

Properties of Familiar Face Representations:

Only Contrast Positive Faces Contain All Information Necessary for Efficient Recognition.

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Abstract

It is difficult to recognise the identity of a face presented in negative contrast. This difficulty, however, is substantially reduced when only the eye region is contrast positive in an otherwise negative face image, and recognition of these so-called contrast chimeras approaches performance with full positive faces. This apparently similar accuracy has led researchers to suggest that familiar face representations are built around the eye region. The present study used the N250r, an event-related brain potential correlate of repetition priming, to examine whether chimera recognition is similarly efficient as positive face recognition. In a series of three experiments, we found a clear N250r for positive but reduced or even absent repetition effects for negative and chimera faces. This finding held true independent of whether the same basic pictures of familiar faces were used as prime and target stimuli (Experiment 1) or not (Experiments 2 and 3). Similar results were also obtained independent of whether positive, negative or chimera primes preceded full positive targets (Experiments 1 and 2) or targets in the same respective contrast format (Experiment 3). These results indicate that only positive faces contain all information necessary for optimal face recognition and that even though contrast chimeras are recognised highly accurately, the underlying processes work less efficiently as compared to normal face recognition. We conclude that familiar face representations are not built around the eyes but comprise detailed information from other regions of the face.

Keywords: face recognition, contrast negation, contrast chimeras, N250r, repetition priming

Properties of Familiar Face Representations:

Only Contrast Positive Faces Contain All Information Necessary for Efficient Recognition.

Humans are remarkably good at recognising familiar faces, even from severely degraded pictures and from images they have never seen before (Burton, Wilson, Cowan, & Bruce, 1999). This high efficiency is less self-evident than one might think, as it can be very difficult to see that different pictures show the same unfamiliar face (Bruce et al., 1999; Jenkins, White, Van Montfort, & Burton, 2011). Accordingly, mental representations of familiar faces need to be robust enough to allow for accurate recognition despite the substantial degree to which a person's appearance can vary across different pictures (Burton, Jenkins, Hancock, & White, 2005; Burton, Kramer, Ritchie, & Jenkins, 2016; Kramer, Young, & Burton, 2018). Such robust representations, or Face Recognition Units (FRU; Bruce & Young, 1986), emerge from exposure to a person's face under varying conditions (Andrews, Jenkins, Cursiter, & Burton, 2015; Ritchie & Burton, 2017). Once a robust representation is established, the process underlying familiar face recognition requires matching a face seen in the visual environment to the stored representation, and a successful match will result in recognition of the face (Bruce & Young, 1986).

Although considerable research effort has been allocated to the question, it is still somewhat unclear what information exactly is stored in an FRU. It is now evident that metric distances between facial features in 2D space, so-called second-order configurations (Maurer, Le Grand, & Mondloch, 2002), play at best a minor role in familiar face recognition (for a recent review, see Burton, Schweinberger, Jenkins, & Kaufmann, 2015). Alternatively, surface reflectance properties of the skin may carry identity information. These properties, also referred to as pigmentation, include albedo, i.e., the reflectance of light of all wavelengths, indicating how dark or light the surface appears, hue, i.e., the difference in reflectance of light of specific wavelengths, and texture, which reflects the spatial variation in

how light is reflected (e.g., Russell, Sinha, Biederman, & Nederhouser, 2006). In addition, patterns of shading across the face can be used as indicators of 3D shape and have been suggested to contribute to face recognition (Johnston, Hill, & Carman, 1992; Kemp, Pike, White, & Musselman, 1996).

Evidence in support of these properties' importance for face recognition comes from studies showing that contrast reversal, as for instance in photographic negatives, severely reduces our ability to identify a known face (e.g., Galper, 1970; Johnston et al., 1992). Interestingly, while both hue and albedo are reversed in photographic negatives, the negation of hue values alone has no effect on face recognition (Kemp et al., 1996). At the same time, negating luminance has a strong disruptive effect. This difficulty with recognising contrast negative faces seems to be primarily related to the loss of pigmentation rather than 3D shape information (Bruce & Langton, 1994; Liu, Collin, & Chaudhuri, 2000; Russell et al., 2006; Vuong, Peissig, Harrison, & Tarr, 2005), which is in line with other evidence suggesting that pigmentation is highly relevant for face recognition (Russell & Sinha, 2007). Given that representations contain the same type of information that is extracted from the perceived stimulus during face recognition, it seems plausible to assume that familiar face representations contain pigmentation information.

Interestingly, pigmentation of the eye region appears to be more important for face recognition than pigmentation information from other parts of the face. Gilad and colleagues (Gilad, Meng, & Sinha, 2009) created so-called contrast chimeras, contrast negative faces in which only the region around the eyes was in positive contrast (see Figure 1). The authors found that these chimeras were recognised surprisingly well, at a similar level as full positive and substantially better than full negative faces. At the same time, positive eyes in isolation were recognised substantially worse, indicating that some form of holistic integration of the positive eye region with the negative rest of the face is necessary for chimera recognition. The authors explained this effect by suggesting that chimeras maintain ordinal contrast relations

within the face, with lower luminance in the eyes relative to surrounding cheeks, forehead, and nose. While these relations remain stable under nearly all naturally possible lighting conditions, full contrast reversal disrupts them. Further research (Sormaz, Andrews, & Young, 2013) has additionally shown that it is indeed specifically the eye region that elicits this effect, as presenting an identically sized area of other face regions (e.g., the mouth or nose region) in positive contrast in an else negative face does not result in better recognition relative to full negative images. Together, these findings seem to suggest that pigmentation information from the eye region appears to be represented in greater detail, but needs to be holistically integrated with the rest of the face, which therefore also provides relevant information for face recognition. If so, one might argue that familiar face representations weigh information from the eye region stronger than information from other parts, and that these representations are built around the eye region (see Bruce & Young, 2012, p. 269).

However, it might be premature to draw this conclusion from the research discussed in the previous paragraphs. Contrast chimeras are highly artificial stimuli that are arguably never encountered in real life outside the lab, and it is not clear whether participants use the same processes to recognise normal faces and contrast chimeras. For instance, one might assume that additional processing steps, not involved in normal face recognition, need to be recruited to integrate the rest of the face with the positive eye region, and that such additional processing would need time. Previous studies, however, used untimed naming tasks and were therefore not well-suited to detect any potential differences in processing time. Accordingly, it remains unclear whether contrast chimeras are recognised as efficiently as normal faces. If this would indeed be the case, this similar recognition efficiency would indicate that face representations are built around the eye region. If, however, chimeras activated face representations less efficiently, this would suggest that information from outside the eye region needs to be available in similar detail for optimal face recognition.

The present series of experiments tested these theoretical considerations by using event-related brain potentials (ERPs). ERPs reflect transient voltage changes in the human electroencephalogram which are time-locked to certain events, such as the presentation of a visual stimulus. They reflect summed post-synaptic potentials and therefore represent a direct measure of the brain's neural activity (Jackson & Bolger, 2014). To the best of our knowledge, only very few previous studies have used ERPs to examine contrast chimeras, and all of them have focused on the N170, a negative peak with a maximum at approximately 170 ms after stimulus presentation at occipito-temporal electrodes (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Eimer, 2011). N170 is known to be substantially larger for faces relative to other object categories (e.g., Rossion & Jacques, 2008), and is further enhanced and delayed for face stimuli that are difficult to process, such as inverted (Eimer, 2000; Rossion et al., 2000), contrast negated (Itier & Taylor, 2002, 2004) or other-race faces (Caharel et al., 2011; Wiese, Kaufmann, & Schweinberger, 2014). Most researchers further agree that N170 is not related to the recognition of individual identity, but reflects the detection of a face-like pattern or the encoding of structural information from the face (Bentin & Deouell, 2000; Eimer, 2000, 2011; Schweinberger, 2011; Schweinberger & Burton, 2003).

An initial study reported a similar N170 for chimeras relative to positive faces, while negative faces elicited larger and delayed N170 peaks (Gandhi, Suresh, & Sinha, 2012). It should be noted, however, that these results are somewhat difficult to interpret, as the authors did not provide figures depicting their actual ERP results. Judging from the presented bar graphs, the N170 amplitude was more positive than the preceding P100 component, which appears highly unusual. In two additional experiments by Fisher, Towler and Eimer (2016; 2015), N170 was again similar for contrast chimeras and full positive faces, but only when the fixation cross preceding the face stimulus was presented at the location of the eye region of the upcoming stimulus. Interestingly, N170 for contrast chimeras was larger relative to positive faces when participants fixated a location over the mouth region of the upcoming

face. Of note, while behavioural experiments asked participants to name famous faces and thus focused on identity processing (Gilad et al., 2009; Sormaz et al., 2013), none of these ERP studies examined familiar face recognition.

