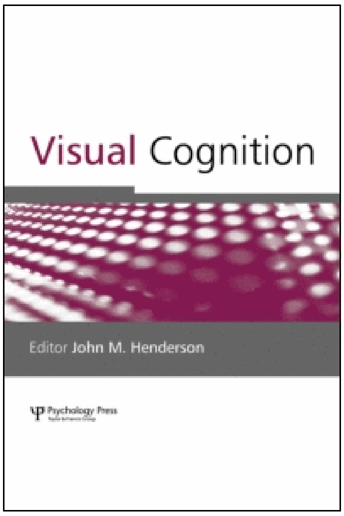

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A reversal of the search asymmetry favouring negative schematic faces

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A reversal of the search asymmetry favouring negative schematic faces

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Quite a number of studies have tested whether the affective valence of stimuli can guide attention in visual search. Studies using schematic affective faces frequently found a relative search asymmetry (RSA), with more efficient search for a negative face in a friendly crowd than vice versa. Whether, however, this effect relates to differences in affect or to the confounded differences in perceptual features is unknown. The present study proposes and tests a similarity-based account for the RSA. Experiments 1a and 1b first replicate the typical RSA. Experiment 2 shows that the stimulus could be simplified to some degree without losing the RSA. Experiments 3 and 4, finally, demonstrate that the RSA could be reversed by a rather simple stimulus change, that leaves the facial expression intact. It is concluded that the strong dependence of the RSA on stimulus factors seriously questions the claim that emotional factors drive the RSA.

Keywords: Attention; Affect; Emotion; Visual search.

Are potentially dangerous objects in the environment (e.g., snakes, spiders, and negative faces) spotted and processed faster than nonthreatening objects? According to the *affective feature hypothesis*, affective stimulus characteristics such as the negative valence of certain emotional facial expressions or the threat potential of certain animals are preattentively

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available, can thus guide attention, and may even involuntarily capture attention (e.g., Eastwood, Smilek, & Merikle, 2001, 2003). Attending to these stimuli in turn speeds up their processing, and allows swift changes in behaviour, if necessary.

This possibility has aroused the interest of researchers from different domains of research, such as perception (e.g., Eastwood et al., 2001, 2003; Nothdurft, 1993; Purcell, Stewart, & Skov, 1996), psychophysiology (e.g., Lipp & Derakshan, 2005), social cognition (Hansen & Hansen, 1988; Öhman, Lundqvist, & Esteves, 2001), emotion (e.g., Calvo & Nummenmaa, 2008; Fox, Lester, Russo, Bowles, Pichler, & Dutton, 2000; Fox, Russo, & Dutton, 2002; Tipples, Atkinson, & Young, 2002; White, 1995), and clinical psychology (e.g., Rink, Reinecke, Ellwart, Heuer, & Becker, 2005). This broad interest (see also a recent and comprehensive review by Frischen, Eastwood, & Smilek, 2008) is understandable when we consider the considerable practical and theoretical importance.

Practically, the preattentive processing of affective valence would allow attention to be guided by unattended (and, by implication, not yet fully perceived) threatening stimuli, enabling immediate detection of stimuli that are important for an individual's survival or well-being. To coin a common example from the emotion literature: A hiker, making his way through a wood, may spot a snake on the ground immediately (cf. LeDoux, 1998). Importantly, he or she may do so not because of the snake's unique perceptual appearance (which would often be camouflaged by the snake's perceptual similarity in colour and form to wooden branches), but just because the cognitive-emotional machinery identified the animal immediately as a life-endangering threat. Detection of threatening stimuli could thus occur without first focusing attention on the object, which allows a much broader scanning of the environment than is possible with piecemeal attentional processing. Importantly, the hiker would be alerted not only by a snake, but also by perceptually quite dissimilar poisonous animals, like spiders or scorpions, given that they are tagged in his or her mental representations as threatening or negative.

Theoretically, the affective feature hypothesis centrally claims that affective valence can be directly accessed by the attention-guiding machinery and guides attention *independently of the perceptual characteristics of a stimulus* (Eastwood et al., 2001). In contrast, existing theories of visual attention (e.g., Treisman & Gelade, 1980; Wolfe, 1994) assume that attention can only be guided by basic perceptual features (e.g., red, tilted, or moving). These theories do not include a mechanism that would allow guidance by affective features. Thus, if the affective feature hypothesis is correct, current models of visual attention would have to be modified to accommodate guidance by affective features (e.g., Frischen et al., 2008).

The affective-feature hypothesis derives its main support from the visual search paradigm, which is the most important paradigm for evaluating claims of preattentive processing and attentional guidance (e.g., Treisman & Gelade, 1980; Wolfe, 1998). In the visual search paradigm, the participant's task is to find a target among nontargets. If the target is defined by a preattentive feature, the target is detected immediately and an attentional scanning of distinct stimuli is not necessary. In this case of *efficient search* or perceptual "pop-out", detection latency for the target is independent of the total number of stimuli presented in a single display (set size). By contrast, in *inefficient search*, the latency to find a target is positively related to set size, that is, response time (RT) increases with increases in the set size. Such positive "set size effects" indicate that the detection of the target is the result of a serial deployment of attention to each individual stimulus in turn, until the target is detected. Search efficiency is determined as the slope b of the linear equation $y = bx + a$ that relates the latency of finding the target y to the set size x. Commonly observed search efficiencies vary between 0 and 150 ms/item, with no clear transition between efficient and nonefficient search. Wolfe (1998) has proposed that there is no strict dichotomy between efficient and inefficient search, and that different degrees of search efficiency can be categorized using verbal labels for certain ranges: A search with a slope of 0–5 ms/item is termed very efficient, 5–10 ms/item is quite efficient, 20–30 ms/tem is inefficient, and over 30 ms/item is very inefficient. Because a flat search slope (e.g., 0–5 ms/item) indicates immediate access to the target without prior scanning of the distractors, efficient search is the gold standard for attentional guidance by preattentively available features of the target (some authors, however, have proposed to accept a relative search asymmetry as evidence for preattentive access; see later).

