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Unconscious Processing of Facial Dominance: The Role of Low-Level Factors in Access to Awareness

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Visual stimuli with social-emotional relevance have been claimed to gain preferential access to awareness. For example, recent studies used the breaking continuous flash suppression paradigm (b-CFS) to show that faces that are perceived as less dominant and more trustworthy are prioritized for awareness. Here we asked whether these effects truly reflect differences in social-emotional meaning or whether they can be equally explained by differences in low-level stimulus properties. In Experiment 1, we successfully replicated dominance- and untrustworthiness-related slowing for upright faces. However, these effects were equally strong for inverted faces, even though it was more difficult to perceive social characteristics in inverted faces. The previously reported correlation between dominance- and untrustworthiness-related slowing in b-CFS and self-reported propensity to trust did not replicate. Experiment 2 showed that dominance-related slowing in b-CFS can also be observed when only presenting the eye region of faces, and even when the eye region was presented inverted and/or with reversed contrast polarity, in which case personality traits were no longer discernible. These results were replicated in Experiment 3 following a preregistration protocol. Altogether, our findings link dominance-related slowing in b-CFS to physical differences in the eye region that are—when presented in isolation—unrelated to the perception of dominance. We conclude that low-level physical stimulus differences provide a parsimonious explanation for the effect of social facial characteristics on access to awareness.

Keywords: continuous flash suppression, awareness, dominance, trust, unconscious

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Conscious awareness is limited in capacity: Only a few stimuli are consciously perceived at any given moment in time. Representations of stimuli are therefore thought to compete for access to conscious awareness (Koch, 2004). This competition is influenced both by top-down factors such as attention, expectation, or memory contents as well as by stimulus-related factors such as saliency (Gayet, Van der Stigchel, & Paffen, 2014). Another stimulus attribute that can determine whether a stimulus gains access to awareness is its social or emotional meaning (Axelrod, Bar, & Rees, 2015; Hedger, Gray, Garner, & Adams, 2016). For example, emotional facial expressions, and in particular threatening or fearful expressions, have an advantage in entering visual awareness (Yang, Zald, & Blake, 2007). However, it is currently debated whether such prioritization of stimuli with particular social-emotional relevance reflects their social-emotional meaning or whether these effects can equally be accounted for by physical, low-level differences between stimuli such as differences in luminance or contrast (Adams, Gray, Garner, & Graf, 2011; Hedger et al., 2016). Answering this question is important to determine whether access to visual awareness involves special mechanisms for social-emotional relevance or whether general visual processing mechanisms are sufficient to explain these effects.

Access to visual awareness is often studied with the breaking continuous flash suppression (b-CFS) paradigm (Jiang, Costello, & He, 2007; Stein, Hebart, & Sterzer, 2011). In this paradigm, a target stimulus, such as a photograph of a face, is presented to one

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eye while high-contrast dynamic masks are flashed into the other eye. At the beginning of a trial, the masks render the target stimulus invisible for up to several seconds until the target eventually overcomes suppression and becomes visible. The time it takes a stimulus to break into awareness is often taken as a measure of competitive strength for access to awareness; with shorter suppression times indicating enhanced unconscious processing (Yang, Brascamp, Kang, & Blake, 2014; for a critical discussion see Stein et al., 2011, and Stein & Sterzer, 2014). For example, more familiar or meaningful stimuli, such as upright faces or bodies, are associated with shorter suppression times than less familiar or meaningful stimuli, such as inverted (i.e., rotated by 180 degrees) faces or bodies (Stein, Sterzer, & Peelen, 2012). The interpretation of such inversion effects is straightforward because upright and inverted stimuli are physically identical, that is, they consist of identical pixels.

Interpreting differences in suppression times between stimuli that are physically different is more challenging. For example, fearful faces are associated with shorter suppression times than happy or neutral faces (Yang et al., 2007). This effect has often been taken to indicate that the emotional meaning of facial expressions is registered unconsciously. Because of their particular behavioral relevance, fearful faces then receive enhanced unconscious processing, perhaps involving dedicated (subcortical) threat detection mechanisms (Tamietto & de Gelder, 2010). However, it is unlikely that the advantage of fearful expressions in b-CFS is genuinely related to the unconscious registration of their emotional meaning. Several lines of evidence indicate that the effect instead reflects low-level physical stimulus differences that are not directly associated with emotional meaning. Although it is more difficult to perceive emotional expressions in inverted faces, a full-strength fear advantage in b-CFS has been obtained for inverted faces (Stein, Seymour, Hebart, & Sterzer, 2014; Yang et al., 2007). As inverted faces contain all low-level physical differences present in upright faces, this finding supports a low-level account of the fear advantage. For example, fearful faces have larger eye whites, possibly resulting in higher local contrast in the eye regions. Indeed, fearful eyes alone are associated with shorter suppression times than neutral or happy eyes (Yang et al., 2007). Moreover, a fear advantage is obtained even when inverted faces are presented with reversed contrast polarity, although it is very hard or impossible to discriminate the emotional expression of these inverted, reversed-contrast faces (Gray, Adams, Hedger, Newton, & Garner, 2013; Hedger, Adams, & Garner, 2015). This provides additional evidence that differences in contrast distributions could underlie the advantage of fearful faces. Indeed, Hedger and colleagues (2015) recently demonstrated that fearful faces have higher effective contrast than neutral faces, and that this difference can account for faster access to awareness. These findings illustrate the difficulty of interpreting differences in suppression times between stimuli that are physically different. Only careful experimentation revealed the low-level origin of the fear advantage in b-CFS.

Most research on the role of social-emotional meaning in access to awareness has been carried out using emotional facial expressions or other dynamically changeable aspects of faces such as eye gaze or head direction. However, in everyday social situations we also evaluate emotionally neutral faces on the basis of nonchangeable facial features. Oosterhof and Todorov (2008) showed that such trait judgments rely on two independent dimensions, facial dominance and trustworthiness, which are associated with distinct facial features. These authors also developed a computational model to systematically vary certain facial features, resulting in faces that are perceived as more or less dominant and trustworthy (see Figure 1a). These trait-like facial dimensions influence access to awareness: Less dominant faces and more trustworthy faces overcome CFS more quickly than more dominant and less trustworthy faces (Getov, Kanai, Bahrami, & Rees, 2015; Stewart, Ajina, Getov, Bahrami, Todorov, & Rees, 2012; also see Abir, Sklar, Dotsch, Todorov, & Hassin, 2018). Interestingly, these effects have been found to be related to individual differences in personality questionnaires, such as a person's propensity to trust others (Stewart et al., 2012), and to variability in gray matter volume in several brain regions (Getov et al., 2015).

Similar to the original interpretation of the fear advantage in access to awareness, dominance- and untrustworthiness-related slowing in b-CFS have been interpreted as reflecting the unconscious extraction of social-emotional meaning. However, because faces varying along these social dimensions are physically different, it is possible, in principle, that the effect is related to these

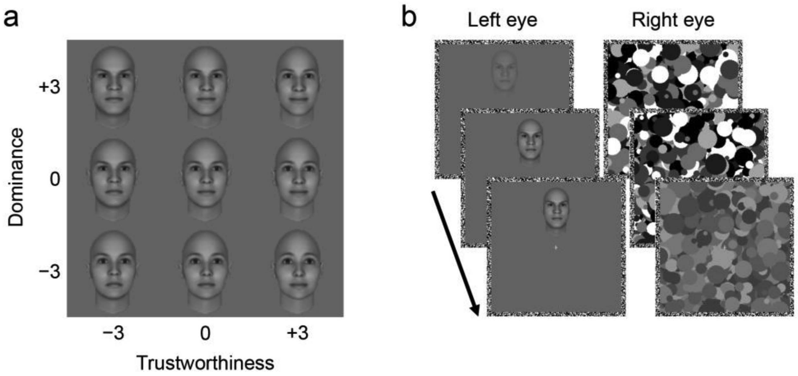

Figure 1. Stimuli and procedure of Experiment 1. (a) Face stimuli varied on the two dimensions of dominance and trustworthiness. (b) Schematic example of a trial from the breaking continuous flash suppression paradigm experiment.

low-level physical differences, even though there are no immediately obvious visual differences between faces varying along dominance and trustworthiness (see Figure 1a). Nevertheless, even subtle physical differences between stimuli can cause differences in suppression times. For example, studies have found that properties such as spatial frequency content, local contrast differences, and even coaligned pixels influence b-CFS (e.g., Rabovsky, Stein, & Abdel Rahman, 2016; Stein & Sterzer, 2012; Yang & Blake, 2012; Yang et al., 2007). Because it is currently unknown how such stimulus differences influence b-CFS, any difference in pixel values could, at least in principle, cause a difference in suppression times.