The first consistently observed ERP correlate of individual face recognition is found over occipito-temporal channels from approximately 200 ms after stimulus onset. This so-called N250 component is more negative for famous (Andrews, Burton, Schweinberger, & Wiese, 2017; Gosling & Eimer, 2011) or newly-learned relative to unfamiliar faces (Kaufmann, Schweinberger, & Burton, 2009; Tanaka, Curran, Porterfield, & Collins, 2006). Of particular relevance for the present study, the N250 elicited by a target face is also more negative when this stimulus is directly preceded by a prime face of the same relative to a different person (Begleiter, Porjesz, & Wang, 1995; Schweinberger, Pfütze, & Sommer, 1995). This N250r effect (r for repetition) is absent for non-facial objects and substantially reduced for inverted faces (Schweinberger, Huddy, & Burton, 2004). Moreover, N250r does not cross stimulus domains, i.e., the effect does not occur if a familiar face is primed by the written name of that person or vice versa (Pickering & Schweinberger, 2003; Wiese, Komes, Tüttenberg, Leidinger, & Schweinberger, 2017), but it is elicited by the repetition of both familiar and unfamiliar faces (Schweinberger et al., 1995; Zimmermann & Eimer, 2014). Interestingly, however, whereas a reduced N250r can be observed even when different pictures of a familiar face are used as primes and targets (Bindemann, Burton, Leuthold, & Schweinberger, 2008; Schweinberger, Pickering, Jentsch, Burton, & Kaufmann, 2002), a corresponding image-independent repetition effect is not observed for unfamiliar faces (Zimmermann & Eimer, 2013). Accordingly, whereas the image-specific part of the N250r might be interpreted as reflecting visual working memory for both familiar and unfamiliar faces, the image-independent part is related to accessing robust representations of familiar faces.

The present study measured the N250r elicited by positive, negative and contrast chimeras to test whether representations of familiar faces are indeed built around the eyes. We

hypothesised that if this was the case, contrast chimera primes should be as efficient to pre-activate a target representation as positive faces. Accordingly, N250r should be similar when familiar faces are preceded by positive and chimera primes, but substantially smaller when preceded by negative primes. While in the first two experiments reported below full positive targets were primed by positive, negative or chimera faces, Experiment 3 kept contrast information between prime and target constant. In addition, we analysed N170 elicited by positive, negative and chimera primes to investigate whether the observed priming effects could be related to differences at early perceptual processing stages.

Experiment 1: Same image priming

In Experiment 1, we tested same image repetition priming. As detailed above, the resulting N250r effects only partly reflect access to image-independent face representations. At the same time, this procedure elicits the largest N250r (Bindemann et al., 2008; Schweinberger et al., 2002). Accordingly, we reasoned that potentially different priming effects for the three contrast conditions would probably be easiest to detect under these conditions, although the interpretation of such differences would be somewhat ambiguous.

In this and the following experiments, we tested the following hypotheses: If chimeras pre-activated the target face representations similarly efficiently as positive faces, both chimera and positive primes should elicit a clear N250r after target presentation. As contrast negative faces are substantially harder to recognise, they should not pre-activate target face representations as efficiently as positive faces, and a small or even absent N250r would be expected after target presentation. Finally, if chimera primes were processed as efficiently as positive faces at early perceptual stages, these conditions should elicit a similar N170, while negative faces should elicit a larger and delayed N170 peak (Itier & Taylor, 2002, 2004).

Methods

Participants

Prior to data collection, the required sample size was estimated on the basis of the N250r effect size obtained in Experiment 1 of Wiese et al. (2017; young adults only) using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007). Calculation of N for a repeated-measures t-test for the difference between repeated and non-repeated conditions ($d_z = 0.93$, power = .99, two-tailed alpha = .05) revealed a sample size of 24. Thus, if N250r in the chimera condition was comparable to the effect for positive faces, we would highly likely observe a statistically significant result in both conditions. We tested a total of 27 participants, three of which were excluded due to insufficient familiarity with the presented celebrities and insufficient numbers of artefact-free trials for EEG analysis ($N < 16$ in any experimental condition). The final sample consisted of 24 Durham university undergraduate students (19 female, mean age = 20.3 years +/- 2.0 SD). All participants were right-handed according to a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971), reported normal or corrected to normal vision, and did not take central acting medication. All gave written informed consent and were compensated with course credit or a monetary reward of £7.5/h. The study was approved by the ethics committee of Durham University's Psychology Department.

Stimuli

We collected six different images of 40 celebrities (musicians, actors, politicians etc.; 240 images in total) from various internet sources. Faces were cropped from the background, copied to a uniform grey background, converted to greyscale and standardised to 190 x 285 pixels (corresponding to 2.9° x 4.3° visual angle at 100 cm viewing distance) for prime stimuli and to 228 x 342 pixels (corresponding to 3.4° x 5.2° visual angle) for targets using GIMP (version 2.8.14; www.gimp.org). Contrast negative versions of all images were created by reversing greyscale values for the images. Contrast chimeras were created analogously to Gilad et al. (2009) by defining an area including the outer canthi of both eyes and eyebrows

and presenting this area in positive contrast, while the rest of the face was presented in negative contrast (see Figure 1). Edges between the different contrast regions were smoothed using GIMP.

Procedure

Participants were seated in a sound-attenuated and electrically shielded chamber, with their heads in a chin rest positioned at a distance of 100 cm from an LCD monitor. Stimuli were combined to prime/target pairs such that all targets were contrast positive face images, whereas primes were either positive, negative or chimeras. Moreover, prime and target could either show the same (repetition) or a different face (non-repetition). The same basic image was used for primes and targets in the repetition conditions (although target images were increased in size, see above). Forty trials per condition were presented, with each of the forty identities occurring in all six conditions, such that no target image was repeated across conditions (i.e., image repetitions occurred only within trials). Assignment of the six different target images per identity to experimental conditions was counterbalanced across participants. A practice block consisting of twelve trials using stimuli from additional celebrities preceded the main experiment to familiarise participants with the task.

Trials started with a red fixation cross (1,000 ms), followed by the prime (500 ms), a second green fixation cross (500 ms), and the target face (1,000 ms). Finally, a response screen (presented until the participants made a response) was presented which asked participants to rate the familiarity of the target (1=unfamiliar, 2=face looks familiar, but no additional information, 3=identity-specific information available, but no name information [e.g., “This is the actor who plays James Bond”], 4=name information available). Participants were asked to withhold their response until this screen was presented and then responded via a key pad. The key assignment for the four response options was presented on the screen. Participants were explicitly instructed to pay close attention to the monitor at all times, but to

respond only to the target faces. Accordingly, the experiment was not designed to test behavioural differences between contrast conditions.

EEG recording and analysis

During the experiment, 64-channel EEG was recorded from sintered Ag/AgCl electrodes mounted in a textile cap (CW-1809 waveguard cap, eemagine, Berlin, Germany) using an ANT ASA lab amp (ANT Neuro, Enschede, The Netherlands) from DC to 120 Hz with a sampling frequency of 512 Hz. Recording sites corresponded to FP1, FPz, FP2, F7, F3, Fz, F4, F8, P9, FC1, FC2, P10, FT9, T7, C3, Cz, C4, T8, FT10, PO9, CP1, CP2, PO10, P7, P3, Pz, P4, P8, POz, O1, Oz, O2, TP9, AF3, AF4, TP10, F5, F1, F2, F6, FC3, FCz, FC4, C5, C1, C2, C6, CP3, CPz, CP4, P5, P1, P2, P6, I1, PO3, PO4, I2, FT7, FT8, TP7, TP8, PO7, PO8. Recording reference was Cz. Blink artefacts were corrected offline using the algorithm implemented in BESA 6.3 (Berg & Scherg, 1994). Trials were segmented from -200 to 500 ms relative to prime onset and from -200 to 1,000 ms relative to target onset, with the first 200 ms as baseline, respectively. An amplitude criterion of 100 μ V and a gradient criterion of 75 μ V were used for artefact rejection. Moreover, for the analysis of target stimuli, only trials in which participants indicated to have identified the face (response options 3 and 4) were analysed. Remaining trials were re-referenced to the common average reference and averaged for each experimental condition separately. Average trial numbers were 76.5 (+/- 3.3 SD) for positive primes, 77.5 (+/- 2.0 SD) for negative primes, and 76.7 (+/- 2.5 SD) for chimera primes, as well as 32.0 (+/- 6.7 SD) for positive repetition, 32.2 (+/- 6.3 SD) for positive non-repetition, 32.5 (+/- 5.8 SD) for negative repetition, 31.9 (+/- 6.5 SD) for negative non-repetition, 32.0 (+/- 6.9 SD) for chimera repetition, and 32.5 (+/- 6.4 SD) for chimera non-repetition target conditions.

In the resulting ERPs, prime N170 amplitude was measured by calculating the mean amplitude between 140 and 190 ms at left- and right-hemispheric occipito-temporal and temporal channels (P9/P10, TP9/TP10). N170 latency was defined as the local minimum

between 130 and 210 ms at TP9 and TP10. Moreover, target N250 was calculated as the mean amplitude between 220 and 300 ms at P9/P10 and TP9/TP10. Statistical analyses were carried out using repeated-measures Analyses of Variance (ANOVA), with degrees of freedom corrected using the Huyn-Feldt procedure when appropriate. Moreover, a priori hypotheses (see above) were tested using repeated-measures t-tests. In line with a “new statistics” approach (Cumming, 2012), confidence intervals (CI) and effect size measures are reported for all ERP priming effects (non-repetition minus repetition conditions) using bias-corrected Cohen’s d (d_{unb}) with the average standard deviation as the denominator. CIs for d_{unb} were calculated using ESCI (Cumming, 2012; Cumming & Calin-Jageman, 2017), CIs for partial eta squared (η_p^2) were calculated using scripts provided by M.J. Smithson (<http://www.michaelsmithson.online/stats/CIstuff/CI.html>).