Although efficient searches for affective—in most cases, positive or negative schematic—faces have been reported (e.g., White, 1995), the majority of studies found search for affective stimuli to be inefficient or very inefficient (e.g., Fox et al., 2000; Horstmann, 2007, 2009; Horstmann & Ansorge, 2009; Horstmann & Bauland, 2006; Horstmann & Becker, 2008; Nothdurft, 1993; Öhman et al., 2001). To evaluate the possibility that this negative result is due to low experimental power, Horstmann (2006; see also Horstmann, 2009) tested stimuli from the literature in a constant experimental set-up and still found considerable variation of search efficiency between stimulus pairs. Moreover, a first calibration experiment revealed that the failure to find clear evidence for efficient search cannot be explained away by assuming that the method was insensitive: A classical pop-out stimulus display (a circle with a line intersecting its basis as the target among circles without lines as nontargets, cf. Treisman & Souther, 1985) showed the expected results pattern of a flat search function.

In an evaluation of this result it might be noted that it is theoretically possible that some feature is preattentively available but found only inefficiently, for example, when the feature contrast between the target and the distractors is small. Thus, the failure to find consistent evidence for efficient search with affective faces does not ultimately disprove the affective-feature hypothesis. However, the results certainly do not, at the same time, provide compelling favouring evidence. Accordingly, in a recent review of "basic features" in vision, Wolfe and Horowitz (2004) state that faces and facial expressions are probably *not* basic features that are available before attention has focused the respective stimulus (but see Frischen et al., 2008).

Some authors have dismissed the efficient-search criterion for preattentive processing and argued that a search advantage in inefficient search is indicative for attentional guidance by a preattentively available feature (e.g., Eastwood et al., 2001). With respect to affective features, previous visual search studies in fact more often than not showed more efficient search for a negative target among positive nontargets than vice versa, that is, a *relative search asymmetry* (RSA) for negative faces (e.g., Fox et al., 2000; Horstmann, 2007; Horstmann, 2009; Horstmann & Bauland, 2006; Horstmann, Scharlau, & Ansorge, 2006; but see Öhman et al., 2001; Nothdurft, 1993; White, 1995). Dismissing the efficient search criterion can be justified by the observation (noted earlier) that efficient search for a basic feature can fail to show up if the feature contrast between the target and the distractor is low. In this case, attentional guidance by the feature becomes less than perfect, leading to relatively inefficient searches. On this account, the slope of the search function becomes a metric of attentional guidance, which can vary from very efficient to very inefficient. The efficient search criterion would then be substituted by the RSA criterion, with the rationale that a relatively shallow slope for a feature means relatively good guidance of attention by that feature.

The RSA criterion is not without problems, however. First of all, inefficient search, by definition, reveals itself by a positive slope of the set size–RT function; that is, every time a nontarget is added to the display, search duration becomes longer. Thus, inefficient search is immediate evidence that the nontargets are processed. Therefore, the observed RSA might not be due to more efficient processing of the *target* stimulus, but to aspects of the *nontarget* stimulus processing. In particular, the classical search asymmetry design confounds the target type with the surrounding nontargets, because whenever the target is constituted by a negative face, it is surrounded by positive nontarget faces and vice versa. Therefore, it is possible that the observed RSA is due to faster rejection of positive nontargets than negative nontargets.

This possibility gains some plausibility when we consider that search slopes are also steeper with crowds entirely consisting of negative faces compared to homogeneous groups of positive faces (e.g., Horstmann, 2007, 2009; Horstmann & Bauland, 2006). In fact, Horstmann (2009) found that search efficiency in target absent trials, where homogeneous crowds of negative or positive faces are displayed, accounted for 99% of the variance in search efficiency in corresponding target present trials, where a positive face is embedded in a negative crowd or where an negative face is embedded in a positive crowd. This result implies that almost all variance in search efficiency is accounted for by the valence of the nontargets, whereas the valence of the target has virtually no influence on search efficiency. Thus, large parts of these effects appear to be a *positive face-distractor advantage*, rather than a *negative face-target advantage* (see also Rauschenberger & Yantis, 2006, for a more general discussion of distractor effects in visual search).

This argument applies most clearly to studies using the search asymmetry design where positive faces are targets and negative faces are distractors in half of the trials, whereas this arrangement is reversed in the other half of the trials. In order to circumvent the confound, Eastwood et al. (2001) compared search for positive and negative face targets among neutral distractors. Although search was not efficient for either target, it was less inefficient for the negative face target. On face value, because the crowds were constant, all effects must be due to characteristics of the target. However, this result appears to hinge on the choice of the neutral distractor. Instead of presenting the "straight line mouth" neutral distractor of Eastwood et al. (2001), Horstmann, Scharlau, and Ansorge (2006) superimposed the positive and the negative face to form an alternative neutral distractor. After replicating the RSA from the confounded search asymmetry design (Experiments 1a and 2a), they showed that their positive and negative face targets were searched for with equal inefficiency among neutral distractors (Experiments 1b and 2b), and the neutral face as a target was found less inefficiently among positive face distractors than among negative face distractors (Experiment 2c and 3c). The least that can be concluded from the diverging results of the studies of Eastwood et al. and Horstmann, Scharlau, and Ansorge is that the choice of the "neutral" distractor stimulus is crucial for tests of search efficiency with negative and positive face targets.