One way to test whether such low-level stimulus properties can account for dominance- and untrustworthiness-related slowing is to test for differences between the low-level properties of the conditions in the absence of differences in social-emotional meaning. In the present study, we used this approach to test whether the effects of facial dominance and trustworthiness on access to awareness can be accounted for by differences in low-level properties between the stimuli used in these conditions.

Experiment 1: Replication With Inversion Control

In Experiment 1, we tested whether dominance- and untrustworthiness-related slowing of access to awareness in b-CFS was specific to upright faces, or whether these effects would similarly be present for inverted faces. Although it is debated which aspects of face processing are impaired by inversion (e.g., Rossion, 2008; Richler, Mack, Palmeri, & Gauthier, 2011), for the present purpose it is important that face inversion interferes with the perception of social characteristics from faces (Santos & Young, 2008) but leaves low-level differences intact. Thus, if low-level differences account for dominance- and untrustworthiness-related slowing of access to awareness, these effects should be of equal size for upright and inverted faces because inverted faces contain all low-level stimulus properties present in upright faces. By contrast, if differences in access to awareness are driven by social-emotional meaning, these effects should be stronger for upright faces. Similar to Stewart and colleagues (2012), we also measured individual differences in personality traits using a questionnaire, in order to replicate the reported negative correlations between dominance- and untrustworthiness-related slowing and an individual's propensity to trust others. If differences in low-level stimulus properties account for dominance- and untrustworthiness-related slowing, no such correlation would be expected.

Method

Participants. Sixty-five participants (47 female, mean age 23.4 years, *SD* = 4.7) took part in the b-CFS experiment. Twenty-two of these 65 participants also completed two short rating experiments, in which they judged the face stimuli from the b-CFS experiment on dominance and trustworthiness (the rating experiment was only introduced in the later stage of testing). All participants reported normal or corrected-to-normal vision. With the exception of one participant who was also involved in conducting the experiment (as a student's research project) all participants were recruited through the University of Trento subject pool, were naïve as to the purpose of the experiment, and received a monetary compensation for their participation.

Statistical power. We did not determine the sample size of *N* = 65 a priori, but ran as many participants as possible within a period of approximately five weeks to increase chances for replicating the key effects reported by Stewart and colleagues (2012) and by Getov and colleagues (2015), namely dominance-related slowing in b-CFS, untrustworthiness-related slowing in b-CFS, and the negative correlation between self-reported propensity to trust and these two effects. Following these previous studies, dominance-related slowing was calculated in two ways, both as the difference in suppression times between most-dominant faces (+3 *SD* in the face trait dimension model by Oosterhof & Todorov, 2008, see below) and neutral-dominant faces (0 *SD*) and as the difference in suppression times between most-dominant faces (+3 *SD*) and least-dominant faces (−3 *SD*). Based on the effect sizes reported by Getov and colleagues, we had 99% power to detect these two effects. Untrustworthiness-related slowing was calculated as the difference in suppression times between least-trustworthy faces (−3 *SD*) and neutral-trustworthy faces (0 *SD*). Based on the effect size reported by Getov and colleagues, we had 75% power to detect this effect (84% power for the one-tailed test).

Following Stewart and colleagues, for the correlations with self-reported propensity to trust, dominance-related slowing was calculated only as the difference in suppression times between most-dominant upright faces (+3 *SD*) faces and neutral-dominant upright faces. Based on the effect sizes reported by Stewart and colleagues, we had 95% power to detect the correlation between self-reported propensity to trust and dominance-related slowing and also 95% power to detect the correlation between self-reported propensity to trust and untrustworthiness-related slowing.

With the 22 participants in the dominance and trustworthiness rating experiments we had 80% power for detecting medium-to-large effects (Cohen's $d > 0.6$).

Stimuli. Observers viewed a 21-in. Mitsubishi CRT monitor (1024 × 768 pixels resolution, 160 Hz refresh rate) dichoptically through a custom-built mirror stereoscope. Visual stimuli were presented with Matlab (The MathWorks, Natick, MA), using the Psychtoolbox (Brainard, 1997) functions. The observer's head was stabilized by a chin-and-head rest at a viewing distance of approximately 57 cm. The mirrors of the stereoscope were adjusted for each observer to yield stable binocular fusion. The screen was midgray. Throughout the experiment, two fusion contours (10.1° × 10.1°) consisting of random black and white pixels (width 0.3°) were displayed side-by-side on the screen such that one contour was shown to each eye (distance between the centers of the two contours 19.8°). A small white fixation cross was presented in the center of each contour. Participants were asked to maintain fixation throughout the experiment (moving the eyes between trials if necessary).

Target stimuli were the same grayscale face stimuli as those used by Stewart and colleagues (2012) and by Getov and colleagues (2015; kindly provided by Spas Getov). These stimuli are computer-generated faces (using Facegen Modeler, Singular Inversions, Toronto, Ontario, Canada) varying on two parameters corresponding to the facial trait dimensions of trustworthiness and dominance (see Oosterhof & Todorov, 2008, for details). The same face identity displayed three different levels of trustworthiness and dominance (−3 *SD*, neutral = 0 *SD*, and +3 *SD* in the face trait dimension model), yielding a set of nine face targets (2.2° × 3.6°; see Figure 1a). Target images were presented either upright or inverted (i.e., rotated by 180 degrees). To induce CFS, we generated 160 Mondrian-like CFS masks (9.5° × 9.5°) consisting of randomly arranged circles (diameter 0.3–1.5°), using the code provided by Martin Hebart (http://martin-hebart.de/webpages/code/stimuli.html).

Procedure and design.

B-CFS experiment. Figure 1b shows a schematic of an example trial from the b-CFS experiment. Each trial started with a 1-s fixation period in which only the fusion contours and the fixation crosses were presented. CFS masks changing at 10 Hz were then presented to one eye, and an upright or inverted face was gradually introduced to the other eye by decreasing its transparency from 100% to 0% over the first second of a trial. Beginning 1 s after trial onset, the contrast of the CFS masks was decreased linearly to zero over 14 s. The face was presented until response, or for a maximum trial length of 16 s. Face targets were presented in four different positions on the horizontal or vertical meridian of the fusion contours, that is, either above, below, left or right of the fixation cross (distance of the center of the square target image to the fixation cross 2.6°, i.e., eccentricity 0.6°). Participants were asked to press one of the four arrow keys on the keyboard corresponding to the four possible face locations to indicate as fast and accurately as possible in which location a face or any part of a face became visible.

There were 288 trials, in which all combinations of two eyes for target presentation, two face orientations, nine face identities, and four face locations occurred twice. Trial order was randomized. Experimental blocks were separated by two obligatory breaks after 96 and 192 trials, respectively. Before starting the CFS experiment, participants received at least 12 practice trials.