Results

Performance.

Faces were assumed as being recognised if participants either indicated that they knew the name (response option “4”) or identity-specific semantic information (e.g., “This is the actor who plays James Bond”; response option “3”) of the target face. Results from familiarity ratings are reported in Table 1. A repeated-measures ANOVA with the within-subjects factors repetition (repeated, non-repeated) and prime type (positive, negative, chimera) did not yield any significant effects, all $F < 1$.

Event-related potentials.

Although the main purpose of the present experiments was to examine the effects of priming on target faces, it is interesting to consider ERPs to prime faces first to see whether processing of full positive, negative and chimera stimuli differed. Visual inspection of the ERP results suggested larger N170 amplitudes for both negative and chimera relative to positive primes (see Figure 2). Moreover, all conditions elicited priming effects following

target presentation, with more negative amplitudes for repeated relative to non-repeated faces, which started approximately 220 ms after target onset (Figure 3). This N250r appeared larger in the positive prime relative to both negative and chimera prime conditions.

Statistical analyses confirmed these observations. A repeated-measures ANOVA on prime N170 amplitude with the within-subjects factors hemisphere (left, right), site (TP, P), and prime type (positive, negative, chimera) revealed a significant main effect of prime type, $F(2, 46) = 22.99, p < .001, \eta^2_p = .500, 90\% \text{ CI } [.306, .607]$. Pairwise comparisons revealed significantly less negative N170 amplitudes for positive relative to both negative and chimera faces, which did not differ (see Table 2)¹. A repeated-measures ANOVA on N170 latency with the factors hemisphere and prime type yielded a significant main effect of prime type, $F(2, 46) = 22.75, p < .001, \eta^2_p = .497, 90\% \text{ CI } [.303, .605]$. Pairwise comparisons revealed significantly earlier N170 latencies for positive relative to both negative and chimera faces, which again did not differ (see Table 2).

A repeated-measures ANOVA on mean amplitudes in the N250r time window (220-300 ms) revealed a significant main effect of repetition, $F(1, 23) = 17.90, p < .001, \eta^2_p = .438, 90\% \text{ CI } [.169, .600]$, as well as a significant interaction of repetition by prime type, $F(2, 46) = 4.31, p < .019, \eta^2_p = .158, 90\% \text{ CI } [.015, .293]$. All prime type conditions elicited significant differences between repeated and non-repeated trials (see Table 2, Figure 3). At the same time, positive primes elicited larger priming effects than chimeras, $M_{\text{diff}} = 0.86 \mu\text{V}, 95\% \text{ CI } [0.17, 1.55], t(23) = 2.58, p = .017, d_{\text{unb}} = 0.49, 95\% \text{ CI } [0.09, 0.91]$, and chimera primes did not elicit stronger priming effects than negative primes, $M_{\text{diff}} = 0.16 \mu\text{V}, 95\% \text{ CI } [-0.39, 0.70], t(23) = 0.59, p = .562, d_{\text{unb}} = 0.10, 95\% \text{ CI } [-0.25, 0.46]$.

Discussion

¹ Please note that N170 results in this and the following experiments do not change if the component is measured against P1 (i.e., the mean amplitude between 100 – 140 ms) rather than baseline.

The results of Experiment 1 do not indicate that contrast chimeras prime face representations as efficiently as positive faces. This interpretation is based on the substantially larger N250r in the positive relative to the chimera condition. However, even though different in size, prime and target stimuli in repetition trials were derived from the same basic image. This presumably resulted in pictorial priming in addition to effects reflecting the repetition of facial identity, and particularly so for the positive relative to the other contrast conditions, as positive primes and targets were arguably more similar. Accordingly, it is possible that the larger N250r for the positive condition resulted from pictorial rather than face identity priming, and that identity priming was similar between conditions. At the same time, this interpretation appears implausible, as it would suggest similar identity priming in the chimera and negative conditions. By contrast, it is more likely that a form of pictorial rather than identity priming caused the significant N250r in the negative condition, as similarity between prime and target was still arguably higher in the repeated than non-repeated condition. This may have resulted in the observed repetition effect, even though the identity of the prime was presumably not recognised in many of the trials.

Even though we cannot completely rule out that repetition effects in Experiment 1 were related to pictorial priming, ERPs to prime stimuli also did not suggest similarly efficient processing of chimera and positive faces. N170 was substantially larger and delayed in the former case, and highly similar to the negative condition. Although N170 likely does not reflect the processing of individual identity, any deficit prior to identity recognition will transfer to this later stage. It is therefore plausible to assume that differential priming effects in the N250r were related to smaller pre-activations of face representations in the chimera and negative conditions.

Experiment 2: Different image priming

Given the above-described confound of pictorial and face identity priming, the results of Experiment 1 cannot be unequivocally interpreted as evidence against the suggestion that face representations are built around the eye region. Experiment 2 was designed to further test this idea under conditions which largely exclude the possibility of pictorial priming. N250r is smaller, but still evident, when different images of the same person are used as primes and targets (Bindemann et al., 2008; Schweinberger et al., 2002), and this remaining effect more clearly reflects the access to robust familiar face representations. In Experiment 2, we therefore tested repetition priming with different images of the same person in the repeated conditions.

Methods

Participants.

We tested a total of 26 participants, two of which were excluded due to insufficient familiarity with the stimuli (see above). The final sample consisted of 24 right-handed Durham University undergraduate students (14 female, mean age = 23.2 years +/- 5.5 SD). Reimbursement and inclusion/exclusion criteria were identical to Experiment 1. All participants gave written informed consent and the experiment was approved by the ethics committee at Durham University's Psychology Department.

Stimuli, procedure and EEG recordings.

Stimuli were identical to those used in Experiment 1. Prime/target pairings were changed, such that in repetition trials, different images of the same person were used as prime and target. All other aspects of the experiment including EEG recording and analysis parameters remained unchanged.

Average trial numbers for EEG analysis were 76.8 (+/- 3.9 SD) for positive primes, 77.2 (+/- 3.3 SD) for negative primes, and 77.1 (+/- 3.3 SD) for chimera primes, as well as 33.5 (+/- 6.5 SD) for positive repetition, 33.8 (+/- 6.3 SD) for positive non-repetition, 33.3

(+/- 6.8 SD) for negative repetition, 33.0 (+/- 6.3 SD) for negative non-repetition, 33.4 (+/- 6.3 SD) for chimera repetition, and 32.8 (+/- 6.8 SD) for chimera non-repetition target conditions.

Results

Performance.

Mean (and SD) familiarity ratings are listed in Table 1. A repeated-measures ANOVA on the proportion of recognised target faces revealed a significant main effect of repetition, $F(1, 23) = 5.65, p = .026, \eta^2_p = .197, 90\% \text{ CI } [.013, .402]$, with more accurate recognition in the repeated relative to the non-repeated condition. Neither the main effect of prime type, $F < 1$, nor the interaction were significant, $F(2, 46) = 2.47, p = .096, \eta^2_p = .097, 90\% \text{ CI } [.0, .221]$.

Event-related potentials.

ERP results are depicted in Figures 4 and 5. Prime N170 results were highly similar to Experiment 1, with enhanced and delayed peaks in the chimera relative to the full positive condition (Figure 4). N250r was smaller relative to Experiment 1, but clearly evident in the positive prime condition (Figure 5). Only very small effects were observed in the negative and chimera prime conditions. Inspection of the waveforms further suggested a delayed onset of repetition effects in the chimera condition, particularly at left-hemispheric electrodes where the effect emerged at approximately 300 ms. We therefore analysed repetition effects in two time windows. The first was identical to Experiment 1 (N250r; 220-300 ms) and the second comprised the following 100 ms (300-400 ms).

A repeated-measures ANOVA on prime N170 amplitude yielded a significant main effect of prime type, $F(2, 46) = 26.92, p < .001, \eta^2_p = .539, 90\% \text{ CI } [.351, .639]$. Pairwise comparisons revealed significantly less negative amplitudes for positive relative to negative and chimera faces, which did not differ (see Table 3). A repeated-measures ANOVA on N170 latency again yielded a significant main effect of prime type, $F(2, 46) = 105.44, p < .001, \eta^2_p$

= .821, 90% CI [.728, .861]. Pairwise comparisons revealed earlier N170 peaks for positive relative to both negative and chimera faces, which again did not differ (see Table 3).

Statistical analysis of target faces in the N250r time window revealed significant main effects of repetition, $F(1, 23) = 5.24, p = .032, \eta^2_p = .185, 90\% \text{ CI } [.009, .390]$, and prime type, $F(2, 46) = 3.37, p = .043, \eta^2_p = .128, 90\% \text{ CI } [.002, .259]$, as well as a significant interaction of repetition by prime type, $F(2, 46) = 4.15, p = .022, \eta^2_p = .153, 90\% \text{ CI } [.013, .287]$. Pairwise comparisons yielded a significant priming effect in the positive condition, but neither in the negative, nor in the chimera priming condition (see Table 3).

