and object categories that were retrospectively attributed by the authors to the face-likeness of some objects. The difference between these studies and the current research is that participants in this experiment categorized the stimuli themselves, thus providing the data about subjective categorization to back-up this existing explanation.

Zion-Golumbic and Bentin [1] amongst others have proposed that the neural system indexed by the N170 is associated primarily with the detection of faces.

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That this system is somewhat sensitive to non-face objects, which are perceived as face like, reveals something important about the tuning of the system. Considering that a face detection system should be triggered by a great variety of faces, seen under an even greater variety of viewing conditions, it is understandable that the system might be partly activated by objects bearing some similarity to faces.

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