Rating experiment. The general setup was identical to the b-CFS experiment. However, face stimuli were shown for a fixed duration of 0.4 s at full contrast to one randomly selected eye and no CFS masks were presented. Each trial started with a 1-s fixation period, followed by the 0.4-s presentation of a face in one of the four positions (selected at random for each trial). Face presentation was followed by the response screen, requiring participants to judge the face on dominance (in the dominance block) or on trustworthiness (in the trustworthiness block) on an ordinal scale from 1 to 4 (low to high). Participants were instructed to be as accurate as possible and to follow their intuition when unsure. Both the dominance block and the trustworthiness block consisted of 18 trials, in which each of the nine target faces was presented once in upright orientation and once in inverted orientation. The rating experiment was always conducted after the b-CFS experiment, and the trustworthiness block always followed the dominance block.

Propensity to trust questionnaire. After completion of the behavioral experiments, all participants filled out part of the propensity to trust survey (Evans & Revelle, 2008). Questionnaire data from one participant was lost, such that the sample for these correlations was based on 64 participants. Following Stewart and colleagues (2012), we used the seven items loading most heavily on the trust factor: Higher scores represent higher trust into others.

Analyses. b-CFS trials with no responses, incorrect responses, or with responses faster than 300 ms were excluded from the analyses (*M* = 2.1%, *SD* = 4.3). For all statistical analyses of the b-CFS experiment, suppression times were log-transformed to account for the positive skew of the data (Gayet & Stein, 2017; Heyman & Moors, 2014; in the online supplementary material we report dominance-related slowing using latency-normalized response times, as an alternative to the log-transformed response times reported here). For intuitive eyeballing of the results in standard units (seconds), the log-transformed means were transformed back. These backtransformed values are used for descriptive statistics throughout the Results section and for plotting of overall reaction times (RTs; Figure 2). The focus of our analyses was on replicating dominance- and untrustworthiness-related slowing (Getov et al., 2015; Stewart et al., 2012) and to compare these effects between upright and inverted faces. For completeness, we also report the results of a full analysis of variance (ANOVA) with all experimental factors. ANOVA results are re-

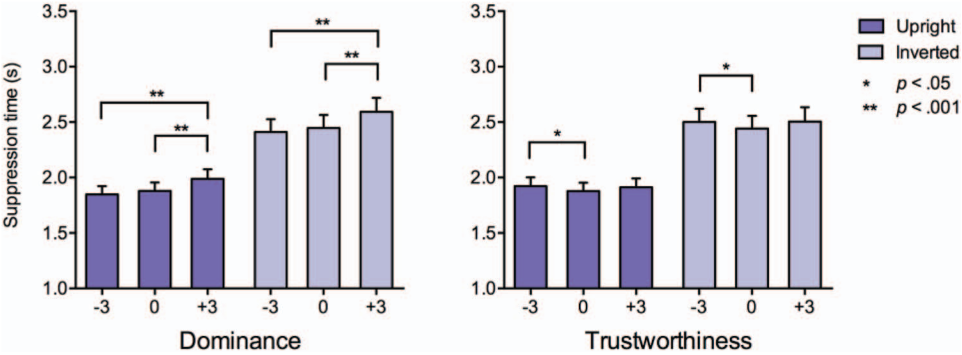

Figure 2. Results from the breaking continuous flash suppression paradigm part of Experiment 1. Bars show average suppression times for faces of varying dominance and trustworthiness, separately for upright and inverted face orientations. For intuitive eyeballing of the differences in standard units (seconds) in these plots, log-transformed suppression times were backtransformed (all statistics are based on the mean log-transformed suppression times). Error bars represent between-subjects standard errors for each condition (for the more relevant variability of differences between conditions, see Figure 3). For both upright and inverted faces, dominance-related slowing (dominance 0 vs. +3 and dominance −3 vs. +3) and untrustworthiness-related slowing (trustworthiness −3 vs. 0) were statistically significant. See the online article for the color version of this figure.

ported as Greenhouse-Geisser corrected if sphericity was violated, reporting adjusted degrees of freedom.

For the dominance and trustworthiness rating experiments, we were similarly interested in comparing the effects of dominance and trustworthiness between upright and inverted faces. For this, we calculated difference scores in a way analogous to the slowing effects for the b-CFS data. That is, the *Dominance Effect I* represents the difference in ratings between most-dominant faces and neutral-dominant faces; the *Dominance Effect II* the difference between most-dominant faces and least-dominant faces, and the "untrustworthiness effect" the difference between least-trustworthy faces and neutral-trustworthy faces. For both rating experiments, we also conducted full ANOVAs with all experimental factors to test for significant interactions with face orientation (for all experiments, results from nonparametric tests of the dominance effects can be found in the online supplementary material).

Results and Discussion

Breaking CFS: Full ANOVA. Means calculated from log-transformed suppression times were first analyzed in a repeated-measures ANOVA with the factors face orientation (upright, inverted), dominance (−3, 0, +3), and trustworthiness (−3, 0, +3). There was a significant main effect of orientation, $F(1, 64) = 254.28$, $p < .001$, $\eta_p^2 = .80$, reflecting shorter suppression times for upright faces (backtransformed RT $M = 1.80$ s) than for inverted faces ($M = 2.30$ s), a significant main effect of dominance, $F(2, 128) = 56.45$, $p < .001$, $\eta_p^2 = .47$, with longer suppression times for most-dominant faces ($M = 2.12$ s) than for least-dominant faces ($M = 1.98$ s, paired t-test $p < .001$) and neutral-dominant faces ($M = 2.01$ s, paired t-test $p < .001$), and a significant main effect of trustworthiness, $F(2, 128) = 4.71$, $p = .011$, $\eta_p^2 = .07$, with shorter suppression times for neutral-trustworthy faces ($M = 2.01$ s) than for least-trustworthy faces ($M = 2.06$ s, paired t-test $p = .003$) and for most-trustworthy faces ($M = 2.04$ s, paired t-test $p = .050$). The interaction between dominance and trustworthiness was also significant, $F(3.53, 225.59) = 3.40$, $p = .013$, $\eta_p^2 = .50$. These results represent successful replications of the effects of facial dominance and trustworthiness on b-CFS reported by Stewart and colleagues (2012) and by Getov and colleagues (2015). Most importantly, however, no interaction with orientation reached significance, all $F < 1$, all $p > .430$, all $\eta_p^2 < .06$. Thus, facial dominance and trustworthiness modulated suppression times for upright and inverted faces to a similar extent (see Figure 2).

Breaking CFS: Dominance- and untrustworthiness-related slowing. To directly quantify the influence of face orientation on the effects of dominance and trustworthiness, we calculated dominance-related slowing and untrustworthiness-related slowing separately for upright and inverted faces (see Figure 3). Dominance-Related Slowing I, calculated as the difference between most-dominant and neutral-dominant faces, was significant for both upright faces (backtransformed RT difference 109 ms difference, $t(64) = 5.56$, $p < .001$, $d = 0.69$), as well as for inverted faces (146 ms difference, $t(64) = 5.81$, $p < .001$, $d = 0.72$). Dominance-Related Slowing II, calculated as the difference between most-dominant and least-dominant faces, was also significant for both upright faces (140 ms difference), $t(64) = 7.23$, $p < .001$, $d = 0.90$, and for inverted faces (182 ms difference), $t(64) = 7.46$, $p < .001$, $d = 0.93$. Finally, also "untrustworthiness-related slowing" (the difference between least-trustworthy and neutral-trustworthy faces) was significant for both upright faces (44 ms difference), $t(64) = 2.39$, $p = .020$, $d = 0.30$, and for inverted faces (59 ms difference), $t(64) = 2.25$, $p = .028$, $d = 0.28$. These results successfully replicate the key effects obtained by Stewart and colleagues (2012) and by Getov and colleagues (2015). However, as can be seen in Figure 3 these effects were virtually identical for upright and inverted faces, all $t < 1$, all $p > .600$. We also carried out exploratory correlation analyses to test whether these effects were related for upright and inverted faces. We did not find such correlations. However, absence of correlations between odd and even trials within the same condition showed that response times were not sufficiently reliable to estimate between-condition correlations across participants in this experiment (see the online supplementary material).