A corresponding analysis of the 300-400 ms time window again yielded a significant main effect of repetition, $F(1, 23) = 13.42, p = .001, \eta^2_p = .368, 90\% \text{ CI } [.110, .547]$, while the repetition by prime type interaction was not significant, $F(2, 46) = 2.34, p = .108, \eta^2_p = .092, 90\% \text{ CI } [.0, .215]$. We nevertheless analysed priming effects for all prime type conditions separately to test our a priori hypothesis of significant priming in the positive and chimera, but not in the negative condition (see above). Similar to the N250r time window, this analysis revealed a significant priming effect in the positive condition, but neither in the negative, nor in the chimera condition (see Table 3).

Discussion

Experiment 2 used different pictures of famous faces as prime and target in the repetition conditions to test for image-independent face identity priming. Clear priming effects were obtained in the N250r time window for positive but neither for negative nor for chimera primes. This pattern was similarly observed in a subsequent 300-400 ms time window. Whereas the non-significant interaction of repetition by prime type in the omnibus ANOVA for this later time window might be interpreted as suggesting similar priming for positive and chimera primes, the repetition effect in the chimera condition was small and very similar to the negative condition. Neither of these two effects were significant when tested in

isolation. Moreover, N170 was again substantially larger and delayed for chimera primes relative to positive prime faces, and highly similar to negative primes. In line with Experiment 1, these findings do not suggest a processing advantage for chimeras over negative stimuli at the level of structural encoding or accessing robust face representations. Our results are therefore difficult to integrate with the idea of face representations that are built around the eyes, but instead suggest that detailed information from other regions of the face is necessary for optimal face recognition.

Of note, and in contrast to Experiment 1, a behavioural priming effect was observed in Experiment 2, with slightly higher familiarity ratings in the repeated relative to the non-repeated conditions. While the reasons for this difference between the two experiments remain somewhat unclear, one might speculate that the different images used as primes and targets in Experiment 2 might have resulted in a strategic attempt to collect information from the prime stimulus. In Experiment 1, such a strategy would have been less useful as the prime image was either repeated or irrelevant for the identification of the target. In Experiment 2, however, subjects might have realised that a successful identification of the prime would be helpful for rating the familiarity of the upcoming target image in half of the trials, as additional perceptual information for the person in question was presented.

Experiment 3: Within-category priming

ERP results from Experiments 1 and 2 converge on the conclusion that contrast chimeras do not activate perceptual face representations as efficiently as positive faces. However, as these experiments did not collect a behavioural response to chimeras, it is not clear whether the present stimulus set actually produced a recognition advantage for chimeras relative to negative faces. Accordingly, it remained possible that some problem with our

specific stimulus set, and not inefficient processing of chimeras in general, might be the cause for the small N250r in this condition.

In addition, the finding that ERP priming effects were similar for chimeras and negative images in the first two experiments, and smaller than for positive faces, could be related to the change in contrast format between prime and target in the first two but not in the latter condition. In other words, for both chimeras and negative faces (large parts of) the contrast information was reversed between prime and target presentation, which was not the case for positive faces. One might therefore argue that some form of visual aftereffect resulting from the contrast reversal had affected the ERPs. If so, a low-level visual aftereffect related to the contrast change, and not inefficient processing of the prime face per se, might have caused the reduced N250r in the chimera condition.

In Experiment 3, we therefore tested whether larger priming effects for chimera stimuli would emerge if the image format remained constant between prime and target in all conditions, e.g., when a chimera prime was followed by a chimera target. Moreover, overt recognition of full positive, negative and chimera targets was measured.

Methods

Participants.

We tested 28 participants, four of which were excluded due to insufficient recognition of the celebrity faces (see above). The final sample consisted of 24 right-handed Durham University undergraduate students (18 female, mean age = 21.5 years \pm 3.8 SD). Reimbursement as well as exclusion/inclusion criteria were identical to the previous experiments. All participants gave written informed consent and the experiment was approved by the ethics committee of Durham University's Psychology Department.

Stimuli, procedure, and EEG recordings.

Stimuli were identical to those in the previous experiments, as were all procedural details except for the following changes. Prime/target pairs were recombined to always show images of the same contrast condition as primes and targets. In other words, positive primes were followed by positive targets, negative primes by negative targets, and chimera primes by chimera targets. As in the previous experiments, targets were larger than prime stimuli, and as in Experiment 2, different images of the same person were used as primes and targets in the repetition condition. To make the task more comparable to previous studies that used untimed naming, the target stimulus remained on the screen during the presentation of the response options until the participants pressed a key. However, key presses were possible only after the response options had appeared on the screen (i.e., 1,000 ms after target onset).

Average trial numbers for EEG analysis were 75.6 (+/- 3.9 SD) for positive primes, 76.2 (+/- 3.9 SD) for negative primes, and 76.0 (+/- 4.5 SD) for chimera primes, as well as 35.7 (+/- 3.9 SD) for positive repetition, 35.4 (+/- 3.4 SD) for positive non-repetition, 29.3 (+/- 5.7 SD) for negative repetition, 28.4 (+/- 6.8 SD) for negative non-repetition, 33.7 (+/- 5.5 SD) for chimera repetition, and 33.0 (+/- 5.1 SD) for chimera non-repetition target conditions.

Results

Performance.

A repeated-measures ANOVA on the proportion of identified target faces (see Table 1) with the factors prime type and repetition revealed significant main effects of repetition, $F(2, 46) = 8.60, p = .007, \eta^2_p = .272, 90\% \text{ CI } [.087, .409]$, with more identifications in the repeated relative to the non-repeated condition, and prime type, $F(2, 46) = 51.72, p < .001, \eta^2_p = .692, 90\% \text{ CI } [.546, .761]$. The interaction was not significant, $F(2, 46) = 1.31, p = .280, \eta^2_p = .054, 90\% \text{ CI } [.0, .160]$. Follow-up tests on the main effect of prime type yielded significantly better recognition of chimera relative to negative faces, $M_{\text{diff}} = 0.13, 95\% \text{ CI}$

[0.09, 0.16], $t(23) = 7.59$, $p < .001$, $d_{\text{unb}} = 0.90$, 95% CI [0.57, 1.29], as well as for positive relative to chimera faces, $M_{\text{diff}} = 0.06$, 95% CI [0.03, 0.09], $t(23) = 4.23$, $p < .001$, $d_{\text{unb}} = 0.58$, 95% CI [0.27, 0.92].

Event-related potentials.

A repeated-measures ANOVA on prime N170 amplitude (see Figure 6) revealed a significant main effect of prime type, $F(2, 46) = 6.96$, $p = .003$, $\eta^2_p = .232$, 90% CI [.058, .370], reflecting less negative N170 amplitudes for positive relative to both negative and chimera primes, which in turn did not differ (see Table 4). An ANOVA on N170 latency yielded a significant main effect of prime type, $F(2, 46) = 26.89$, $p < .001$, $\eta^2_p = .539$, 90% CI [.351, .639]. Pairwise comparisons revealed earlier N170 peaks in the positive relative to both negative and chimera conditions, while the latter two did not differ (see Table 4).

A repeated-measures ANOVA on target ERPs in the N250r time window (see Figure 7) revealed main effects of repetition, $F(1, 23) = 4.70$, $p < .041$, $\eta^2_p = .170$, 90% CI [.004, .375], and prime type, $F(2, 46) = 23.41$, $p < .001$, $\eta^2_p = .504$, 90% CI [.311, .611], but no significant interaction, $F(2, 46) = 2.24$, $p = .118$, $\eta^2_p = .089$, 90% CI [.0, .210]. To test our a priori hypothesis of significant priming in the positive and chimera but not in the negative conditions, repeated-measures t-tests were calculated to test repetition effects for the three priming conditions separately. This analysis revealed significant repetition effects in the positive condition. At the same time, neither the negative nor the chimera primes elicited significant priming (see Table 4).

A corresponding ANOVA in the 300-400 ms time window again revealed significant main effects of repetition, $F(1, 23) = 18.84$, $p < .001$, $\eta^2_p = .450$, 90% CI [.181, .610], and prime type, $F(2, 46) = 21.44$, $p < .001$, $\eta^2_p = .482$, 90% CI [.286, .593], which were again not modulated by a significant repetition by prime type interaction, $F(2, 46) = 1.35$, $p = .568$, $\eta^2_p = .024$, 90% CI [.0, .162]. Separate analyses of the three priming conditions revealed

significant repetition effects in the positive, chimera, and in the negative condition (see Table 4). Neither the positive nor the chimera priming effect was significantly larger than the negative effect; positive vs. negative: $M_{diff} = 0.32 \mu V$, 95% CI [-0.41, 1.05], $t(23) = 0.90$, $p = .378$, $d_{unb} = 0.22$, 95% CI [-0.28, 0.74]; chimera vs. negative: $M_{diff} = 0.25 \mu V$, 95% CI [-0.36, 0.87], $t(23) = 0.86$, $p = .401$, $d_{unb} = 0.21$, 95% CI [-0.28, 0.70].