This line of reasoning directly leads to the second possible criticism of the affective-feature account of the RSA: Even if the RSA were by and large due to more efficient search for negative target faces than for positive target faces, the RSA might still be due to perceptual features of the stimuli, and not their emotional content. Of course, in categories established by evolution or culture, such as positive and negative faces, the affective content and the perceptual features are necessarily confounded. Any effect might thus be attributable to affective or perceptual features. As we have pointed out in the beginning, when observers pick out negative stimuli more efficiently on the basis of perceptual features, this must not count as evidence for preattentive processing of affective valence.

One strategy to make one or the other alternative more plausible has been to test faces upside down. The rationale behind this procedure is that inversion complicates face specific configural processing while holding constant low level features (cf. Maurer, LeGrand, & Mondloch, 2002). This reasoning, however, faces two difficulties, one empirical and one theoretical. Empirically, some studies found the RSA reduced by face inversions (e.g., Eastwood et al., 2001), whereas others found no influence of face inversion on the RSA (e.g., Fox et al., 2000; Horstmann, 2006; Lipp, Price, & Tellegen, 2009b; Öhman et al., 2001). Thus, there is not typical result of face inversion on search efficiency. Theoretically, it is unclear what effects face inversion has on the processing of facial affect. The processing disadvantage for upside-down faces may be particularly severe for the processing of face identity which depends highly on configural processing (Yin, 1969), whereas emotion recognition might not depend so much on configurational than on componential processing (McKelvie, 1995; see also Horstmann & Bauland, 2006, for additional evidence from Thatcherized faces). On the other hand, studies using nonfacial stimuli have revealed that in some cases, stimulus inversion changes the basic perceptual properties of complex stimuli (Enns & Rensink, 1990; Wolfe, 2001; see also Maurer et al., 2002). To conclude, we believe that face inversion experiments have not solved the problem of deconfounding effects of perceptual and affective features.

A second strategy has been to experimentally create affective stimuli. This has only been done by two studies to date. Beatty, Cave, and Pauli (2005) used an aversive conditioning procedure to establish a "threatening" stimulus. Importantly, they used compound stimuli (a configuration of eight dark or light congruent triangles forming a square) for target and distractors, where even a highly regular pattern ("propeller") could be found only very inefficiently among irregular distractors. Whether the target was threatening did not influence search efficiency, thus implying that experimentally acquired affective valence could not be discerned preattentively. Gerritsen, Frischen, Blake, Smilek, and Eastwood (2008) followed up with a study where they used neutral faces as stimuli. These neutral faces were paired with negative and positive adjectives in an evaluative conditioning procedure. Their three experiments gave somewhat inconsistent results, with Experiments 1 and 2, but not Experiment 3, showing the predicted results. A finally conducted meta-analysis on the three experiments, however, revealed a small RSA accounting for 4% of the variance, favouring the faces previously paired with the adjective "hostile" over the faces paired with the adjective "peaceful". To sum up, the only two studies to date that tested the RSA for experimentally created stimuli show inconsistent answers to the question of whether valence guides attention when the mapping of valence to stimuli is balanced and thus not confounded with stimulus features.

AIM OF PRESENT RESEARCH

The aim of the present research was to contribute to a clarification of the factors underlying the RSA for schematic positive and negative faces, which can be considered a centrepiece in the evidence for the affective feature hypothesis. Theoretically we propose *the perceptual factors hypothesis*, which states that the RSA observed with schematic faces is due to specific perceptual configurations of the positive and the negative schematic faces. Empirically, our aim is to demonstrate that perceptual factors alone are sufficient to account for the RSA. In the critical experiments, perceptual characteristics ($p+$ and $p-$) that are normally confounded with negative and positive valence of schematic face stimuli ($a+$ and $a-$), respectively, are varied to the effect that $p+$ appears with $a-$ and $p-$ appears with $a+$. According to the affective feature hypothesis, search should be more efficient for the target with the affective feature $a-$ than for the target with the affective feature $a+$ irrespectively of whether the target also possesses the perceptive feature $p+$ or the perceptive feature $p-$ (we will refer to the pattern henceforth as the standard RSA). In contrast, the perceptual feature hypothesis predicts a different pattern. Search should be more efficient for the target with the perceptive feature $p-$ than for the target with the perceptive feature $p+$ irrespectively of whether the target also possesses the affective feature $a+$ or the affective feature $a-$ (we will refer to the pattern henceforth as the reversed RSA). Importantly, such a reversal of the standard RSA would then show that perceptual properties of schematic positive and negative face stimuli alone are sufficient to explain the RSA.

What is the crucial perceptual property? Schematic faces invariantly use upward versus downward pointing curves as mouths to represent positive and negative affective valence. Because upward versus downward pointing curves are tantamount with positive and negative facial valence, and are thus not amenable for experimental variation, independent variation of this critical feature does not appear to be possible. However, the crucial perceptual property driving the RSA may not be the curved line per se but rather the relation of the curved line to the perceptual context of the face, which is common to both the positive and the negative faces (see also Frischen et al., 2008, for an emphasis on a relational interpretation of features). Typically, affective face stimuli consist of a circle or an oval as the face's outline, two dots or small circles as the eyes, sometimes a stroke or a triangle as the nose, and a line as the mouth (sometimes, the faces differed also in the orientation of short lines representing eyebrows, and, in one case, the eyes were also different for positive and negative faces). Thus, eyes, nose, and face outline form the constant context, and curve orientation is varied to obtain a positive and a negative face stimulus.