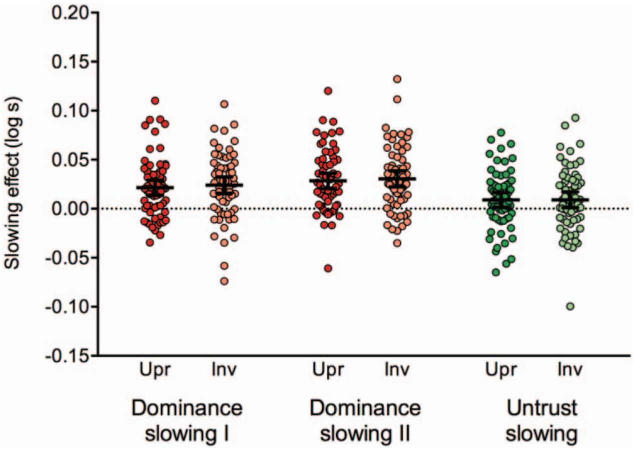

Figure 3. Overview of the key comparisons from the breaking continuous flash suppression paradigm part of Experiment 1, separately for upright and inverted faces. *Dominance-Related Slowing I* was calculated as the difference in mean log-transformed suppression times between most-dominant faces and neutral-dominant faces. *Dominance-Related Slowing II* refers to the difference between most-dominant faces and least-dominant faces. *Untrustworthiness-related slowing* refers to the difference between least-trustworthy faces and neutral-trustworthy faces. Every circle represents a participant; horizontal black lines represent the group means; vertical error bars represent 95% confidence intervals. All effects were significantly different from zero, and the effects did not differ significantly between upright and inverted faces. See the online article for the color version of this figure.

Dominance rating: Full ANOVA. Having established that facial dominance and trustworthiness influence awareness of both upright and inverted faces, we next tested whether inversion indeed impaired perception of dominance (this section) and trustworthiness (Trustworthiness Ratings section, below) of our stimuli. If inversion interfered with the perception of social-emotional meaning, ratings of inverted faces should be less strongly influenced by stimulus manipulations along these dimensions than ratings of upright faces. Dominance ratings were first analyzed in a repeated-measures ANOVA with the factors face orientation (upright, inverted), dominance (−3, 0, +3), and trustworthiness (−3, 0, +3). There were significant main effects of dominance and trustworthiness, both $F(2, 42) > 47.14$, both $p < .001$, both $\eta_p^2 >$

.69, and a significant interaction between dominance and trustworthiness, $F(2.93, 61.58) = 3.86$, $p = .014$, $\eta_p^2 = .16$. More importantly, both the interaction between orientation and dominance and the interaction between orientation and trustworthiness were significant, $F(2, 42) = 3.98$, $p = .026$, $\eta_p^2 = .16$, and, $F(2, 42) = 23.25$, $p < .001$, $\eta_p^2 = .53$, respectively. Different levels of facial dominance and trustworthiness had a stronger effect on dominance ratings for upright faces than for inverted faces.

Dominance ratings: Dominance- and untrustworthiness-related effects. This difference between upright and inverted faces can be seen in Figure 4 (left panel). The Dominance Effect I, representing the difference in ratings between most-dominant faces and neutral-dominant faces, was statistically significant for both upright faces, $t(21) = 5.29$, $p < .001$, $d = 1.12$, and inverted faces, $t(21) = 3.95$, $p = .001$, $d = 0.84$. Although this effect was numerically larger for upright faces ($M = 0.67$, $SD = 0.59$) than for inverted faces ($M = 0.45$, $SD = 0.54$), the difference between upright and inverted faces was not statistically significant, $t(21) = 1.14$, $p = .260$, $d = 0.24$. The Dominance Effect II, the difference between most-dominant faces and least-dominant faces, was significant for both upright faces, $t(21) = 6.41$, $p < .001$, $d = 1.37$, and inverted faces, $t(21) = 5.70$, $p < .001$, $d = 1.22$. The untrustworthiness effect, the difference in dominance rating between least-trustworthy faces and neutral-trustworthy faces, was significant only for upright faces, $t(21) = 7.40$, $p < .001$, $d = 1.47$, but not for inverted faces, $t < 1$, $d = 0.09$. Importantly, both the Dominance Effect II and the untrustworthiness effect were significantly larger for upright than for inverted faces, $t(21) = 2.85$, $p = .009$, $d = 0.61$, and $t(21) = 5.27$, $p < .001$, $d = 1.12$, respectively. Together, these results show that perception of facial dominance was more strongly influenced by stimulus manipulations along the dominance and trustworthiness dimensions when the faces were presented upright than when they were inverted. This demonstrates that inversion indeed interfered with dominance perception.

Trustworthiness ratings: Full ANOVA. Next, we repeated these analyses for perception of trustworthiness, first analyzing trustworthiness ratings in a repeated-measures ANOVA with the factors face orientation (upright, inverted), dominance (−3, 0, +3), and trustworthiness (−3, 0, +3). The main effect of trustworthiness was significant, $F(1.40, 29.38) = 12.02$, $p = .001$, $\eta_p^2 = .36$. There was also a significant main effect of orientation, $F(1, 21) = 7.22$, $p = .014$, $\eta_p^2 = .26$, with higher trustworthiness ratings for upright faces ($M = 2.71$, $SD = 0.39$) than for inverted faces ($M = 2.39$, $SD = 0.60$), and a significant interaction between dominance and trustworthiness, $F(4, 84) = 2.89$, $p = .027$, $\eta_p^2 = .12$. More importantly, the interaction between orientation and trustworthiness was significant, $F(2, 42) = 4.44$, $p = .018$, $\eta_p^2 = .17$. Thus, similar to the dominance ratings different levels of facial trustworthiness had a stronger effect on trustworthiness ratings for upright faces than for inverted faces.

Trustworthiness ratings: Dominance- and untrustworthiness-related effects. Indeed, the untrustworthiness effect, that is, the difference between least-trustworthy faces and neutral-trustworthy faces, was significant for upright faces, $t(21) = 3.27$, $p = .004$, $d = 0.70$, but not for inverted faces, $t(21) = 1.42$, $p = .172$, $d = 0.30$, and was significantly larger for upright than for inverted faces, $t(21) = 2.09$, $p = .049$, $d = 0.45$ (see Figure 4, right panel).