Discussion

Experiment 3 yielded some limited evidence for priming effects in the chimera condition. While the omnibus ANOVA in the N250r time window did not suggest differential effects for the three priming conditions, separate t-tests revealed significant priming in the positive condition only. It should be noted, however, that the respective statistical test in the chimera condition just failed to reach statistical significance, whereas negative faces did not elicit any observable priming effect (see Figure 7c). This finding is in some contrast to Experiment 2, which revealed no observable priming effect in the chimera condition. It therefore appears possible that a small N250r exists when chimera targets are primed by chimera primes, but not when positive targets are primed by chimera primes. Keeping the contrast format for prime and target presentation constant is per se unlikely to drive this effect, as this explanation would similarly assume repetition effects in the negative condition, which was not observed. Importantly, however, even if an N250r for chimera priming under the conditions of Experiment 3 existed, it is at best a small effect that appears to be more difficult to elicit relative to the positive condition.

Analysis of the 300 – 400 ms time window revealed ERP repetition effects in all conditions. Of note, as in the previous experiments, only trials in which the target was identified entered the ERP analysis. Accordingly, ERP repetition effects might represent more efficient identification in the repeated condition, even for negative faces. Contrast negation does not completely eliminate the viewer's ability to recognise a familiar face (Bruce &

Langton, 1994; Sormaz et al., 2013). Moreover, in the present study identities were repeatedly presented in the course of the experiment, although in different pictures. Accordingly, participants may have identified negative faces not only from identity-specific information that is spared by contrast negation but also on the basis of their knowledge about which identities were in the stimulus set acquired in the course of the experiment. It appears that presenting the same identity as a prime, even in the negative condition and even in a different picture, facilitated face recognition to some extent. It is important to note, however, that no clear difference between the negative and chimera priming conditions was observed.

Although N170 was again similar for chimera and negative primes, the analysis of recognition ratings revealed a large chimera effect, with substantially better recognition performance in the chimera relative to the negative condition (Gilad et al., 2009; Sormaz et al., 2013). This effect emerged even though performance for negative faces was relatively good as compared to previous studies, which might be related to the repeated presentation of identities, as discussed in the previous paragraph. Finally, positive images were more likely recognised than chimeras, even though the effect size was considerably smaller relative to the chimera advantage over negative images. This finding replicates a similar pattern in a previous study (Sormaz et al., 2013) and might be related to the contribution of detailed information from areas other than the eye region to face recognition.

General Discussion

The present study used an ERP correlate of repetition priming in face recognition, the N250r, to examine whether perceptual representations of familiar faces contain more detailed information from the eye region relative to the rest of the face. This assumption was derived from previous studies that have shown a recognition advantage for contrast chimeras, with a contrast-positive eye region in an otherwise negative face, relative to negative faces. If

familiar face representations were indeed built around the eye region, the N250r for contrast chimeras should be similar to the repetition effect observed for positive faces, whereas small or absent N250r effects would be expected for negative faces. This prediction was based on the assumption that both positive and chimera, but not negative primes should efficiently pre-activate the target representation. In a series of three experiments, we did not find conclusive evidence to support this hypothesis. In none of the three experiments did we find an N250r for chimera (or negative) faces that was comparable to the repetition effect for positive faces. These findings are not easy to integrate with familiar face representations that are built around the eyes, but instead suggest that these representations contain detailed information from outside the eye region.

The present findings replicate previous research (Bindemann et al., 2008; Schweinberger et al., 2002; Zimmermann & Eimer, 2013), as a clear N250r was observed for positive faces even when the specific image was changed for prime and target presentation. In contrast, negative primes did not elicit an N250r when the image changed (in Experiments 2 and 3). The image-independent part of the N250r can be interpreted as reflecting facilitated access to robust perceptual representations of familiar faces (i.e., FRUs in Bruce and Young's [1986] terms). Such representations do not seem to be activated by the negative prime, and therefore remain at baseline activation level until the target is presented. This interpretation is well in line with the classic finding that contrast negative faces are difficult to recognise. We did observe a significant N250r in the negative condition of Experiment 1, in which the same image was used as prime and target. This effect, however, was substantially smaller than the N250r in the positive condition and presumably reflects pictorial rather than identity priming.

As shown in previous studies, contrast chimeras are much easier to recognise than negative faces (Gilad et al., 2009; Sormaz et al., 2013), and accordingly one might assume that chimera primes would be able to activate familiar face representations. However, as noted above, we did not find clear evidence for this assumption. In Experiment 1, the N250r

observed in the chimera condition was smaller than in the positive condition and very similar to the negative condition. In line with the argument in the previous paragraph, this N250r is best interpreted as reflecting a form of pictorial rather than identity priming. In Experiment 2, arguably the strongest test for the hypothesis of familiar face representations that are built around the eyes, N250r was completely absent in the chimera condition. The most promising result was obtained in Experiment 3, in which a chimera N250r was detected as a statistical trend. This was observed when both prime and target stimuli were contrast chimeras. If we assume that the small N250r observed in Experiment 3 is a real effect, this pattern suggests that chimeras can prime chimeras but not positive faces. One potential interpretation of such a pattern would be to suggest that eye-centred representations exist in addition to positive representations, and that each representation is selectively primed by the respective prime face. This interpretation might be seen as reminiscent of previous findings suggesting neurons specifically tuned to eyes rather than full faces (Itier, Alain, Sedore, & McIntosh, 2007; Itier, Latinus, & Taylor, 2006). In real life, however, viewers have to recognise faces with natural contrast information and an eye-centred representation that is only activated by contrast chimeras is hardly useful for this task. Together, the present findings therefore do not support the idea that contrast chimeras can efficiently activate familiar face representations, which therefore seem to contain detailed information from outside the eye region.

We further examined a later time window from 300 to 400 ms in both Experiments 2 and 3 to test whether repetition priming effects for chimera stimuli would emerge with a time delay relative to positive faces. Whereas in Experiment 2 neither chimera nor negative primes elicited significant priming effects in this time window, both did in Experiment 3. Priming effects were slightly larger for chimeras relative to negative faces in Experiment 3, but again this difference was small and not statistically significant. Together, these findings therefore do not provide conclusive evidence for a processing advantage in the chimera conditions in this later time range.

These results clearly suggest that the processes underlying chimera and normal face recognition are not identical, but they do not explain why contrast chimeras are easier to recognise than negative faces. This effect has been repeatedly observed before and was also evident in the present study. Behavioural experiments that show a chimera recognition advantage typically use naming tasks. In Experiment 3, we adapted this task to the requirements of an ERP experiment, in which verbal responses should be avoided due to the resulting contamination of EEG data by movement artefacts. Similar to previous experiments, however, the task in the present study asked participants to access name information. In addition, both in previous studies and when judging targets in our Experiment 3, participants were not under time pressure and were able to thoroughly explore the stimulus. This is clearly different to the processing demands related to the prime faces in our experiments, which were presented for only 500 ms and were quickly followed by the target. While this presentation time was sufficient to derive identity information from positive faces, it was presumably not long enough for chimera recognition, which again indicates less efficient processing.

Results from the prime N170 further support this conclusion. N170 is assumed to reflect structural encoding (Bentin et al., 1996; Eimer, 2011), i.e., the transformation of the visual face stimulus into an internal representation (Bruce & Young, 1986). In the present study, contrast chimeras consistently elicited an increased and delayed N170, very similar to negative faces and clearly different from positive faces. Interestingly, previous studies have also found that N170 to isolated eyes is enhanced relative to full faces (Bentin et al., 1996; Itier et al., 2007), while at the same time identity is hard to recognise from the eye region alone (Gilad et al., 2009; Sormaz et al., 2013). Most researchers agree that the N170 reflects processes preceding the recognition of individual identity (Bentin et al., 1996; Bentin & Deouell, 2000; Eimer, 2000, 2011; Schweinberger, 2011). However, as face processing is assumed to be a largely serial process (Bruce & Young, 2012), any difficulty at an early processing stage will be carried over to later stages. Accordingly, difficulties with chimera

stimuli at an early perceptual processing stage will affect subsequent stages of face recognition. In the context of repetition priming, perceptual difficulties with the prime stimulus will result in less accurate structural descriptions, which in turn will not sufficiently activate familiar face representations. Consequentially, no priming effect is observed when the target is presented.

As noted in the introduction, previous studies by Fisher and colleagues (2016; 2015) observed a similar N170 for contrast chimeras and positive faces when the preceding fixation cross was located over the eye region, but a larger N170 for chimeras when it was located over the mouth region. In the present study, we did not control the exact location of the fixation cross relative to the features of the upcoming faces. As we used “natural” images with slightly varying viewing angles, the precise location also varied to some extent. For most faces, however, the fixation cross was located close to the nasion, i.e., within the region presented in positive contrast for chimera stimuli. One difference between the stimuli used in the present and these previous studies is that, in our case, faces were presented with outer features (hair, ears, etc.) whereas in the studies by Fisher and colleagues only the inner features were presented. As a consequence, the nasion was located in the middle of the stimulus in our experiments but in the upper half in these previous studies. It is therefore possible that the amount of facial information in the upper hemifield influenced the difference between studies. Moreover, the task in the previous studies was to detect an image repetition, which can be solved by focusing on a restricted region of the face, whereas in the present study participants focused on identity processing, which presumably required the integration of information from the whole face. Differences in attentional focus due to task demands might have further contributed to the varying findings.