These stimuli, however, do not only differ in mouth curve orientation, but also in the relationships between the mouth curve and the constant context of the other facial features. Because the mouth repeats the spatially adjacent outline in the positive faces, these stimuli look simpler and have a stronger degree of self-similarity than the schematic angry faces, in which the curvature of the mouth contrasts with the adjacent curvature of the face's outline (Horstmann, Scharlau, & Ansorge, 2006). In the present investigation, we suggest that it is in particular the concordance versus contrast of the mouth and the adjacent segment of the circular face outline (the chin) in the positive versus the negative face which is the crucial perceptual property driving the RSA. Thus, the critical Experiments 3 and 4 manipulated the outline of the face in order to change eliminate, or even reverse the concordance between mouth and chin.

There are several theoretical reasons to assume that simplicity, self-similarity, and concordance may be important in the generation of the RSA. First, it has been argued that the positive face's mouth is perceptually masked by the adjacent face's outline, rendering the discriminating feature in the positive face targets difficult to perceive (White, 1995). Second, assuming that visual search efficiency is determined in particular by two processes, guidance by the target and rejection of distractors, we have to ask whether the speed of these two processes is affected by simplicity, Gestalt goodness, and self-similarity. Whether these variables affect attentional guidance is unclear; however, there are good reasons to assume that they affect distractor rejection.

A reason to expect that self-similarity would affect distractor rejection can be concluded from Duncan and Humphreys' (1989) analysis of the role of distractor rejection in visual search. According to their theory, the rejection of a distractor leads to the inhibition of similar concurrently displayed distractors, with the degree of inhibition being related to the degree of similarity. It is thus conceivable that the rejection of a negative face distractor leads to a strong inhibition of a positive face target, because the smiling mouth is closely aligned to the face's outline (which is the common, and thus nondiscriminating, element in all faces), whereas the rejection of a positive face distractor leads to less strong inhibition of a negative face target, because the angry mouth is not aligned with the face's outline.

A further reason to expect that simplicity affects distractor rejection can be discerned from Rauschenberger and Yantis' (2006) research on the role of stimulus redundancy in visual search. These authors provided evidence that distractor complexity (arguably the inverse of redundancy) has considerable impact on search performance, presumably because complex (less redundant) stimuli are more costly to process when encountered as distractors. Thus, rejection of positive distractor faces might proceed easier and might show less dependence on the set size, because they are simpler (or more redundant) than negative faces, which in turn produces the RSA for the negative face when it constitutes the target.

Either way, whether positive schematic faces have a simpler perceptual organization or exhibit a greater similarity of the discriminating feature (mouth) with a nondiscriminating feature (facial outline), the view that perceptual principles are the main source of differential search efficiency for negative and positive schematic faces suggests that appropriate changes in the mouth–chin ensemble of the stimuli should eliminate, and even reverse the search pattern.

EXPERIMENT 1a

The aim of Experiments 1a and 1b was to replicate the basic RSA for a negative schematic face, which is reflected in a reduced set size effect when a negative target face is presented among positive nontarget faces than vice versa (i.e., when a positive target face is embedded among negative nontarget faces). In Experiments 1a and 1b, the set size was varied between 1, 6, and 12 stimuli. If the basic RSA can be replicated, then the set size effect (i.e., increase in RT with increases in the set size) should be smaller for the negative target among positive crowds, compared with the positive target among negative crowds.

Experiments 1a and 1b were identical, with the exception that the face stimulus in Experiment 1a had a nose (a vertical stroke), which was omitted in Experiment 1b. The stimulus used in Experiment 1a was closely modelled after the stimulus tested by White (1995). In one of the following critical experiments testing the novel faces, however, the nose was omitted; for this reason it was desirable to test whether omitting the nose itself made any difference.

Method

Participants. These were eight students (one woman), with a mean age of 22.2 years ($SD = 1.7$).

Apparatus. A computer, connected to a 15-inch colour monitor for stimulus presentations, and to a keyboard to collect the manual responses, controlled the experiment. Experimental Run Time System (ERTS) was used for event scheduling and response registration.

Design. A 3 (set size: 1 vs. 6 vs. 12) × 2 (target/crowd identity: Positive target/negative crowd vs. negative target/positive crowd) × 2 (target presence:

Present vs. absent) design was employed.[1] Each of the resulting 12 experimental conditions were replicated 25 times. Target stimulus/crowd identity was varied between homogeneous blocks of trials. Set size and singleton presence varied randomly within blocks. Dependent variables were mean correct RTs and error rates. The order of blocks (positive vs. negative target face), and judgement (target present vs. absent) to response (left vs. right response key) mapping were counterbalanced across participants.

Stimuli. The stimuli were composed of a circle representing the outlines of the faces, two circles as the eyes, a stroke as the nose, and a curved line as the mouth. Positive and negative faces were differentiated only by the orientation of the curve forming the mouth (pointing upwards or downwards). Figure 1a shows an example of positively and negatively valenced stimuli, respectively.