Correlations between b-CFS effects and propensity to trust. Finally, we tested for correlations between dominance- and untrustworthiness-related slowing for upright faces and participant's self-reported propensity to trust. The correlation between propensity to trust and dominance-related slowing (the difference in log-transformed suppression times between most-dominant upright faces and neutral-dominant upright faces, the Dominance Effect I), was not significant, $r(63) = -.052$, $p = .680$ (see Figure 5, left panel). Similarly, there was no significant correlation between propensity to trust and untrustworthiness-related slowing for upright faces $r(63) = -.166$ $p = .186$ (see Figure 5, right panel). Thus, although we had 95% power to detect these correlations and sufficient variability in both the questionnaire measure and the b-CFS measures, we failed to replicate the findings by Stewart and colleagues (2012). It should be noted that the correlation with untrustworthiness-related slowing was still within the confidence

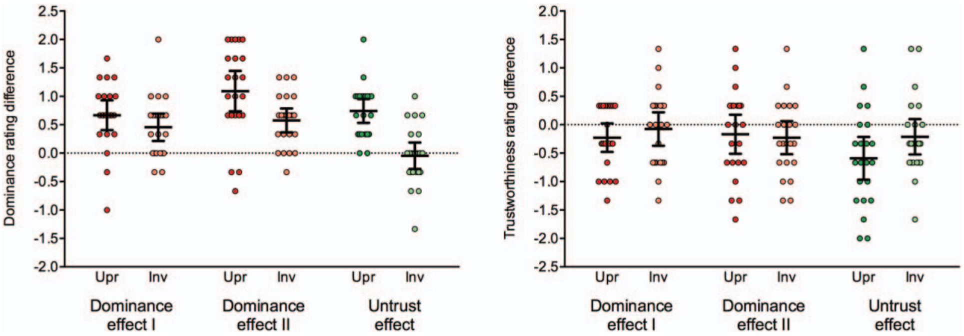

Figure 4. Overview of the key comparisons from the dominance and trustworthiness ratings of Experiment 1, separately for upright and inverted faces. The Dominance Effect I was calculated as the difference in ratings between most-dominant faces and neutral-dominant faces. The Dominance Effect II is the difference between most-dominant faces and least-dominant faces. The untrustworthiness effect is the difference between least-trustworthy faces and neutral-trustworthy faces. Every circle represents a participant; horizontal black lines represent the group means; vertical error bars represent 95% confidence intervals. In the dominance rating experiment (left plot), the Dominance Effect II and the untrustworthiness effect were significantly larger for upright than for inverted faces. In the trustworthiness rating experiment (right plot), the untrustworthiness effect was significantly larger for upright than for inverted faces. See the online article for the color version of this figure.

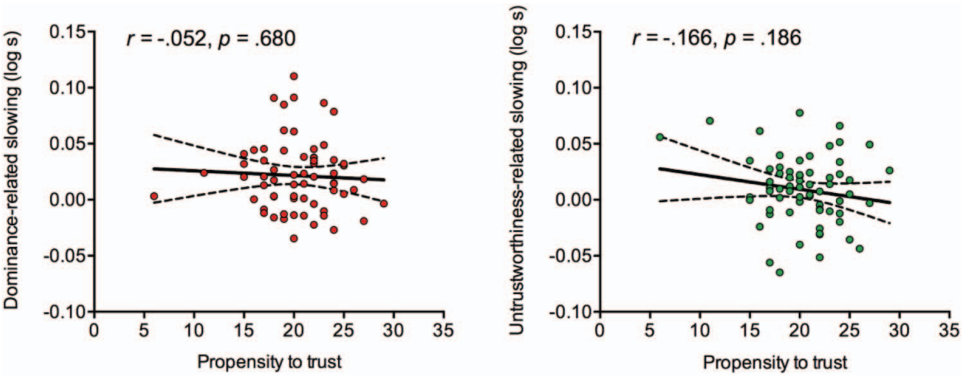

Figure 5. The relationship between self-reported propensity to trust and dominance- and untrustworthiness-related slowing in the breaking continuous flash suppression paradigm. Every circle represents a participant; black solid lines represent the best-fitting linear regression line and the dashed line the associated 95% confidence intervals. See the online article for the color version of this figure.

interval of the correlation reported by Stewart and colleagues. It can therefore be debated whether this should indeed count as a genuine failure to replicate (Patil, Peng, & Leek, 2016). The correlation with dominance-related slowing, however, fell outside the confidence interval of that previous study. The absence of a negative correlation between dominance- and untrustworthiness-related slowing and the participant's propensity to trust others is consistent with low-level stimulus differences: driving dominance- and untrustworthiness-related slowing. In summary, Experiment 1 showed that face inversion does not affect dominance and trustworthiness effects in b-CFS, while at the same time inversion does reduce perceived dominance and trustworthiness differences between faces. Furthermore, there was no evidence that propensity to trust was related to the b-CFS effects.

Experiment 2: Exploring the Relevant Low-Level Factor

What low-level stimulus property might underlie these differences in breakthrough from CFS? For the sake of simplicity, in Experiment 2 we focused on the strong effect of facial dominance on b-CFS calculated as the difference between most-dominant and least-dominant faces, because this contrast yielded the largest effect size in Experiment 1 (for the effect of trustworthiness, see the online supplementary material). One difference between most- and least-dominant faces lies in the eye region: As can be seen in Figure 1a least-dominant faces have overall larger eyes, including larger irises and larger eye whites than most-dominant faces. This gives the impression of higher local contrast between the dark irises and the light eye whites in the eye regions of least-dominant faces. Such differences in local contrast may account for the effect of social dominance on b-CFS. For example, the advantage of fearful over neutral or happy faces in b-CFS appears to be related to local contrast differences in the eye regions (Yang et al., 2007).

Thus, in Experiment 2 we explored whether dominance-related slowing can be accounted for by lower local contrast in the eye regions of most-dominant than least-dominant faces. This hypothesis makes several predictions. First, dominance-related slowing should be found when presenting the eye regions alone, without a face. Second, this effect should be independent of a participant's ability to perceive the stimuli as more or less dominant and should therefore also be present for inverted eye regions (see Figure 6). Third, if local contrast differences in the eye regions account for dominance-related slowing, a similar effect should be obtained for eye regions with reversed contrast polarity (see Figure 6). We tested these predictions in Experiment 2a (eye regions only, inverted eye regions) and in Experiment 2b (inverted eye regions, inverted eye regions with reversed contrast polarity).

Method

Participants. Several of the participants in Experiment 2 had taken part in Experiment 1 before (because of a limited subject pool). In Experiment 2a, there were 16 participants (12 female, mean age 22.7 years, *SD* = 4.6), including the first author of the paper. All other participants were recruited through the University of Trento subject pool, were naïve as to the purpose of the experiment, and received a monetary compensation for their participation. Eight of these 16 participants had taken part in Experiment 1 before. In Experiment 2b, there were 16 participants (13 female, mean age 22.0 years, *SD* = 2.8), eight of whom had taken part in Experiment 2a before (on a separate day). Seven of these 16

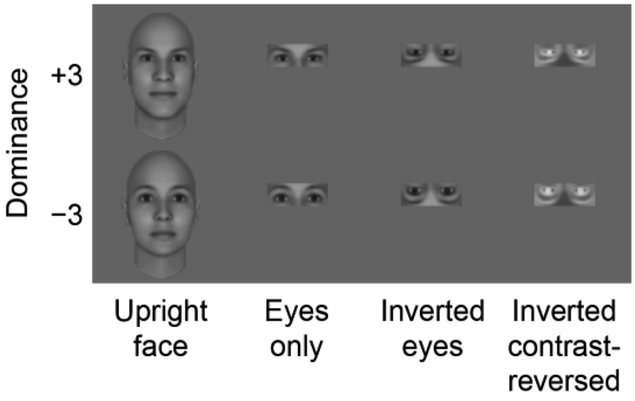

Figure 6. Example stimuli from Experiment 2A and 2B. In these experiments, only most- and least-dominant faces were included.

participants had taken part in Experiment 2a before. Five participants took part in all three Experiments 1, 2a, and 2b. All participants in Experiment 2b were recruited through the University of Trento subject pool, were naïve as to the purpose of the experiment, and received a monetary compensation for their participation.

Statistical power. Experiment 2 was an exploratory study. Nevertheless, because Dominance-Related Slowing II for upright faces was expected to be a large effect (effect size in Experiment 1 $d = 0.90$) we had 85% power for detecting this effect with the 16 participants who participated in Experiment 2a and 2b.

Stimuli. The general experimental setup was identical to Experiment 1. However, because the focus was on the comparison of most- versus least-dominant faces we only used six face targets with three levels of trustworthiness (-3 *SD*, neutral $= 0$ *SD*, and $+3$ *SD* in the face trait dimension model) and two levels of dominance (-3 *SD* and $+3$ *SD*). The goal was to average across the three levels of trustworthiness to compare the two levels of dominance that were of interest in Experiment 2. We did not consider the trustworthiness dimension.

