Not Just Another Face in The Crowd: Detecting Emotional Schematic Faces During Continuous Flash Suppression

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To test whether threatening visual information receives prioritized processing, many studies have examined visual search for emotional schematic faces. Still, it has remained unclear whether negative or positive schematic faces are processed more efficiently. We used continuous flash suppression, a variant of binocular rivalry, to render single emotional schematic faces invisible and measured whether negative or positive faces have an advantage in accessing awareness. Across three experiments, positive faces were detected more quickly than negative faces. A fourth experiment indicated that this positive face advantage was unrelated to the valence of the face stimuli but due to the relative orientation of the mouth curvature and the face contour. These findings demonstrate the impact of configural stimulus properties on perceptual suppression during binocular rivalry and point to a perceptual confound present in emotional schematic faces that might account for some ambiguous results obtained with schematic face stimuli in previous studies.

Keywords: emotional schematic faces, awareness, binocular rivalry, continuous flash suppression

As the rapid detection of threatening stimuli is essential for survival, many theories on sensory processing of emotional stimuli converge on the notion that negatively charged information can be processed in a largely automatic and nonconscious manner, captures attention and receives prioritized processing (Öhman & Mineka, 2001; Pessoa, Kastner, & Ungerleider, 2002; Phelps & LeDoux, 2005; Tamietto & de Gelder, 2010; Vuilleumier, 2005). Support for a processing advantage of negatively charged stimuli is often derived from experiments measuring visual search performance for emotional facial expressions. Searching for an angry face embedded in a crowd of happy faces is faster than searching for a happy face embedded in a crowd of angry faces (Hansen & Hansen, 1988). This detection advantage for angry target faces, dubbed the "anger superiority" or "face-in-the-crowd" effect, was originally found with photographs depicting angry and happy faces. However, after confounding low-level differences between photographs had been spotted (Purcell, Stewart, & Skov, 1996), a wealth of subsequent visual search studies replaced emotional face photographs by well-controlled schematic line-drawings of faces (for reviews see Frischen, Eastwood, & Smilek, 2008; Horstmann, 2007).

Is there an advantage for "threatening" information when low-level stimulus confounds are eliminated and facial expressions are depicted in such a greatly impoverished, schematic manner? Replicating the original face-in-the-crowd effect, studies investigating visual search for emotional schematic faces have consistently revealed that a negative target face is found more quickly in a crowd of positive distractor faces than a positive target face in a crowd of negative distractor faces (Eastwood, Smilek, & Merikle, 2001; Fox et al., 2000; Horstmann, 2007; Horstmann, Scharlau, & Ansorge, 2006; Öhman, Lundqvist, & Esteves, 2001). However, it remains debated which factors contribute to this relative search asymmetry. In agreement with the notion of a threat advantage, some studies concluded that the relative search asymmetry is caused by faster detection of negative target faces (Eastwood et al., 2001; Lipp, Price, & Tellegen, 2009a; Öhman et al., 2001; Schubö, Gendolla, Meinecke, & Abele, 2006).

However, not all findings are consistent with this interpretation. Notably, responses in target-absent trials have often been found to be faster for positive than for negative crowds (Fox et al., 2000; Horstmann, 2007; Horstmann et al., 2006; White, 1995; see also Hampton, Purcell, Bersine, Hansen, & Hansen, 1989; Hansen & Hansen, 1988). This suggests that positive distractor faces are processed more efficiently, thereby questioning the idea that the face-in-the-crowd effect can be attributed exclusively to faster detection of negative target faces. Horstmann et al. (2006) directly tested the possibility that the apparent advantage for negative target faces might actually reflect faster processing of positive faces. In their study, search performance did not differ between negative and positive target faces when they were embedded in neutral crowds. Moreover, a neutral target face was detected more quickly among positive than among negative distractors, indicating that positive faces are more quickly classified as distractors (see also Hahn, Carlson, Singer, & Grolund, 2006). Indeed, faster processing of positive compared to negative faces dovetails with

growing evidence obtained with other stimuli and tasks (Calvo & Nummenmaa, 2008; Juth, Lundqvist, Karlsson, & Öhman, 2005; Leppänen & Hietanen, 2004; Leppänen, Tenhunen, & Hietanen, 2003).