The faces measured 1.8×1.8 cm. Viewing distance was 100 cm. In each trial, 1, 6, or 12 facial stimuli were presented without overlap within an area of about 12×9 cm. The search displays consisted either of a group of homogeneously positive or negative faces (target absent trials), or contained one discrepant face (target present trials). Individual faces were presented on an imaginary 4×3 (horizontal $\times$ vertical) position matrix. Mean distance between the positions (centre-to-centre) was 3 cm. Average positions were altered by random jitter (displacement from centre: 0.3–0.4 cm) to eliminate possible suprastimulus cues to the target that may have resulted from a regular arrangement (Duncan & Humphreys, 1989). All stimuli were coloured white and presented against a constantly black background.

Procedure. Written instructions requested participants to report the presence or absence of the target face by pressing one of two response keys. The identity of the target face in a given block was indicated by a message on the computer screen. The general instructions emphasized both speed and accuracy. Participants worked on 20 practice trials, followed by two blocks of 150 trials each. Half of the participants searched for the positive face in the first block and for the negative face in the second block; for the other half, this assignment was reversed.

The face stimuli were preceded by a 1000 ms fixation cross and followed by the 1100 empty-screen intertrial interval. They were presented until a response was made, but a trial was aborted if no response was registered

[1] It might be noted that the set size 1 condition differs from the set size 6 and the set size 12 conditions, in that no search has to be performed in order to respond. However, Horstmann, Scharlau, and Ansorge (2006) reported that the slopes are virtually the same, whether computed on the set sizes 1, 6, and 12 or on the set sizes 2, 6, and 12.

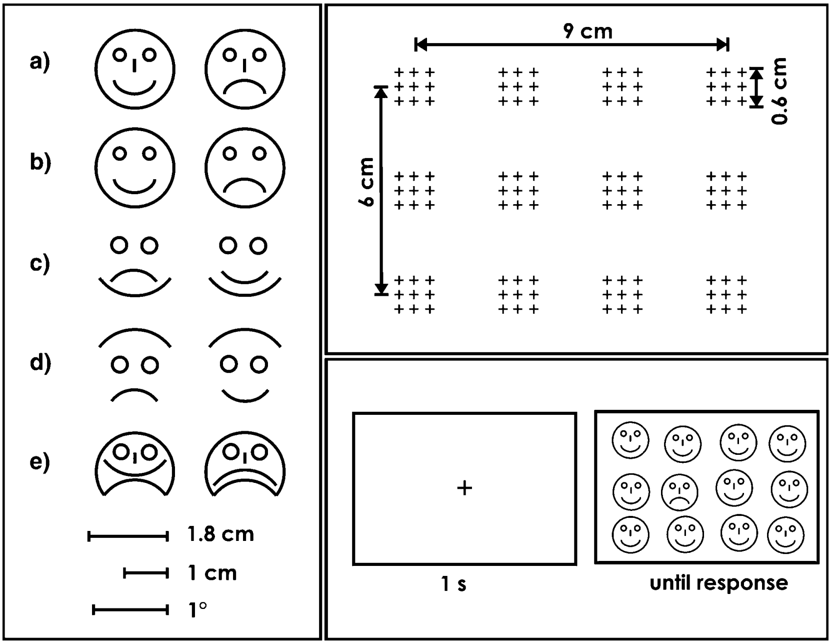

Figure 1. Overview of the stimuli and the procedures used in the present experiments. Left: The stimulus pairs used in the Experiments. Right top: Each cross indicates a possible position for a stimulus (note that within a nine-cross block, only one stimulus could appear). Right bottom: Sequence of events within a trial.

within 6 s. If participants pressed the wrong key, a 100 ms tone provided error feedback.

Results

Data treatment. For the analysis of RTs, RTs <200 ms or >3000 ms and errors were excluded (removing the RT outliers eliminated less than 1% of the trials). Mean reaction times for each of the 12 experimental conditions were calculated. Because the main interest are the slopes of the RT–set size functions, separate linear regressions with RT as the dependent variable and set size as the independent variable were computed for each of the 2 (target presence: Present vs. absent) $\times$ 2 (target stimulus identity: Happy vs. angry) conditions, separately for each participant, to obtain individual estimates of the two parameters b (slope) and a (intercept). The regression parameters were subjected to separate ANOVAs. For the analysis of the errors, error scores were computed as the proportion of false responses. Analogous to the RT analysis, the statistical tests were performed on the slope and intercept parameters.

Mean correct RT and errors for each experimental condition are depicted in Figure 2.

Slopes. Figure 2 shows the grand means for RTs and errors of Experiment 1a. Table 1 summarizes the results of the ANOVAs for the present and the following experiments, and Table 2 reports the mean slopes and intercepts. The ANOVA of the slopes for RTs revealed significant main effects for target presence, revealing shallower slopes for target present than for target absent trials (33 vs. 68 ms/item, averaged over the two targets), and target stimulus identity, revealing shallower slopes for negative targets among positive nontargets than for positive targets among negative nontargets (36 vs. 67 ms/item, averaged over target presence). A corresponding