It remains unclear at present whether these or other differences between the experiments caused the different results. One might therefore speculate whether an N250r similar to the effect observed for positive faces would have been detected in the present

experiments if only the inner features had been presented. We note that a finding of a similar $N250r$ for chimeras and positive faces under these conditions would hardly disqualify our main conclusion. If such strictly controlled and arguably ecologically less valid conditions were necessary to equate the efficiency of chimera and positive recognition, positive stimuli would still be processed more efficiently in most naturally occurring circumstances.

Even though the present findings clearly indicate less efficient processing of chimera relative to full positive faces, we acknowledge that they do not clarify why chimera faces are recognised better than contrast negative faces. As noted above, one critical factor for normal versus chimera face recognition might be time. More specifically, whereas normal face recognition appears to be effective within the 500 ms during which primes were presented in our experiments, this might not be the case for chimeras. With more time, however, it might be possible to use additional processing to infer the whole face from the positive eyes and the otherwise negative face. Moreover, the finding that this inference is possible with detailed eye information, but not with positive information from other parts of the face (see Sormaz et al., 2013) seems to suggest that the eyes are particularly important for this process. The present results, however, seem to suggest that any such inferential process is not necessary for contrast positive faces, and it therefore appears to be not involved in normal face recognition. Future studies that compare the processing of familiar and unfamiliar chimera and positive faces might help to further clarify these issues.

In conclusion, the present findings indicate that chimeras are processed less efficiently than positive faces, which is at variance with the suggestion that familiar face representations are built around the eyes. Instead, our results suggest that such robust representations contain detailed information from outside the eye region. While our results say little about why contrast chimeras are recognised more accurately than negative faces, we believe that they support a more important point: It appears likely that the processes underlying chimera and positive face recognition are not identical. Therefore, even if we understood how artificially

created contrast chimeras are recognised, this might still give us only limited insight into the mechanisms underlying the recognition of more naturalistic face stimuli. This point is certainly not restricted to chimeras but similarly holds true for other types of artificial face stimuli, and while this line of argument has been brought forward from a more theoretical perspective before (Burton, 2013), the present study provides empirical evidence for its legitimacy. It therefore appears more fruitful for future face recognition research to focus on the processing of ecologically more valid, e.g., “ambient” face stimuli.

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Table 1. Mean and SD proportion of target identification for Experiments 1-3.

| | | <u>Positive Prime</u> | | <u>Negative Prime</u> | | <u>Chimera Prime</u> | |
|--------------|----|-----------------------|--------|-----------------------|--------|----------------------|--------|
| | | Repeated | Non-R. | Repeated | Non-R. | Repeated | Non-R. |
| Experiment 1 | M | 0.83 | 0.83 | 0.84 | 0.83 | 0.83 | 0.82 |
| | SD | 0.16 | 0.16 | 0.15 | 0.16 | 0.16 | 0.16 |
| Experiment 2 | M | 0.85 | 0.84 | 0.84 | 0.85 | 0.85 | 0.83 |
| | SD | 0.16 | 0.15 | 0.16 | 0.15 | 0.15 | 0.16 |
| Experiment 3 | M | 0.94 | 0.93 | 0.76 | 0.73 | 0.88 | 0.86 |
| | SD | 0.09 | 0.08 | 0.15 | 0.17 | 0.12 | 0.12 |

Table 2. Pairwise comparisons of ERP measures in Experiment 1.

| ERP measure | Effect | M _{diff} | 95% CI | t(23) | p | Bonferroni | d _{unb} | 95% CI |
|----------------|-------------------------------------|-------------------|-------------|-------|-------|------------|------------------|-------------|
| N170 amplitude | | | | | | | | |
| | positive vs. negative primes | 1.16 μ V | 0.73, 1.59 | 5.53 | <.001 | * | 0.41 | 0.23, 0.61 |
| | positive vs. chimera primes | 1.01 μ V | 0.60, 1.41 | 5.13 | <.001 | * | 0.34 | 0.18, 0.52 |
| | negative vs. chimera primes | 0.15 μ V | -0.15, 0.45 | 1.06 | .302 | | 0.05 | -0.05, 0.15 |
| N170 latency | | | | | | | | |
| | positive vs. negative primes | 10.75 ms | 6.97, 14.53 | 5.89 | <.001 | * | 0.84 | 0.48, 1.24 |
| | positive vs. chimera primes | 9.54 ms | 5.81, 13.72 | 5.29 | <.001 | * | 0.68 | 0.37, 1.03 |
| | negative vs. chimera primes | 1.21 ms | -2.10, 4.52 | 0.76 | .458 | | 0.10 | -0.17, 0.38 |
| N250r | | | | | | | | |
| | repetition effect - positive primes | 1.73 μ V | 0.89, 2.57 | 4.28 | <.001 | * | 0.70 | 0.33, 1.11 |
| | repetition effect - negative primes | 1.03 μ V | 0.38, 1.68 | 3.27 | .003 | * | 0.40 | 0.14, 0.69 |
| | repetition effect - chimera primes | 0.87 μ V | 0.28, 1.46 | 3.08 | .005 | * | 0.36 | 0.11, 0.61 |

Asterisks indicate significant effects after Bonferroni correction (with adjusted alpha = $.05/3 = 0.17$).

Table 3. Pairwise comparisons of ERP measures in Experiment 2.

| ERP measure | Effect | M _{diff} | 95% CI | t(23) | p | Bonferroni | d _{unb} | 95% CI |
|----------------|-------------------------------------|-------------------|--------------|-------|-------|------------|------------------|-------------|
| N170 amplitude | positive vs. negative primes | 1.87 μV | 1.08, 2.65 | 4.90 | <.001 | * | 0.73 | 0.38, 1.11 |
| | positive vs. chimera primes | 1.97 μV | 1.33, 2.62 | 6.30 | <.001 | * | 0.79 | 0.47, 1.16 |
| | negative vs. chimera primes | 0.11 μV | -0.25, 0.47 | 0.62 | .542 | | 0.04 | -0.09, 0.17 |
| N170 latency | positive vs. negative primes | 12.65 ms | 10.30, 14.99 | 11.16 | <.001 | * | 1.20 | 0.82, 1.66 |
| | positive vs. chimera primes | 10.73 ms | 9.48, 11.98 | 17.73 | <.001 | * | 1.03 | 0.73, 1.39 |
| | negative vs. chimera primes | 1.92 ms | -0.15, 3.98 | 1.92 | .067 | | 0.19 | -0.01, 0.39 |
| N250r | repetition effect - positive primes | 1.01 μV | 0.48, 1.53 | 3.98 | <.001 | * | 0.38 | 0.17, 0.62 |
| | repetition effect - negative primes | 0.41 μV | -0.27, 1.08 | 1.25 | .224 | | 0.14 | -0.09, 0.39 |
| | repetition effect - chimera primes | -0.08 μV | -0.61, 0.53 | -0.26 | .796 | | -0.03 | -0.23, 0.18 |
| 300-400 ms | repetition effect - positive primes | 1.27 μV | 0.68, 1.86 | 4.47 | <.001 | * | 0.38 | 0.19, 0.60 |
| | repetition effect - negative primes | 0.63 μV | -0.04, 1.30 | 1.96 | .062 | | 0.20 | -0.01, 0.42 |
| | repetition effect - chimera primes | 0.54 μV | -0.12, 1.19 | 1.70 | .103 | | 0.16 | -0.03, 0.36 |

Asterisks indicate significant effects after Bonferroni correction (with adjusted alpha = .05/3 = 0.17).

Table 4. Pairwise comparisons of ERP measures in Experiment 3.

| ERP measure | Effect | M _{diff} | 95% CI | t(23) | p | Bonferroni | d _{unb} | 95% CI |
|----------------|-------------------------------------|-------------------|-------------|-------|-------|------------|------------------|-------------|
| N170 amplitude | positive vs. negative primes | 0.79 μV | 0.16, 1.43 | 2.58 | .017 | | 0.26 | 0.05, 0.49 |
| | positive vs. chimera primes | 1.01 μV | 0.42, 1.61 | 3.51 | .002 | * | 0.32 | 0.12, 0.55 |
| | negative vs. chimera primes | 0.22 μV | -0.32, 0.76 | 0.85 | .402 | | 0.07 | -0.09, 0.24 |
| N170 latency | positive vs. negative primes | 9.58 ms | 6.14, 13.03 | 5.76 | <.001 | * | 0.87 | 0.49, 1.30 |
| | positive vs. chimera primes | 7.35 ms | 5.34, 9.37 | 7.54 | <.001 | * | 0.69 | 0.44, 0.99 |
| | negative vs. chimera primes | 2.23 ms | -0.61, 5.07 | 1.62 | .118 | | 0.20 | -0.05, 0.47 |
| N250r | repetition effect - positive primes | 0.73 μV | 0.20, 1.26 | 2.87 | .009 | * | 0.20 | 0.05, 0.36 |
| | repetition effect - negative primes | 0.08 μV | -0.55, 0.71 | 0.25 | .802 | | 0.02 | -0.14, 0.19 |
| | repetition effect - chimera primes | 0.50 μV | -0.01, 1.00 | 2.01 | 0.56 | | 0.13 | -0.01, 0.27 |
| 300-400 ms | repetition effect - positive primes | 0.93 μV | 0.34, 1.53 | 3.25 | .004 | * | 0.35 | 0.12, 0.60 |
| | repetition effect - negative primes | 0.61 μV | 0.05, 1.18 | 2.25 | .034 | | 0.23 | 0.02, 0.46 |
| | repetition effect - chimera primes | 0.87 μV | 0.43, 1.30 | 4.10 | <.001 | * | 0.29 | 0.13, 0.47 |

Asterisks indicate significant effects after Bonferroni correction (with adjusted alpha = .05/3 = 0.17).