In sum, despite extensive research using schematic faces, it still remains unclear whether negative or positive faces receive privileged processing. The difficulties in interpreting results from visual search studies mainly arise from the fact that visual search performance is not only modulated by properties of the target stimulus, but is governed to a large degree by the interplay between both target and distractor properties (Duncan & Humphreys, 1989). For example, search for a negative face (downward curved mouth line) compared to a positive face (upward curved mouth line) is faster among a crowd of neutral faces with straight mouth lines (Eastwood et al., 2001), but not among a crowd of neutral faces with superimposed downward and upward curved mouth lines (Horstmann et al., 2006). The interpretation of such heterogeneous results is further complicated by the lack of an appropriate measure for target-distractor similarity. Thus, in a first step to readdress the issue of enhanced processing of negative or positive stimuli, we sought to eliminate potential influences from the interaction between target and distractor properties. To that end, we isolated negative and positive target faces from the crowd of distractor faces and measured detection performance for single negative and positive target faces under conditions of binocular rivalry suppression.

Binocular rivalry refers to the alternations in perception that occur when two dissimilar images are presented to corresponding locations of the two eyes. The relative predominance of the rivaling stimuli can serve as a measure of their competitive strength in dominating conscious awareness (Blake & Logothetis, 2002; Leopold & Logothetis, 1999; Silver & Logothetis, 2004). Using this measure, photographs of emotional faces have been found to predominate when paired with photographs of neutral faces (Alpers & Gerdes, 2007; Amting, Greening, & Mitchell, 2010; Bannerman, Milders, de Gelder, & Sahraie, 2008). However, differences in relative predominance during binocular rivalry can result either from a strengthening of the stimulus representation after achieving dominance or from shorter durations of perceptual suppression. As we were not interested in higher-level mechanisms that stabilize a conscious percept but sought to investigate early detection processes that gate access to awareness, here we adopted

a psychophysical technique recently introduced by Jiang et al. (2007) that allowed us to specifically track the duration of perceptual suppression for negative and positive schematic faces.

This method makes use of continuous flash suppression (CFS, Tsuchiya & Koch, 2005), an offshoot of binocular rivalry in which dynamic, high-contrast Mondrian-like masks flashed to one eye suppress a static stimulus presented to the other eye from awareness (see Figure 1). The duration of such interocular suppression can be regarded as a marker of a stimulus' competitive strength for access to awareness, reflecting competition even at unconscious processing stages (Jiang et al., 2007). Recent studies have demonstrated the sensitivity of this measure of perceptual suppression to differences between stimuli in gaining access to awareness. For example, shorter suppression durations have been found for photographs of fearful compared to neutral and happy faces (Sterzer, Hilgenfeldt, Freudenberg, Bermpohl, & Adli, 2011; Tsuchiya, Moradi, Felsen, Yamazaki, & Adolphs, 2009; Yang, Zald, & Blake, 2007). However, similar to the low-level stimulus differences that complicate the interpretation of visual search studies using photographic stimuli (Purcell et al., 1996) and that eventually sparked the use to schematic faces, the advantage of fearful faces in overcoming interocular suppression is at least partly attributable to low-level differences between fearful and neutral faces, such as local contrast differences around the eye and mouth regions (Yang et al., 2007).

Here we probed whether the timing of access to awareness during CFS differs between negative and positive schematic faces that were constructed from the same basic features, thus eliminating potential low-level differences. In Experiments 1 and 2, we measured suppression durations for different negative and positive schematic faces. On the account that the visual system is preferentially tuned to negatively charged information, we would expect shorter suppression durations for negative faces. By contrast, if positive faces are processed more efficiently, we would predict faster access to awareness for positive schematic faces. In Experiments 3 and 4, we then narrowed down potential mechanisms modulating access to awareness for emotional schematic faces. The results from the present study will have important implications for the interpretation of experiments using emotional schematic faces and will shed further light on factors governing the dynamics of conscious perception during binocular rivalry.

Figure 1. Schematics of example trials in the (a) CFS condition and in the (b) control condition. In the CFS condition, high-contrast, multicolored Mondrian-like masks (see, e.g., Sterzer et al., 2008) were flashed at 10 Hz to one eye, while a face stimulus was faded in to the other eye. In the control condition, the masks and the face stimulus were presented binocularly. The example face stimulus shown here is taken from Experiment 1.

Experiment 1

In Experiment 1, we compared perceptual suppression durations for neutral, negative and positive schematic faces similar to those employed in the widely cited visual search study by Öhman et al. (2001).