Because the target stimuli used in Experiment 1 (those used by Stewart & colleagues, 2012 and by Getov & colleagues, 2015) had small differences in mean pixel intensity, standard deviation of pixel intensities, and overall face size, for Experiment 2 we equated these factors across the six face exemplars. This did not result in any noticeable difference from the original stimuli (compare Figure 1a and Figure 6) but was necessary to exclude the possibility that b-CFS differences were caused by these factors rather than differences in local contrast in the eye regions.

To test whether the eye regions alone yielded dominance-related slowing in b-CFS, we masked the face stimuli such that only a rectangular area including the eyes and eyebrows was presented (see Figure 6). This rectangular area had the same size for all six faces. For the inverted eye region condition this rectangular area was rotated by 180 degrees, and for the inverted contrast-reversed eye region condition pixel values in this area were inverted.

Procedure and Design.

B-CFS experiment. The trial structure was identical to Experiment 1. In both Experiment 2a and 2b there were 288 trials, in which all combinations of two eyes for target presentation, three stimulus conditions (Experiment 2a: upright face, eyes only, inverted eyes; Experiment 2b: upright face, inverted eyes, inverted contrast-reversed eyes), six face identities, and four face locations occurred twice. Trial order was randomized. Experimental blocks were separated by two obligatory breaks after 96 and 192 trials, respectively. Before starting the CFS experiment, participants received at least 12 practice trials.

Rating experiment. All participants completed a dominance rating similar to Experiment 1, now judging the stimuli from Experiment 2 on dominance. Because the focus of Experiment 2 was on dominance-related effects we did not include a trustworthiness rating. The rating was always conducted after the b-CFS experiment. We did not include the propensity to trust questionnaire.

Analyses. B-CFS trials with no responses, incorrect responses, or with responses faster than 300 ms were excluded from the analyses (Experiment 2a: $M = 4.9\%$, $SD = 6.1$; Experiment 2b: $M = 4.9\%$, $SD = 6.6$). Again, for all statistical analyses of the b-CFS experiments, suppression times were log-transformed but for intuitive eyeballing of the results in standard units (seconds), the log-transformed means were transformed back (Figure 7). Both for the b-CFS experiments and for the dominance rating experiment, we were interested in the difference between most- and least-dominant faces (analogous to Experiment 1's "dominance-related slowing II" and "dominance effect II").

Results and Discussion

Breaking CFS. For Experiment 2a, a repeated-measures ANOVA with the factors stimulus condition (upright faces, eyes only, inverted eyes) and dominance (-3, $+3$) on the means of the log-transformed suppression times yielded a significant main effect of condition, $F(2, 30) = 50.09$, $p < .001$, $\eta_p^2 = .77$, with overall shortest suppression times for upright faces and slowest for inverted eyes (see Figure 7, left panel), and a significant main effect of dominance, $F(1, 15) = 19.96$, $p < .001$, $\eta_p^2 = .57$, reflecting dominance-related slowing, and a significant interaction, $F(2, 30) = 4.29$, $p = .023$, $\eta_p^2 = .22$. As in Experiment 1, dominance-related slowing was significant for upright faces (74 ms difference), $t(15) = 2.67$, $p = .017$, $d = 0.67$. Dominance-related slowing was also significant and numerically even larger for eyes only (292 ms difference), $t(15) = 3.89$, $p = .001$, $d = 0.97$, and for inverted eyes (447 ms difference), $t(15) = 3.57$, $p = .003$, $d = 0.89$ (see Figure 8, left panel). These results show that a whole intact face is not required for dominance-related slowing. The eye region alone—upright or inverted—is sufficient for the effect.

Also for Experiment 2b, a repeated-measures ANOVA with the factors stimulus condition (upright faces, inverted eyes, inverted contrast-reversed eyes) and dominance (-3, $+3$) yielded a significant main effect of condition, $F(1.13, 16.91) = 32.09$, $p < .001$, $\eta_p^2 = .68$, with overall shortest suppression times for upright faces and longest for inverted contrast-reversed eyes (see Figure 7, right panel), a significant main effect of dominance, $F(1, 15) = 18.07$, $p = .001$, $\eta_p^2 = .55$, and a significant interaction, $F(1.51, 22.71) = 3.89$, $p = .046$, $\eta_p^2 = .21$. In this experiment, dominance-related slowing was not significant for upright faces (22 ms difference, $t < 1$, $d = 0.19$), but there were significant dominance-related slowing effects for inverted eyes (434 ms difference), $t(15) = 3.42$, $p = .004$, $d = 0.85$, and for inverted contrast-reversed eyes (310 ms difference), $t(15) = 2.67$, $p = .018$, $d = 0.67$ (see Figure 8, left panel). Although it seems hard or impossible to distinguish least- and most-dominant stimuli when only the inverted eye region is shown in reversed contrast (see Figure 6 and results from the dominance rating experiment in the next section), these stimuli were sufficient for dominance-related slowing in b-CFS. This provides evidence that local contrast differences in the eye regions, which are preserved in contrast-reversed inverted eye regions, may indeed be the low-level stimulus factor underlying dominance-related slowing.

In both experiments, suppression times for eye-only stimuli were longer than for whole faces, most likely reflecting the difference in stimulus size. Although it would be desirable to have matched suppression times, we decided to use the original face stimuli to create these eye-only versions to avoid introducing unknown confounds by additional stimulus manipulations (e.g., changing the size, contrast, or luminance). To address the concern that effects might have increased with longer overall suppression times (e.g., Gayet & Stein, 2017), we

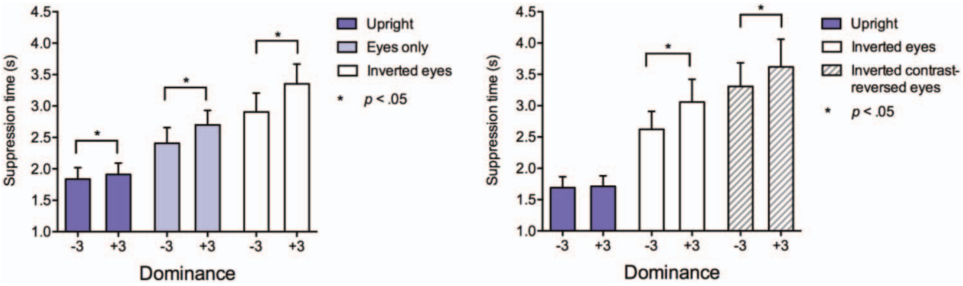

Figure 7. Results from the breaking continuous flash suppression paradigm parts of Experiment 2a (left panel) and Experiment 2b (right panel). Bars show average suppression times for least- and most-dominant stimuli, separately for the different stimulus conditions. For intuitive eyeballing of the differences in standard units (seconds) in these plots, log-transformed suppression times were backtransformed (all statistics are based on the mean log-transformed suppression times). Error bars represent between-subjects standard errors for each condition (for the more relevant variability of differences between conditions, see Figure 8). See the online article for the color version of this figure.

also calculated latency-normalized dominance effects for all b-CFS experiments (Supplemental Table S4 in the online supplementary material). Latency-normalization reduced both between-subjects variability and between-condition variability in overall RTs. The results from this analysis were very similar, revealing significant dominance-related slowing for eye-only stimuli with effect sizes that were similar or even larger than for upright faces.

Dominance ratings. It is still possible, however, that participants did perceive differences in dominance in the stimuli that contained eye regions only, even when inverted or contrast-reversed. In that case, dominance-related slowing for these stimuli could still reflect differences in social-emotional meaning rather than low-level differences. To decide between these possibilities, we tested whether dominance ratings of eye-region stimuli were less strongly influenced by differences in dominance than ratings of upright faces.