Figure legends

Figure 1. Examples of contrast positive, contrast negative and contrast chimera faces. Images are published with explicit permission of the depicted persons.

Figure 2. ERP results for prime faces in Experiment 1. a) Grand Average ERPs at left and right-hemispheric occipito-temporal electrodes. b) Mean and individual N170 amplitudes at P9/P10/TP9/TP10. Error bars reflect 95% CIs. c) Mean and individual participants' N170 latency at TP9/TP10. Error bars reflect 95% CIs.

Figure 3. Effects of repetition priming in Experiment 1. a) Illustration of priming conditions and sample stimuli. Please note that famous faces were used in the experiment. Images are published with explicit permission of the depicted persons. b) Grand Average ERPs to target stimuli at left and right occipito-temporal electrodes P9/P10 and TP9/TP10. Vertical lines show the N250r time window. c) Mean and individual N250r priming effects at electrodes TP9/TP10 and P9/P10. Error bars reflect 95% CIs. Note that CIs are within subjects.

Figure 4. Analysis of prime faces in Experiment 2. a) Grand Average ERPs at left and right-hemispheric occipito-temporal electrodes. b) Mean and individual N170 amplitudes at P9/P10/TP9/TP10. Error bars reflect 95% CIs. c) Mean and individual participants' N170 latency at TP9/TP10. Error bars reflect 95% CIs.

Figure 5. ERP effects of repetition priming in Experiment 2. a) Illustration of the repeated conditions. Please note that famous faces were used in the experiment. Images are published with explicit permission of the depicted persons. b) Grand Average ERPs to target stimuli at left and right occipito-temporal electrodes P9/P10 and TP9/TP10. Vertical lines show the

N250r and the 300 – 400 ms time windows. c) Mean and individual N250r priming effects at electrodes TP9/TP10 and P9/P10. Error bars reflect 95% CIs. d) Mean and individual priming effects in the 300 – 400 ms time window at electrodes TP9/TP10 and P9/P10. Error bars reflect 95% CIs. Note that CIs are within subjects.

Figure 6. ERP analysis of prime faces in Experiment 3. a) Grand Average ERPs at left and right-hemispheric occipito-temporal electrodes. b) Mean and individual participants' N170 amplitudes at P9/P10/TP9/TP10. Error bars reflect 95% CIs. c) Mean and individual participants' N170 latency at TP9/TP10. Error bars reflect 95% CIs.

Figure 7. Effects of repetition priming in Experiment 3. a) Illustration of the repeated conditions. Please note that famous faces were used in the experiment. Images are published with explicit permission of the depicted persons. b) Grand Average ERPs to target stimuli at left and right occipito-temporal electrodes P9/P10 and TP9/TP10. Vertical lines show the N250r and the 300 – 400 ms time windows. c) Mean and individual N250r priming effects at electrodes TP9/TP10 and P9/P10. Error bars reflect 95% CIs. d) Mean and individual priming effects in the 300 – 400 ms time window at electrodes TP9/TP10 and P9/P10. Error bars reflect 95% CIs. Note that all CIs are within subjects.