Method

Participants. In all experiments, participants (age range 19–34 years) were naïve to the purpose of the study, had normal or corrected-to-normal visual acuity, and received monetary compensation. In Experiment 1, there were 16 observers (nine female).

Apparatus and stimuli. Participants viewed the stimuli on a 17-in CRT screen through a custom-built mirror stereoscope. A white frame (6.0° × 6.0°) was displayed to each eye, with the remainder of the screen being gray. Participants were asked to fixate a white cross (0.6° × 0.6°) centered within the white frames throughout each experimental block. Stable binocular fusion was ensured before starting the experiment.

Neutral, negative ("threatening") and positive ("friendly") schematic faces (1.7° × 2.3°; see Figure 2a) were modeled after the study by Öhman et al. (2001, Experiments 1–4). As in the original study, negative and positive faces consisted of the exact same features (i.e., eyebrows, eyes, mouth) only differing in their ver-

tical orientation, while neutral faces were constructed on the basis of slightly different features (straight eyebrows, symmetrical eyes, straight mouth line).

Procedure. Each trial started with a 2-s fixation period, followed by the stimulus sequence. To induce CFS, high-contrast colored Mondrian-like masks (6.0° × 6.0°; Sterzer, Haynes, & Rees, 2008; Sterzer et al., 2011; Sterzer, Jalkanen, & Rees, 2009) refreshed at 10 Hz were presented within the white frame displayed to one eye. Concurrently, a face was gradually introduced to one quadrant of the frame displayed to the other eye (eccentricity 1.2°). Against the midgray background (50% black) the contrast of the face was ramped up over a period of two seconds from trial onset by decreasing the luminance of the facial features from 50% to 95% black while increasing the luminance of the face's "skin" (i.e., the area within the oval-like face shape) from 50% to 40% black, and then remained constant until the end of the trial (see Figure 1). Participants were required to press one of four keys corresponding to the four quadrants to indicate as fast and accurately as possible where the face appeared (cf. Sterzer et al., 2011; Yang et al., 2007). They were instructed to respond as soon as any part of the face became visible. Trials terminated upon response or after 15 s in case participants did not press a key.

To probe whether potential effects were specific to detection under conditions of interocular suppression, we also included a
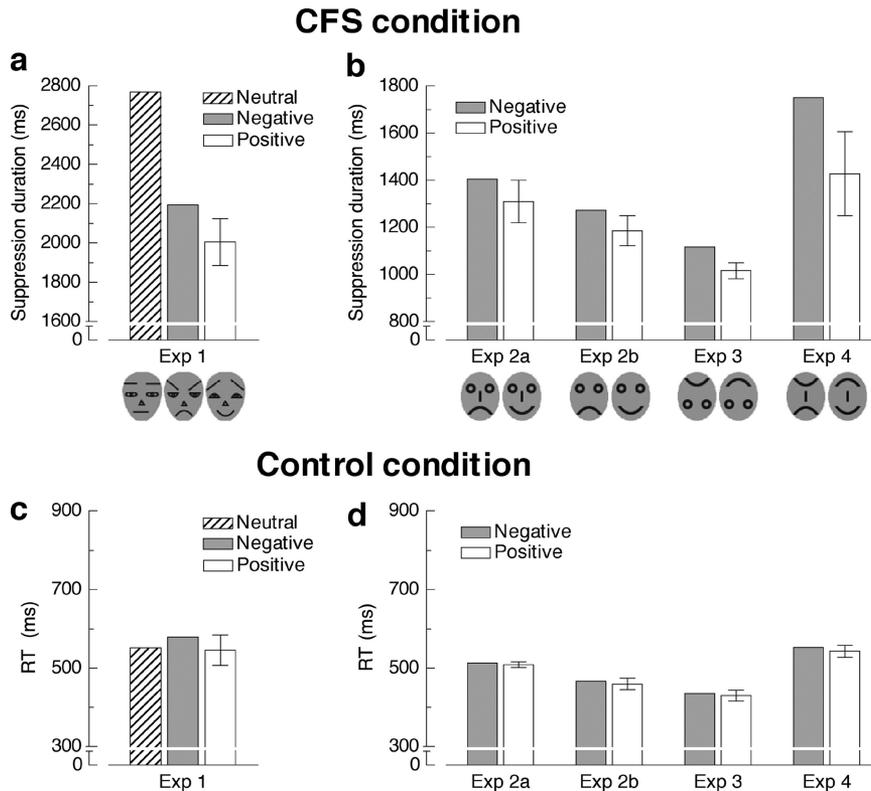
Figure 2. Results from all experiments. Mean suppression durations from the CFS conditions of (a) Experiment 1 and (b) Experiments 2–4. Mean response times from the control conditions of (c) Experiment 1 and (d) Experiments 2–4. Please note the different y-scales. Because different observers participated in the experiments, overall suppression times are not directly comparable. Error bars represent the 95% confidence interval for the respective paired comparison between negative and positive faces.