For Experiment 2a, a repeated-measures ANOVA with the factors stimulus condition (upright faces, eyes only, inverted eyes) and dominance (-3, $+3$) on the mean dominance ratings yielded only a significant main effect of dominance, $F(1, 15) = 18.70$, $p = .001$, $\eta_p^2 = .56$. As can be seen from Figure 8 (right panel), dominance ratings were significantly higher for most-dominant faces than for least-dominant faces, $t(15) = 2.70$, $p = .016$, $d = 0.68$. Interestingly, this rating difference was also significant for eyes only, $t(15) = 3.89$, $p = .001$, $d = 0.97$, meaning that the eye regions alone were perceived as more or less dominant. For inverted eyes, however, there was no significant rating difference, $t(15) = 1.37$, $p = .190$, $d = 0.34$, indicating that participants failed to extract differences in dominance for these stimuli. Still, in the absence of a significant interaction, these results are inconclusive since the effect for inverted eyes was not significantly smaller than the effect for upright faces.

For Experiment 2b, a repeated-measures ANOVA with the factors stimulus condition (upright faces, inverted eyes, inverted contrast-reversed eyes) and dominance (-3, $+3$) on the mean dominance ratings yielded a significant main effect of dominance, $F(1, 15) = 5.28$, $p = .036$, $\eta_p^2 = .26$, and, crucially, a significant interaction, $F(2, 30) = 4.22$, $p = .024$, $\eta_p^2 = .22$. As can be seen

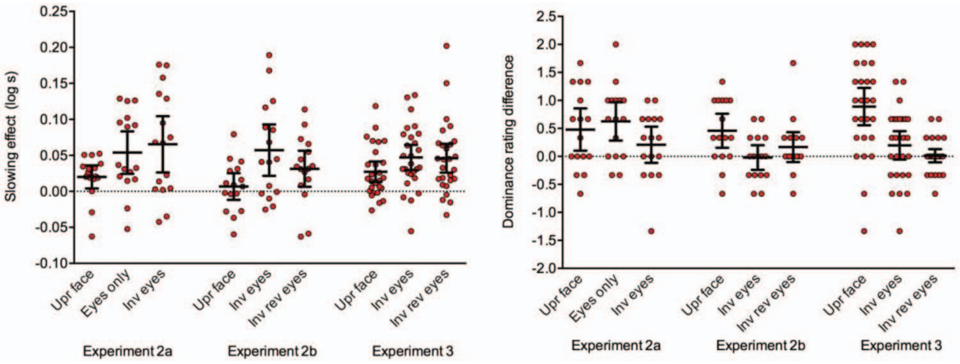

Figure 8. Overview of the dominance effects from the breaking continuous flash suppression paradigm parts (left panel) and dominance ratings (right panel) of Experiments 2a, 2b, and 3, separately for the different stimulus conditions. The b-CFS dominance slowing effect was calculated as the difference in mean log-transformed suppression times between most-dominant faces and least-dominant stimuli. Similarly, the dominance rating difference refers to the difference in mean dominance ratings between most-dominant faces and least-dominant stimuli. Every circle represents a participant; horizontal black lines represent the group means; vertical error bars represent 95% confidence intervals. See the online article for the color version of this figure.

from Figure 8 (right panel), dominance ratings were significantly higher for most-dominant upright faces than for least-dominant upright faces, $t(15) = 3.22$, $p = .006$, $d = 0.81$. There were no significant rating differences for inverted eyes ($t < 1$, $d = 0.05$) and contrast-reversed inverted eyes, $t(15) = 1.33$, $p = .204$, $d = 0.33$. These results indicate that participants were unable to perceive differences in dominance for inverted eyes and for contrast-reversed inverted eyes.

Together, the results from the dominance ratings show that for inverted contrast-reversed eye regions participants were unable to perceive differences in dominance. At the same time, these stimuli yielded large dominance-related slowing effects in b-CFS. This is consistent with the notion that a low-level factor that is fully preserved in contrast-reversed eye regions (such as local contrast differences) rather than (or in addition to) social-emotional meaning accounts for differences in access to awareness.

Experiment 3: Preregistered Replication

Experiment 3 was a preregistered replication of Experiment 2b (the preregistration protocol can be found under https://osf.io/avd9z/). The experiment was intended to be an exact replication, with some differences regarding the apparatus (computer, screen) and laboratory environment (the experiment was conducted at Donders Institute in Nijmegen, Netherlands, rather than at University of Trento, Italy).

Method

Participants. Twenty-seven participants (20 female, mean age 22.1 years, $SD = 4.4$) with normal or corrected-to-normal vision were recruited from the Donders Institute subject pool to take part in Experiment 3. They were naïve to the purpose of the experiment and received course credits or a small monetary compensation for their participation.

Statistical power. The sample size of 27 participants was based on a power analysis for testing dominance-related slowing in b-CFS for inverted, contrast-reversed eye regions, which is the crucial test for demonstrating that a low-level factor in the eye regions accounts for differences in access to awareness. A sample size of $N = 27$ yields 80% power to detect a medium effect size (Cohen's d of 0.5) at an alpha level of 0.05 (one-tailed).

Stimuli. Participants viewed a 24-in. BenQXL2420Z monitor (1,920 × 1,080 pixels resolution, 120 Hz refresh rate) dichoptically through a custom-built mirror stereoscope. The same stimuli were used as in Experiment 2b, and stimulus sizes were matched in degrees of visual angle.

Procedure and design. Both the b-CFS experiment and the dominance rating experiment were identical to Experiment 2b.

Analyses. All participants performed with higher accuracy than the exclusion criterion of 75% correct that we had specified in the preregistration protocol. As in previous experiments, b-CFS trials with no responses, incorrect responses, or with responses faster than 300 ms were excluded from the analyses ($M = 4.4\%$, $SD = 6.3$). Again, for all statistical analyses of the b-CFS experiments, suppression times were log-transformed but for intuitive eyeballing of the results in standard units (seconds), the log-transformed means were transformed back.

Results and Discussion

Breaking CFS: Confirmatory analyses following the preregistration protocol. To test for dominance-related slowing, mean suppression times were analyzed in a repeated-measures ANOVA with the factors dominance and stimulus condition (upright face, inverted eyes, contrast-reversed eyes). As expected, this analysis yielded a significant main effect of dominance, $F(1, 26) = 43.73$, $p < .001$, $\eta_p^2 = .63$, showing that least-dominant stimuli were associated with shorter suppression times than most-dominant stimuli (see Figure 9). Moreover, as hypothesized dominance-related slowing was also significant for stimuli consisting of inverted, contrast-reversed eye regions alone (367 ms difference), $t(26) = 4.72$, $p < .001$, one-tailed, $d = 0.91$ (see Figure 8, left panel). These results replicate Experiment 2b, showing that even when inverted and contrast-reversed the eye regions can cause dominance-related slowing of access to awareness.

Dominance ratings: Confirmatory analyses following the preregistration protocol. Consistent with our hypotheses, most-dominant intact, upright faces received significantly higher dominance ratings than least-dominant intact, upright faces, $t(26) = 5.48$, $p < .001$, one-tailed, $d = 1.06$, while there was no significant rating difference for stimuli consisting of inverted, contrast-reversed eye regions, $t(26) = 0.21$, $p = .416$, one-tailed, $d = 0.04$ (see Figure 8, right panel). Thus, although these eye regions affected suppression times in b-CFS, participants seemed unable to perceive differences in dominance in those stimuli.