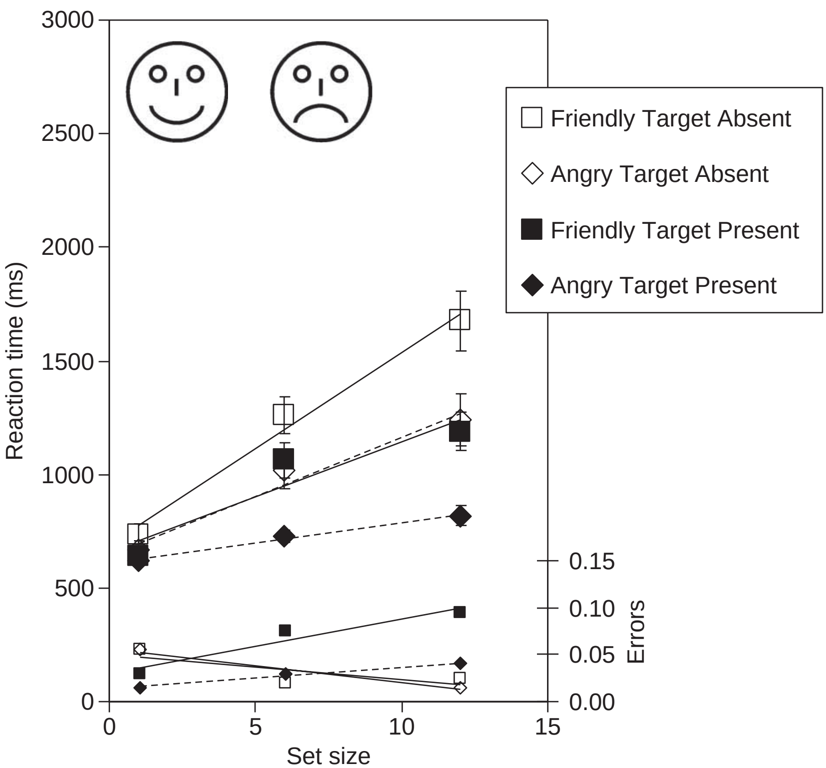

Figure 2. Mean correct RTs and error rates for each of the 12 conditions in Experiment 1a. Error bars show the standard errors of the mean for the RTs. Filled symbols represent target present trials and unfilled symbols target absent trials. Diamonds code for searches for a negative schematic face target, whereas squares code for searches for a positive face target. The figure also displays the linear trends obtained by linear regression analysis.

TABLE 1
Slopes and intercepts for RTs and errors in Experiments 1, 2, 3, and 4

	Slope		Intercept	
Stimulus pair	*RT*	*Errors*	*RT*	*Errors*
Exp. 1a				
PTP	48.6	0.006	656.2	0.029
NTP	17.9	0.003	609.6	0.014
PTA	84.9	−0.003	687.5	0.051
NTA	52.0	−0.003	644.9	0.059
Exp. 1b				
PTP	33.8	0.005	601.3	0.030
NTP	15.3	0.001	575.4	0.041
PTA	76.0	0.000	619.1	0.020
NTA	31.8	−0.003	615.1	0.036
Exp. 2				
PTP	41.0	0.009	688.8	−0.003
NTP	11.3	0.001	712.8	0.016
PTA	73.8	0.000	778.1	0.020
NTA	46.4	−0.001	720.5	0.043
Exp. 3 "Reference"				
PTP	29.7	0.003	615.3	0.016
NTP	10.5	−0.002	623.2	0.028
PTA	52.0	0.001	676.3	0.012
NTA	24.0	−0.003	667.7	0.045
Exp. 3 "Critical"				
PTP	21.3	0.003	640.1	0.026
NTP	29.3	0.011	633.7	0.001
PTA	43.7	−0.001	672.8	0.021
NTA	73.4	0.001	621.9	0.028
Exp. 4				
PTP	34.6	0.003	758.3	0.038
NTP	66.8	0.010	722.5	0.021
PTA	88.0	0.000	710.6	0.005
NTA	136.3	−0.001	747.9	0.063

PTP = positive target present, NTP = negative target present, PTA = positive target absent, and NTA = negative target absent.

ANOVA of the slopes for error proportions revealed steeper slopes in the target present than in the target absent condition (0.004 vs. −0.003 errors/item).

Intercepts. The ANOVA of the intercepts for RTs revealed no significant main effects or interactions.

TABLE 2
Frequencies for Experiments 1a, 1b, and 4

	Slope		*Intercept*	
Stimulus pair	*RT*	*Errors*	*RT*	*Errors*
Exp. 1a				
Presence (P)	*57.88*	*5.92*	1.67	1.52
Stimulus (S)	*19.95*	0.40	2.20	0.05
P × S	0.05	0.50	0.02	0.48
Exp. 1b				
Presence	*27.91*	*8.79*	3.04	0.43
Stimulus	*16.39*	2.78	0.38	0.64
P × S	4.26	0.13	0.51	0.03
Exp. 2				
Presence	*10.24*	5.50	5.44	*5.76*
Stimulus	*10.81*	2.54	0.48	0.88
P × S	0.06	5.65	2.93	0.03
Exp. 4				
Presence	*32.77*	*13.44*	0.36	0.44
Stimulus	*19.50*	2.78	0.00	*12.08*
P × S	2.26	8.79	2.79	*14.94*

Critical *F*, with $df = 1$ for the nominator and $df = 7$ for the denominator, is 5.56, $p = .05$. Values exceeding the critical value are italicized.

Discussion

The experiment replicated the more efficient search (36 ms/item) for negative face targets in positive face crowds than for positive face targets in negative face crowds (67 ms/item). This effect of a relative search asymmetry could be found in numerous studies with schematic stimuli. Before we proceed to the experiments of current interest, Experiment 1b further tests whether inclusion or omission of a "nose" makes any difference to the results.

EXPERIMENT 1b

Method

Participants. Eight students (seven women), with a mean age of 22.3 years ($SD = 1.7$), participated in Experiment 1b.