control condition in which we used the same CFS masks and faces as in the CFS condition, but presented them binocularly. Faces were displayed at a randomly selected time point between two and six seconds after trials onset at full contrast on top of the masks (cf. Sterzer et al., 2011).

There were eight blocks consisting of 20 trials each, 15 CFS and five control trials in random order. For each trial, the eye for stimulus presentation (dummy coded for the control condition), the face's emotion and the quadrant in which the face was presented were selected at random.

Analysis. We computed mean response times (RTs) for trials with correct responses only and excluded trials in which the face remained invisible for longer than 10 s (cf. Jiang et al., 2007). Mean RTs were submitted to a repeated measures ANOVA with the factors emotion (neutral, negative, positive) and condition (CFS, control). We were specifically interested in the emotion-by-condition interaction which would indicate an effect of emotion specific to the CFS condition.

Results and Discussion

Trials with erroneous or exceedingly long responses were rare ($M = 5.1\%$, $SD = 6.8\%$). The analysis of mean RTs revealed a significant interaction between emotion and condition, $F(2, 30) = 42.26$, $p < .001$. While there was no significant influence of emotion on RTs in the control condition, $F(2, 30) = 1.09$, $p = .349$ (see Figure 2c), suppression durations in the CFS condition differed significantly between emotions, $F(2, 30) = 45.35$, $p < .001$. As can be seen from Figure 2a, suppression durations for neutral faces were significantly longer than for both negative and positive faces, smallest $t(15) = 6.20$, both $p < .001$, and, more importantly, positive faces overcame suppression significantly more quickly than negative faces, $t(15) = -3.37$, $p = .004$.

Shorter suppression durations for both negative and positive relative to neutral faces are consistent with longer predominance of emotional compared to neutral schematic faces during conventional binocular rivalry, reported by Alpers and Gerdes (2007). However, in agreement with most visual search studies (e.g., Eastwood et al., 2001; Öhman et al., 2001), both in the present Experiment 1 and in the study by Alpers and Gerdes neutral faces consisted of slightly different features than negative and positive faces. As the dynamics of binocular rivalry are extremely sensitive even to subtle low-level stimulus differences (e.g., Blake, 1977; Fox & Rasche, 1969; Levelt, 1965), it is difficult to draw firm conclusions from prolonged suppression durations for neutral faces. In the following experiments we therefore dropped the neutral condition and included negative and positive faces only.

The adoption of schematic instead of naturalistic face stimuli owes its particular elegance to the direct comparison of negative and positive faces, as they are constructed from the same basic features but nevertheless convey opposite emotional meanings. While Alpers and Gerdes (2007) obtained no difference in predominance between negative and positive faces, here we revealed a significant modulation of perceptual suppression by facial emotion. On average, positive faces gained access to awareness roughly 200 ms earlier than negative faces. Clearly, this substantial shortening of suppression durations for positive faces runs counter to the view that negative faces receive prioritized processing.

Therefore, we next set out to replicate this effect using a different set of stimuli.

Experiment 2

Experiment 2 was designed to test whether the advantage of positive faces applies not only to the specific stimuli used in Experiment 1 but also to even more simplistic schematic faces which have also found wide application in the visual search literature.

Method

Participants. A new group of 21 observers (15 female) participated in Experiment 2. Eleven participants were assigned to Experiment 2a, and 10 to Experiment 2b.

Stimuli. Except for the face exemplars, Experiment 2 was the same as Experiment 1. In Experiment 2a, we included negative ("sad" or "angry") and positive ("happy") faces modeled after the study by Fox et al. (2000, Experiments 4 and 5). In Experiment 2b, we used the same two faces, but deleted the line representing the nose, thereby reducing the difference between negative and positive faces to the orientation of the mouth line (see Figure 2b).