Breaking CFS: Additional analyses. The repeated-measures ANOVA with the factors dominance and stimulus condition on mean suppression times did not yield a significant interaction between dominance and stimulus condition, $F(2, 52) = 2.39$, $p = .102$, $\eta_p^2 = .08$: Dominance-related slowing was significant also for intact upright faces (126 ms difference), $t(26) = 3.98$, $p < .001$, $d = 0.77$, and for stimuli consisting of only inverted eye regions with normal contrast polarity (271 ms difference), $t(26) = 5.56$, $p < .001$, $d = 1.07$.

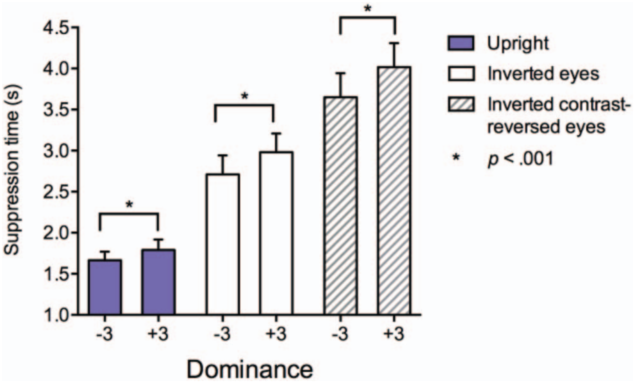

Figure 9. Results from the breaking continuous flash suppression paradigm part of Experiment 3. Bars show average suppression times for least- and most-dominant stimuli, separately for the different stimulus conditions. For intuitive eyeballing of the differences in standard units (seconds) in these plots, log-transformed suppression times were backtransformed (all statistics are based on the mean log-transformed suppression times). Error bars represent between-subjects standard errors for each condition (for the more relevant variability of differences between conditions, see Figure 8). See the online article for the color version of this figure.

Dominance ratings: Additional analyses. A repeated-measures ANOVA with the factors dominance and stimulus condition revealed a significant interaction between dominance and stimulus condition, $F(2, 52) = 12.79$, $p < .001$, $\eta_p^2 = .33$, indicating that the rating difference between least- and most-dominant stimuli was larger for intact faces than for the stimuli consisting only of eye regions. Indeed, also for inverted eye regions there was no significant rating difference, $t(26) = 1.60$, $p = .122$, $d = 0.31$ (see Figure 8, right panel).

General Discussion

The present study tested whether the previously reported influence of social factors on access to awareness for faces (Getov et al., 2015; Stewart et al., 2012) can be accounted for by low-level stimulus differences. In Experiment 1 we first replicated the effects of facial dominance and trustworthiness on suppression times in the b-CFS paradigm. Similar to previous studies (Getov et al., 2015; Stewart et al., 2012) more dominant and less trustworthy faces took longer to overcome suppression and break into awareness. Although these previous studies tested awareness only for normal upright faces, we also included inverted faces as a control for potential low-level differences. Interestingly, similar effects of dominance-related slowing and untrustworthiness-related slowing were obtained for inverted faces. Furthermore, we failed to replicate the previously reported correlation between participants' self-reported propensity to trust and these b-CFS effects (Stewart et al., 2012). In Experiment 2, we then tested whether local contrast differences in the eye regions may account for dominance-related slowing. Indeed, we found that the eye regions alone, even when presented inverted and with reversed contrast polarity, yielded the effect in b-CFS. Experiment 3 replicated these effects for stimuli consisting of inverted, reversed-contrast eye regions alone. Together, our findings indicate that differences in low-level physical properties provide a parsimonious explanation for these social-emotional influences on awareness of faces under CFS.

This conclusion is based on the observation that several stimulus manipulations (face inversion, eye inversion, contrast-reversal) reduced the perception of social characteristics from faces, while they did not reduce the size of the effects obtained with b-CFS. This raises the possibility that the b-CFS effects may not be directly related to social-emotional meaning but rather to some physical aspect of the face stimuli. Results from Experiments 2 and 3 provide evidence that local contrast differences in and around the eye regions may be the key physical stimulus difference. Such local contrast differences are fully preserved even when the eye regions are extracted from the face, presented in inverted orientation and at reversed contrast polarity. Although such stimuli were not perceived as more or less dominant anymore, they nevertheless evoked full-blown dominance-related slowing in b-CFS. Future studies should use a larger set of face exemplars with different dominance ratings (e.g., see Abir et al., 2018) rather than just the most- and least-dominant faces to allow correlating suppression times for different face exemplars between conditions. This could help decide whether similar or different mechanisms mediate dominance-related slowing in different stimulus conditions. For example, a recent study used a large stimulus set to show that the stimulus dimension that best predicted the breaking CFS times of upright faces was similar but not identical to the dimension that best predicted breaking CFS times of inverted faces (Abir et al., 2018).

Our approach was inspired by recent work on the influence of emotional facial expressions on access to awareness. Here, the advantage of fearful faces in overcoming b-CFS was found to be unchanged when faces were inverted and contrast-reversed, although these manipulations reduced or eliminated the perception of fear (Gray et al., 2013; Hedger et al., 2015). Similar to the present logic, this has been taken to indicate that low-level physical differences rather than differences in emotional meaning account for the fear advantage in access to awareness. It should be noted that this approach does not provide unequivocal evidence that the same processes mediate dominance-related slowing for normal, upright faces and for inverted faces or stimuli consisting of eye regions only. It is still possible that awareness of the original, upright faces involves higher-level mechanisms related to the stimuli's social-emotional meaning while awareness of inverted faces and eye-only stimuli is driven by lower-level mechanisms related to physical stimulus properties. Also, given some preserved dominance judgment abilities, it is possible that the effects for inverted faces and upright eye-only stimuli were at least partly related to their social-emotional meaning. However, it appears more parsimonious to account for all these effects by considering low-level stimulus differences that were equally present in all comparisons.

Although the effects of facial dominance and fearful expression appear to be well explained by physical stimulus factors, we do not claim that high-level stimulus properties can never influence suppression times (e.g., Gayet, Paffen, Belopolsky, Theeuwes, & Van der Stigchel, 2016; Schmack, Burk, Haynes, & Sterzer, 2016). We would also like to point out that effects of facial dominance and emotional expression may differ for other visual paradigms, such as visual search (Frischen, Eastwood, & Smilek, 2008; but see, e.g., Calvo & Marrero, 2009). It is possible that b-CFS is particularly sensitive to low-level stimulus properties (Stein & Sterzer, 2012; Stein et al., 2012), and that other paradigms are better suited for detecting effects that genuinely reflect the stimuli's social-emotional meaning.

One promising avenue for future research is to exclude differences in low-level stimulus properties by associating neutral stimuli with social-emotional meaning through learning procedures. For example, Gayet and colleagues (2016) found shorter suppression times after a grating had been paired with electric shocks. However, such effects may be limited to learning protocols that have direct consequences for participants and that do not require semantic processing. Studies that associated faces with affective knowledge failed to obtain effects on b-CFS (Rabovsky et al., 2016; Stein, Grubb, Bertrand, Suh, & Verosky, 2017). This is consistent with other recent studies finding little evidence that higher-level semantic meaning can influence access to awareness under CFS (e.g., Heyman & Moors, 2014; Moors, Boelens, van Overwalle, & Wagemans, 2016; Moors, Hesselmann, Wagemans, & van Ee, 2017). Future studies are necessary to map out the exact level of processing at which social-emotional meaning can impact conscious perception.

In summary, we provided evidence that differences in low-level stimulus properties provide a simple explanation for facial dominance effects on access to awareness for full faces, as these faces include the low-level differences that alone give rise to the full-strength effect. Although this does not rule out an additional influence of perceived dominance on access to awareness, perception of social-emotional factors is not required to explain extant data. More generally, our findings show that even subtle low-level differences can confound the comparison of physically different stimuli when measuring access to awareness in b-CFS. Future studies need to exclude the influence of such differences when studying the influence of social-emotional relevance on access to awareness.

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