Design, stimuli, and procedure. These were the same as before except that the "nose" was omitted from the schematic face stimuli (see Figure 1b).

Results

Slopes. Figure 3 shows the grand means for RTs and errors of Experiment 1b. Table 1 summarizes the results of the ANOVAs, and Table 2 reports the mean slopes and intercepts. The ANOVA of the slopes for RTs revealed significant main effects for target presence, revealing shallower slopes for target present than for target absent trials (25 vs. 54 ms/item), and target stimulus/crowd identity, revealing shallower slopes for negative targets/positive crowds than for positive targets/negative crowds (24 vs. 55 ms/item). A corresponding ANOVA of the slopes for errors proportions revealed steeper slopes in the target present than in the target absent condition (0.003 vs. -0.002 errors/item).

Intercepts. The ANOVA of the intercepts for RTs revealed no significant main effects or interactions.

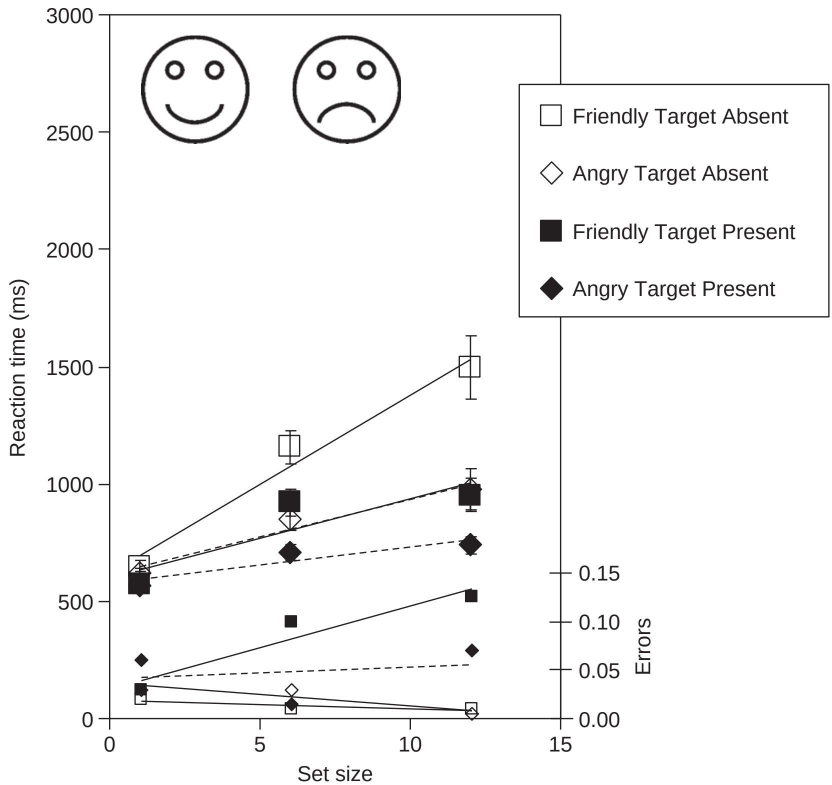

Figure 3. Mean correct RTs and error rates for each of the 12 conditions in Experiment 1b. See also Figure 2.

Discussion

Experiment 1b revealed basically the same results pattern as Experiment 1a, attesting the robustness of the effects, and indicating that the presence or absence of the nose has no impact on the RSA. It is, however, interesting to note, that search is slightly less efficient with than without the nose, consistent with the observation that search is generally less efficient with more complex stimuli (Horstmann, 2009).

Taken together, Experiments 1a and 1b demonstrate that the RSA for negative faces can be replicated in the present design, and with the present schematic face stimuli. The next experiments were conducted to identify the potential perceptual factors that supposedly underlie the RSA for negative faces.

EXPERIMENT 2

After having replicated the basic effect, we now wanted to know whether it is based on the perceptual attributes located in the lower half of the face, that is, the mouth and adjacent chin, as suggested in the introduction. Many studies found an RSA for negative face stimuli that differed from positive faces only in the curvature of the mouth-line, which might tap mechanisms of redundancy and/or self-similarity to the spatially adjacent facial outline. To examine whether the RSA critically depends on this ensemble, we erased 75% of the faces' outline in Experiment 2, leaving only the lower 25% "chin" part (see Figure 1c for an example of the stimuli). A replication of the RSA with these stimuli would yield prima facie evidence that the critical component underlying the RSA is in fact the mouth–chin ensemble.

Method

Participants. Eight students (three women), with a mean age of 24.3 years ($SD = 3.1$), participated in Experiment 2.

Design, stimuli, and procedure. These were basically the same as in Experiment 1b except that the upper 75% of the faces outline were erased (see Figure 1c).