Procedure. The stimulus sequence was identical to Experiment 1. Participants were now required to indicate as quickly and accurately as possible whether the face appeared to the left or to the right of the fixation cross by pressing the respective arrow key (cf. Jiang et al., 2007). Furthermore, we now included an equal number of CFS and control trials. The experiment consisted of six blocks containing 64 trials each. Within each block, each combination of two conditions, two eyes for stimulus presentation (dummy coded for the control condition), two faces and four quadrants occurred twice and trial order was randomized.

Results and Discussion

Misses and errors were rare ($M = 3.3\%$, $SD = 4.3\%$). The pattern of results was similar to Experiment 1. The emotion-by-condition interaction approached significance for Experiment 2a, $F(1, 10) = 4.95$, $p = .050$, and was significant for Experiment 2b, $F(1, 9) = 7.99$, $p = .020$. As in Experiment 1, emotion did not significantly modulate RTs in the control condition (Experiment 2a: $t(10) = 1.42$, $p = .185$; Experiment 2b: $t(9) = 1.02$, $p = .337$; see Figure 2d). However, as evident from Figure 2b, in the CFS condition positive faces were again detected significantly more quickly than negative faces (Experiment 2a: $t(10) = 2.35$, $p = .040$; Experiment 2b: $t(9) = 3.09$, $p = .013$).

The results from Experiment 2b suggest that the advantage of positive faces in entering awareness can be reduced to an effect generated by the upward curved line representing the mouth. We next asked whether this effect could be better explained by what we tentatively term "emotional" or "perceptual" accounts. Certainly, this distinction is to a large degree arbitrary (see, e.g., Horstmann & Bauland, 2006), but for the present purpose we consider it useful for labeling two different levels of explanation. In that sense, an emotional account would attribute the difference between negative and positive faces in overcoming suppression to the fact that the mouth line is charged with different valences depending on its orientation. In contrast, one possible perceptual

explanation could state that upward curved lines are simply processed faster than downward curved lines.

Experiment 3

In a first step to distinguish between these explanations, for Experiment 3 we rotated negative and positive faces by 180 degrees. Face inversion is known to disrupt face-specific configural processing (e.g., Maurer, Le Grand, & Mondloch, 2002; Yin, 1969) and is often supposed to attenuate emotional effects (e.g., de Gelder, Teunisse, & Benson, 1997; Derntl, Seidel, Kainz, & Carbon, 2009; Eimer & Holmes, 2002). Accordingly, an emotional account would predict that face inversion would reduce the positive face advantage. Alternatively, if the positive face advantage could be ascribed to the upward orientation of the mouth line, in Experiment 3 we would expect a reversed effect with shorter suppression durations for negative faces.

Method

Participants. A new set of nine participants (six female) took part in Experiment 3.

Stimuli and procedure. Except for the inverted vertical orientation of the face stimuli (see Figure 2b) Experiment 3 was identical to Experiment 2b.

Results and Discussion

Misses and errors were rare ($M = 3.1\%$, $SD = 3.2\%$). The interaction between emotion and condition was significant, $F(1, 8) = 32.53$, $p < .001$. As in the previous experiments, there was no effect of emotion in the control condition, $t(8) < 1$ (see Figure 2d). In the CFS condition, positive faces were again detected more quickly than negative faces, $t(8) = 6.83$, $p < .001$. Thus, earlier access to awareness for positive faces was virtually unaffected by inversion (see Figure 2b). These results support none of our originally proposed explanations for the positive face advantage, neither the emotional nor the perceptual account.

Clearly, the positive face advantage cannot be attributed to the orientation of the curved mouth line regarded in isolation. Alternatively, one might posit a crucial role of the orientation of the curved mouth line relative to the neighboring oval luminance contour that distinguishes the face shape from the gray background. In positive schematic faces, the curvature of the mouth and the face contour are roughly parallel. By contrast, in negative faces this mouth-contour congruency is disrupted by flipping the mouth vertically. Since parallelism is a fundamental Gestalt-like principle of figure ground organization (Metzger, 1953; Palmer, 1999), enhanced figure ground contrast might mediate faster access to awareness for positive faces. While perceptual dominance during binocular rivalry is modulated by Gestalt-like grouping principles (Alais & Blake, 1999; de Weert, Snoeren, & Koning, 2005; Silver & Logothetis, 2004; Yu & Blake, 1992), it has long been doubted that contextual factors can influence perceptual suppression (Blake & Logothetis, 2002). However, as recent studies using the present measure of suppression duration have revealed a strong impact of configural factors on perceptual suppression (Jiang et al., 2007; Stein, Senju, Peelen, & Sterzer, 2011; Yang et al., 2007; Zhou, Zhang, Liu, Yang, & Qu, 2010), we next asked whether the positive face advantage might be due to the orientation of the mouth curvature relative to the face contour.