Figure 1

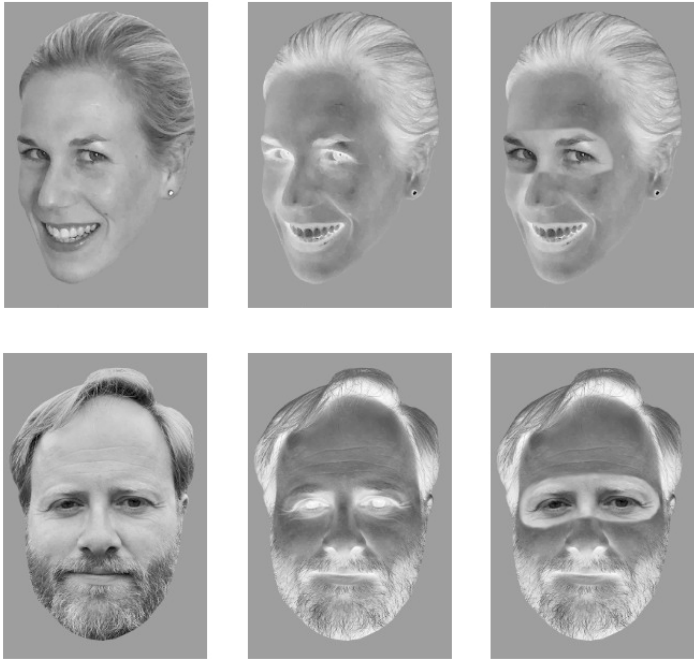


Figure 2

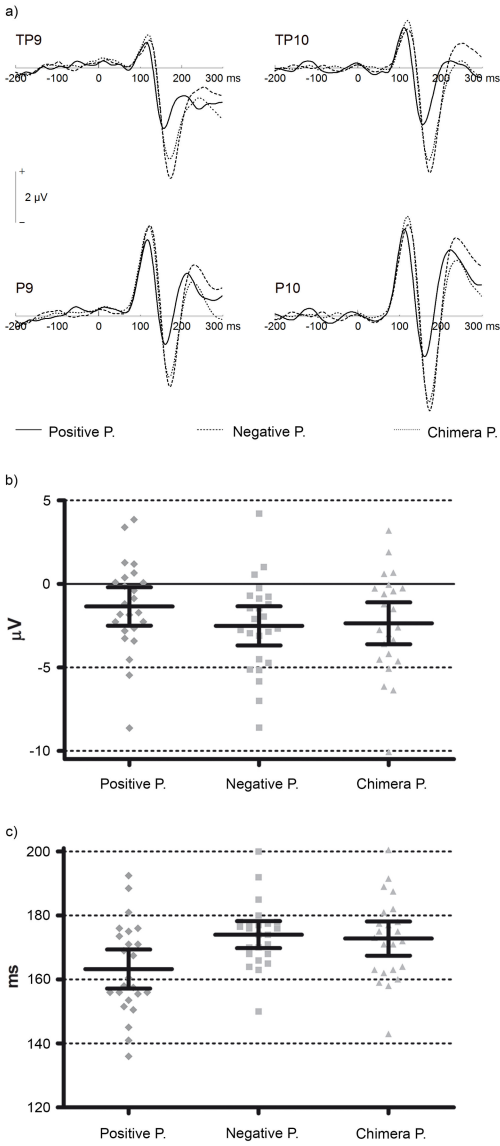


Figure 3

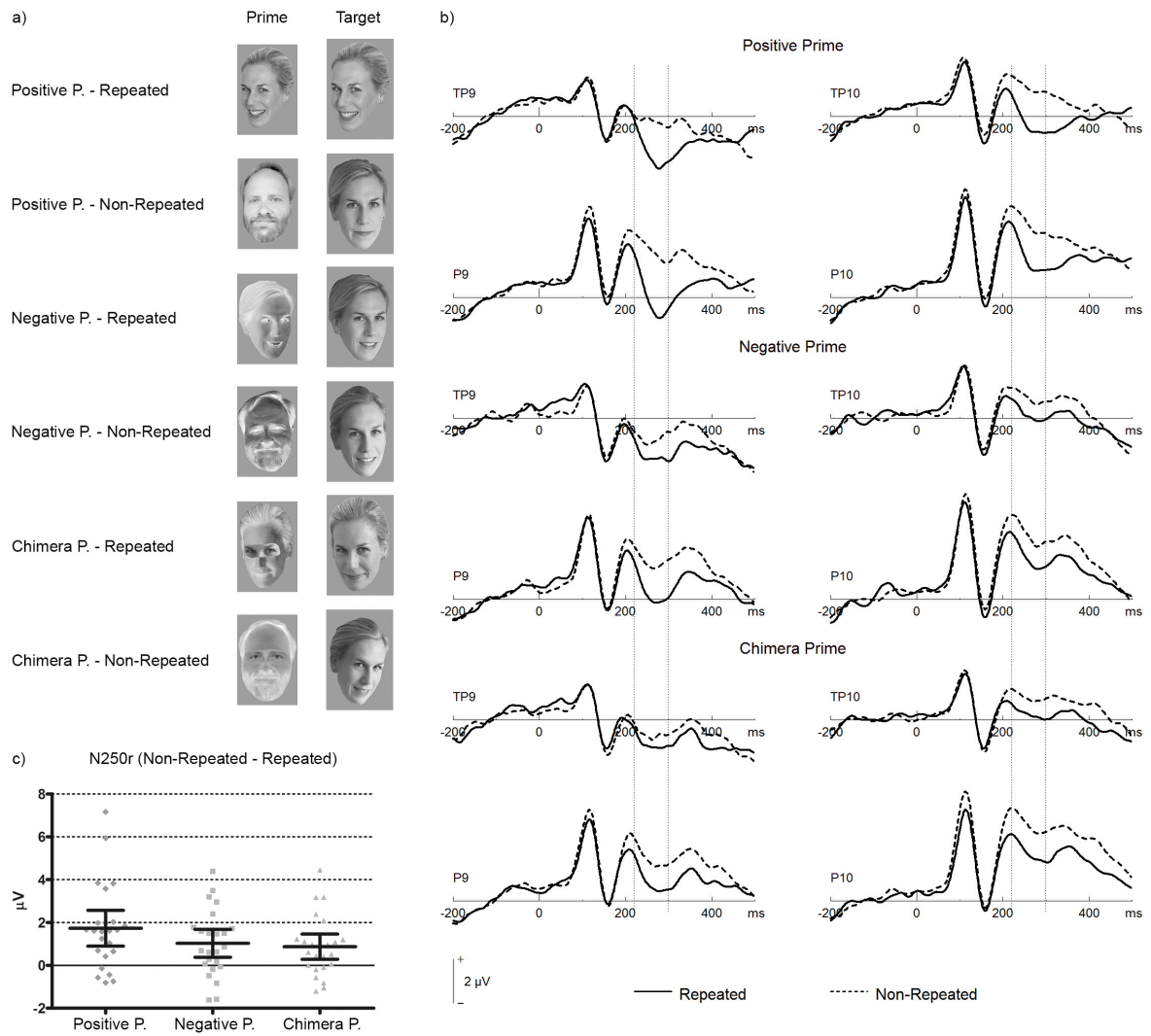


Figure 4

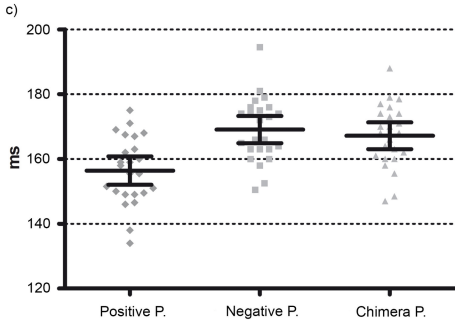
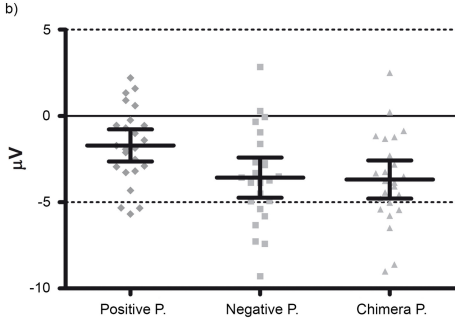
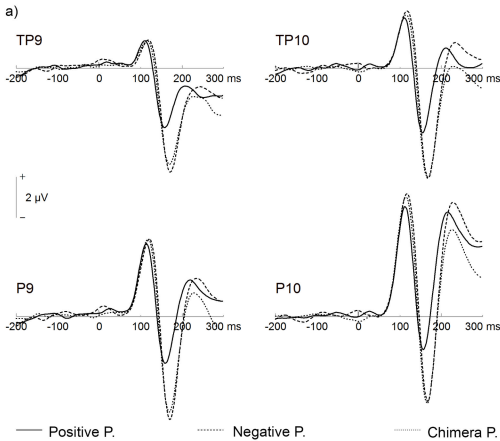


Figure 5

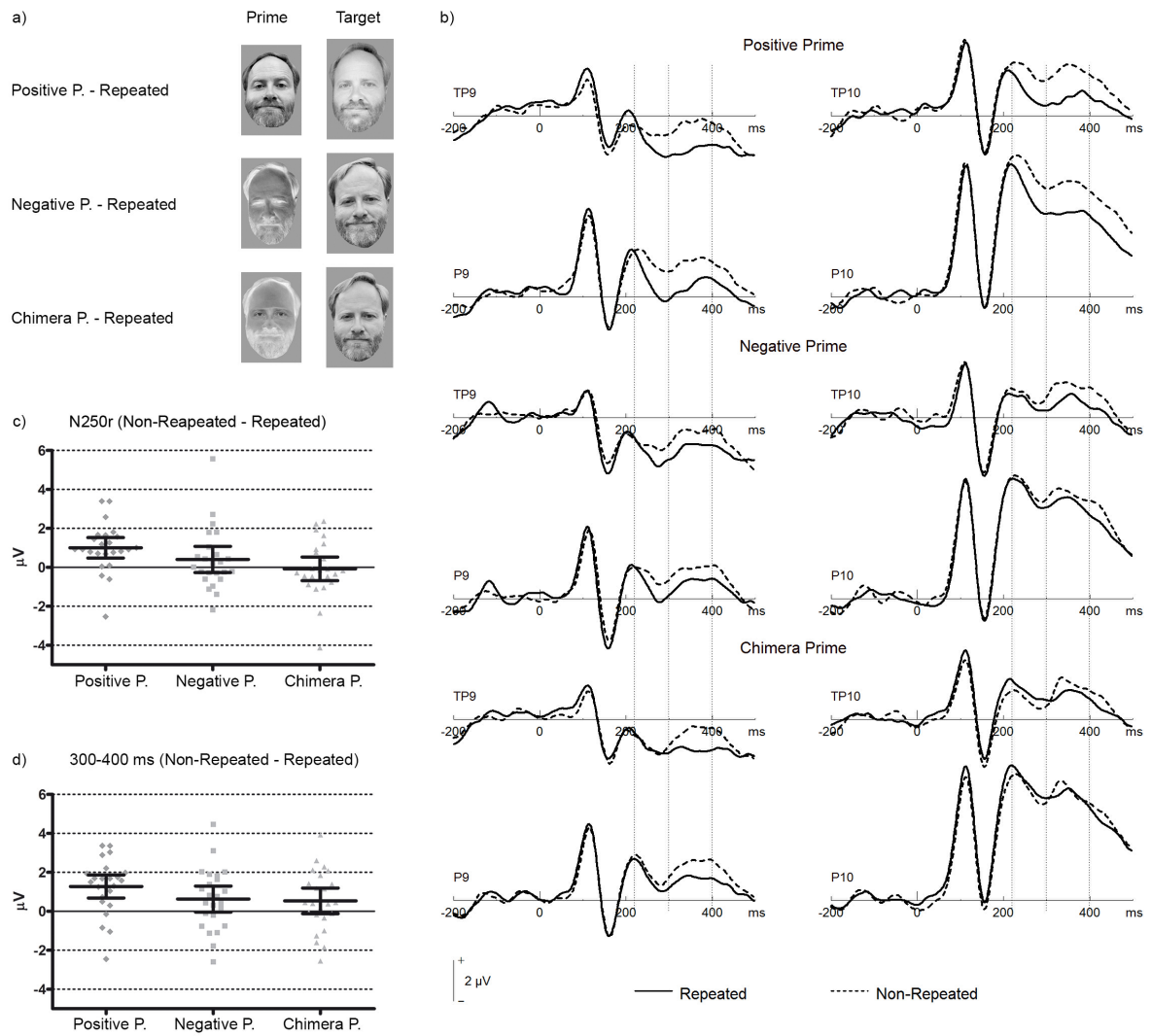


Figure 6

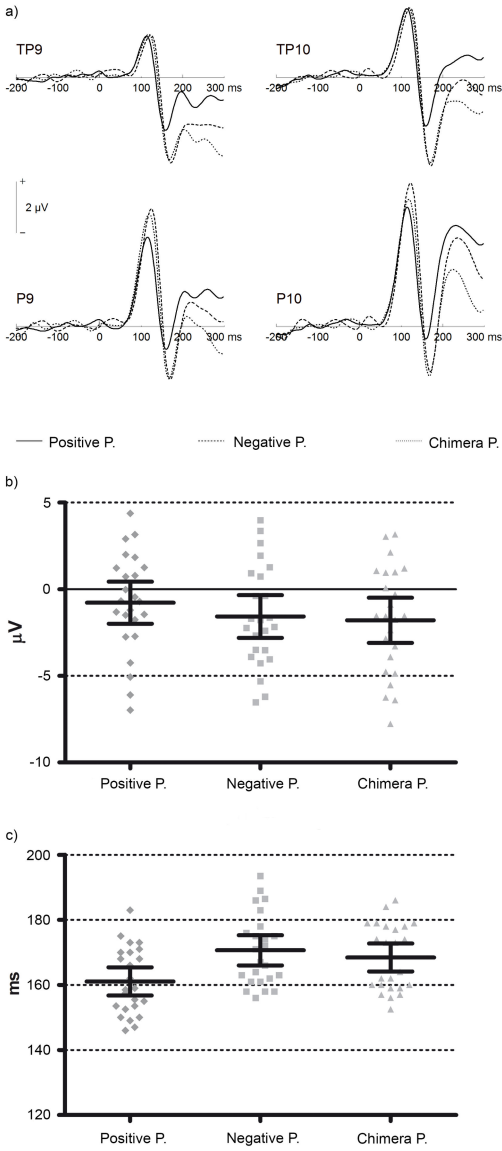


Figure 7