Experiment 4

In Experiment 4, we tested whether the mouth-contour congruency in positive faces might explain the advantage of positive faces in gaining access to awareness. To that end, we created stimuli in which the difference between negative and positive faces regarding mouth-contour congruency was amplified, while the subjective impression of a face or emotional expression was greatly diminished (see Figure 2b). Thus, an emotional account would predict a reduced or eliminated positive face advantage, whereas a perceptual account based on differences in mouth-contour congruency would predict an even larger positive face advantage than in the previous experiments.

Method

Participants. Eight new observers (two female) participated in Experiment 4.

Stimuli and procedure. Experiment 4 was identical to Experiment 2a, except that the two circles representing the eyes were replaced by a mirror copy of the mouth line (see Figure 2b). This manipulation maximized the difference between negative and positive faces regarding mouth-contour congruency, while both faces contained both an upward as well as a downward curved line.

Results and Discussion

Again, misses and errors were rare ($M = 4.9\%$, $SD = 4.8\%$). The interaction between emotion and condition was significant, $F(1, 7) = 17.32$, $p = .004$. While no significant reaction time (RT) differences emerged in the control condition, $t(7) = 1.42$, $p = .199$ (see Figure 2d), in the CFS condition positive faces were suppressed for shorter durations than negative faces, $t(7) = 4.28$, $p = .004$. Thus, mouth-contour congruency appears to play a key role in mediating the positive face advantage during interocular suppression. If this difference in parallelism was actually the determining factor underlying the positive face advantage, one may expect the largest effect with the stimuli used in Experiment 4, as these contained even two curved "mouth" lines, both either aligned or misaligned with the face contour, depending on the face's "emotion."

Indeed, notwithstanding the difficulties arising from the between-subjects comparison, Figure 2b shows that the advantage of positive faces in overcoming CFS was amplified in Experiment 4 (effect size 322 ms) compared to Experiments 2 and 3 (effect sizes 87–101 ms). Statistically, the increased positive face advantage was reflected in significant experiment-by-emotion interactions for all comparisons between Experiment 4 and Experiments 2a, 2b, and 3, all $p < .05$. To ensure that the increased effect in Experiment 4 was not due to the overall slightly prolonged RTs, we computed a normalized positive face advantage as the mean RT difference between negative and positive faces divided by the mean RT for negative faces (cf. Tsuchiya et al., 2009). Using this measure, the positive face advantage was again significantly larger in Experiment 4 than in Experiments 2a, 2b, and 3, all $p < .05$.

Clearly, we cannot definitely rule out that the stimuli used in Experiment 4 continued to induce the perception of different valences. Still, the increased positive face advantage in Experiment 4 runs counter to an emotional account and strongly favors a perceptual explanation. Had the emotional meaning been the critical factor underlying faster access to awareness of positive faces, the positive face advantage should have been larger with the original face-like emotional schematic faces used in the previous experiments. However, as we found the exact opposite, the present findings suggest that the positive face advantage can be traced back to the differences between negative and positive faces regarding mouth-contour congruency.

General Discussion

In the present study, we tested whether negative or positive schematic faces have precedence in access to visual awareness. We used CFS to measure the time negative and positive faces needed to overcome interocular suppression and to break into awareness. Contrary to the widely held notion of a processing advantage for negative stimuli, the results from Experiments 1–3 revealed that positive schematic faces enter awareness more quickly than negative faces. Yet, the advantage of positive faces did not appear to be related to their positive valence. Rather, Experiment 4 indicated that the parallel orientation of the mouth curvature and the face contour caused positive faces to overcome suppression more quickly. As parallelism is known to facilitate figure-ground segregation (e.g., Metzger, 1953; Palmer, 1999), this suggests that unconscious processing during interocular suppression is biased toward higher figure-ground contrast, which in turn might cause faster detection of positive faces. Hence, the present results provide new insights into the impact of stimulus configuration on the dynamics of visual awareness during binocular rivalry. In addition, we believe that our findings bear importantly on the interpretation of results obtained with emotional schematic faces in other paradigms such as visual search.

Relevance for Binocular Rivalry

The mere orientation of the mouth curvature relative to the contour of our face-like stimuli modulated suppression durations. This demonstrates how binocular rivalry can serve as a particularly sensitive tool for measuring the competitive strength of different stimuli in accessing and modulating conscious awareness. In relating faster detection of positive faces to facilitated figure-ground segregation, we follow the idea originally put forward by Logothetis and colleagues that binocular rivalry can reveal fundamental principles of grouping and segmentation in the visual system (e.g., Leopold & Logothetis, 1999). This notion has received support from studies investigating interocular grouping (e.g., Kovács, Papathomas, Yang, & Fehér, 1996; Logothetis, Leopold, & Sheinberg, 1996; Suzuki & Grabowecky, 2002) and its modulation by Gestalt-like principles (e.g., Alais & Blake, 1999; de Weert et al., 2005; Silver & Logothetis, 2004). Throughout the present experiments, the sensitivity of the CFS condition to the alignment of the mouth curvature and the face contour contrasted with the absence of a positive face advantage in the control condition. The null effect obtained in the control condition vividly illustrates that "for many visual stimuli, grouping and image segmentation occur so

effortlessly and automatically that it is difficult to measure the underlying processes psychophysically" (Silver & Logothetis, 2004) and thus, further underlines the power of binocular rivalry to uncover effects that might have gone unnoticed by other measures.

However, both the influence of Gestalt-like factors on interocular grouping as well as other effects of contextual information (e.g., Fukuda & Blake, 1992; Hong & Shevell, 2008; Paffen, Tadin, te Pas, Blake, & Verstraten, 2006; Sobel & Blake, 2002) and high-level stimulus properties (Engel, 1956; Yu & Blake, 1992) on the dynamics of binocular rivalry have previously been considered to be limited to the modulation of perceptual dominance while leaving perceptual suppression largely unaffected (Blake & Logothetis, 2002). Still, the modulation of suppression durations by the relative orientation of the mouth curvature and the face contour is consistent with more recent studies that revealed strong effects of configural stimulus properties on the duration of perceptual suppression induced by CFS (Jiang et al., 2007; Stein et al., 2011; Yang et al., 2007; Zhou et al., 2010). In these studies, upright face photographs were found to access awareness more quickly than inverted face photographs, leading to the conclusion that some aspects of face-specific configural processing escape interocular suppression and can proceed without awareness (e.g., Zhou et al., 2010).

The present findings show that even the spatial relationship between two curved lines can gate access to awareness during CFS. Furthermore, in contrast to previous results obtained with face photographs, this configural effect appears to be unrelated to face-specific processing, as its strength is undiminished by inversion (Experiment 3) and even boosted when the impression of a face is reduced while the difference in mouth-contour congruency is amplified (Experiment 4). Accordingly, we conjecture that this effect might be caused by early unconscious processes involved in figure-ground segmentation that continue to operate during interocular suppression. Although speculative, on a physiological level the positive face advantage might be traced back to neurons in primary visual cortex that are sensitive to contextual influences and show both enhanced responding to parallel oriented lines (Kapadia, Ito, Gilbert, & Westheimer, 1995) as well as partially preserved activity during interocular suppression (e.g., Leopold & Logothetis, 1996; Maier et al., 2008; Wilke, Logothetis, & Leopold, 2006). In sum, faster detection of positive schematic faces during CFS appears to be reducible to the operation of early visual processes and is unlikely to involve dedicated face- or emotion-specific processes.

Relevance for Visual Search

Before turning to the implications of the present findings for other studies using emotional schematic faces, it is important to acknowledge that the exact relationship between processes engaged by binocular rivalry and normal stereo viewing is presently not fully understood. Nevertheless, binocular rivalry is now widely regarded as a unique window into the mechanisms of competition and selection between stimulus representations that govern real world vision as well (e.g., Andrews & Purves, 1997; Clifford, 2009; Leopold & Logothetis, 1999; Logothetis et al., 1996; Sterzer, Kleinschmidt, & Rees, 2009). From this point of view, future studies using emotional schematic faces, even in other paradigms, should be mindful of the processing advantage of positive faces.

As preferential access to awareness appears to be unrelated to the face's emotional meaning, the positive face advantage constitutes an undesirable confound for studies investigating the effect of emotional valence on visual processing. Thus, on a pessimistic note, the attempt to eliminate influences from low-level confounds present in photographs of emotional facial expressions has introduced a new perceptual confound caused by the unnaturally exaggerated congruency between the mouth curvature and the face contour in positive schematic faces which contrasts with the unnatural incongruency in negative schematic faces. Interestingly, this concern has been raised before by Purcell and Stewart (2006, as cited in Frischen et al., 2008). By revealing the functional consequences of this congruency confound, the present results provide empirical support for Purcell and Stewart's objections against the application of schematic faces.

How could the positive face advantage uncovered by CFS help to reconcile findings from the visual search literature? Clearly, more efficient processing of positive distractors could account both for the face-in-the-crowd effect as well as for faster responses to positive crowds in target-absent trials (for a similar stance, see Horstmann et al., 2006). Importantly, the face-in-the-crowd effect is eliminated when the face's contours are removed (Schubö et al., 2006). Thus, the alignment of the mouth curvature relative to the face contour does not only affect interocular suppression, but apparently modulates visual search performance as well. If the congruency confound could exhaustively account for all findings from visual search, one would expect face inversion to have no effect on performance, as it retains the differences between negative and positive faces regarding mouth-contour congruency (see Experiment 3). Unfortunately, work exploring the effect of inversion on the face-in-the-crowd effect has yielded conflicting results, with a number of studies reporting no effect of inversion (Lipp, Price, & Tellegen, 2009b; Nothdurft, 1993; Öhman et al., 2001; White, 1995), while others found the face-in-the-crowd effect to be restricted to upright faces (Eastwood et al., 2001; Fox et al., 2000).

This indicates that the mere processing advantage of positive faces might not be the only factor influencing search performance in multielement displays. Furthermore, the less consistently reported advantage of negative over positive targets embedded in neutral crowds (e.g., Eastwood et al., 2001; Öhman et al., 2001; but see Horstmann et al., 2006) points to an additional, antagonistic effect evoked by negative targets, possibly related to their potential to draw and hold attention (e.g., Dolan, 2002; Fox, Russo, Bowles, & Dutton, 2001; White, 1996). This highlights the limitations of our present attempt to relate the results obtained with CFS to visual search. Arguably, attentional mechanisms engaged by visual search in multielement displays are less involved in detecting single stimuli during CFS. Notably, similar to the detection advantage of positive faces, recent evidence suggests that the putative attentional bias toward negative faces is virtually unrelated to emotional valence but is due to configurations of particular line segments that render negative targets salient among distractors with different configurations (Coelho, Cloete, & Wallis, 2010; see also Horstmann, Becker, Bergmann, & Burghaus, 2010).

Implications for Emotion Research

In summary, we revealed an advantage for positive over negative schematic faces in accessing awareness that we attribute to the difference in congruency between the mouth curvature and the face contour. On the one hand, this finding demonstrates how stimulus configuration can affect perceptual suppression during binocular rivalry. On the other hand, the positive face advantage may constitute a confounding influence in studies that employ schematic faces as seemingly well-controlled stimuli to investigate the processing of emotional facial expressions. Apparently, the mere rearrangement of identical features in schematic faces can introduce new perceptual confounds resulting from the configuration of those features. Together with other recent studies that uncovered related and additional stimulus confounds in schematic emotional faces (e.g., Coelho et al., 2010; Horstmann et al., 2010) our findings seriously challenge the assumption that schematic faces would control for low-level differences between different emotional facial expressions.

As schematic faces additionally suffer from limited ecological validity, future studies on the processing of emotional facial expressions are well advised to return to using naturalistic depictions of faces. In fact, it is possible that the influence of potential low-level confounds is not stronger in well-controlled (e.g., contrast and luminance matched) photographs of emotional faces than in schematic depictions of emotional facial expressions. In a broader theoretical sense, it is worth considering that these so-called "low-level" physical differences between photographs of emotional faces may even constitute the features that are key for discriminating between emotional facial expressions (e.g., Smith, Cottrell, Gosselin, & Schyns, 2005) and for eliciting perceptual biases such as rapid threat detection (e.g., Horstmann & Bauland, 2006). By contrast, emotion researchers interested in the visual processing of different valences per se can conclusively isolate valence-related from perceptual effects by adopting emotional learning paradigms in which neutral stimuli are associated with different valences (e.g., Alpers, Ruhleder, Walz, Mühlberger, & Pauli, 2005; Notebaert, Crombez, Van Damme, De Houwer, & Theeuwes, 2011). Thus, if the focus is on the processing of visual representations of emotions rather than on the visual processing of specific emotional facial expressions, such emotional learning paradigms may be advisable for future studies on emotional vision.

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