Results

Slopes. Figure 4 shows the grand means for RTs and errors of Experiment 2. Table 1 summarizes the results of the ANOVAs, and Table 2 reports the mean slopes and intercepts. The ANOVA of the slopes for RTs revealed significant main effects for target presence, revealing shallower slopes for target present

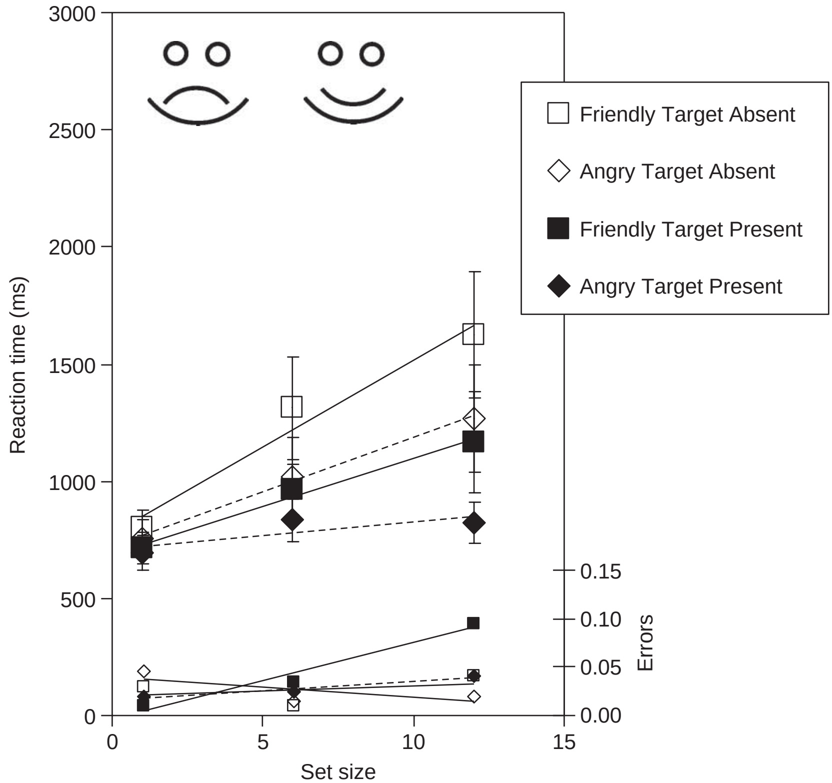

Figure 4. Mean correct RTs and error rates for each of the 12 conditions in Experiment 2. See also Figure 2.

than for target absent trials (26 vs. 60 ms/item). Moreover, the main effect for target stimulus was significant, revealing shallower slopes for negative targets among positive crowds than for positive targets/negative crowds (29 vs. 57 ms/item). A corresponding ANOVA of the slopes for error proportions revealed a marginally significant main effect for target presence, reflecting steeper slopes in the target present than in the target absent condition (0.005 vs. -0.001 errors/item).

Intercepts. The ANOVA of the intercepts for RTs revealed no significant main effects or interactions. The corresponding ANOVA for the errors revealed a main effect of target presence, indicating more errors in the target present condition (0.03) than in the target absent condition (0.01). Thus, target misses were more frequent than false alarms.

Discussion

Experiment 2 indicates that eliminating most of the face's outline has virtually no impact on the RSA. This is a first indication that the RSA may not be driven by a holistic mechanism that depends on the complete configuration of a schematic face, but may in fact be due to some critical components. Importantly, the results are consistent with the idea that perceptual properties of the mouth–chin ensemble drive the RSA. The next experiments were designed to further identify the critical conditions for the RSA.

EXPERIMENT 3

The aim of Experiments 3 was to test our similarity-based account of the RSA. As in Experiment 2, faces were composed of eyes, mouth, and a line segment from the head's outline. Experiment 3, however, tested two stimulus pairs in a within-subjects design: First, the *reference* pair of emotional faces was identical to the stimulus tested in Experiment 2, that is, faces consisted of eyes, mouth, and adjacent facial outline segment located at the bottom of the face ("chin"). Second, the *critical* pair of emotional faces consisted of the same components, but differed from the reference stimuli in that the facial outline segment was rotated around the circles centre by 180°. In other words, the visible facial outline segment was positioned at the top of the circle ("forehead"). Thus, in the reference pair, the friendly faces were more self-similar than the negative faces, whereas in the critical stimuli, the negative faces were more self-similar (because the curvature of the mouth-line was parallel to the facial outline located at the top).

If our reasoning is correct and the RSA depends critically on the similarity between the discriminating feature (the mouth) and a nondiscriminating feature that is common to all stimuli (parts of the outline), then we should be able to reverse the RSA by reversing these similarity relations. That is, we would expect to find the classical RSA for negative faces with the reference stimuli, but a reversed RSA, that is a RSA for positive faces, with the critical stimuli. Such a result pattern would strengthen the view that the classical RSA is primarily driven by perceptual and not affective factors.

Note that this reasoning is based on the assumption that similarity between salient components of the stimulus is more important than spatial proximity. If, in contrast, spatial proximity is of overriding importance, the critical stimuli might not show any benefits for either positive or negative faces, because the critical parts are located further away from each other.

Method

Participants. Twelve students (seven women), with a mean age of 24 years ($SD = 2.3$), took part voluntarily, and for remuneration (€4).

Design. The complete experiment consisted of two stimulus conditions, each comprising two blocks: One with the positive face as the target and the negative face as the distractor, and one with the reversed mapping. That is, for each stimulus condition, the design was the same as in the previous experiments.

The stimulus conditions only differed in the tested stimuli. A constant mapping procedure was used as before: Within each block, identities of target and distractors were fixed, and the variables set size and target presence were varied randomly from trial to trial within blocks. The order of the blocks within each subexperiment was balanced, as was the stimulus–response mapping (left vs. right response key for target present vs. absent responses). To keep the task simple for the participants, the stimulus–response mapping remained the same over the two stimulus conditions. Both stimulus conditions (reference vs. critical stimulus pair) appeared equally often at the first or the second serial position, in order to control for positional order effects.

Apparatus. The experiment was controlled by a computer connected to a 17-inch colour monitor that was run with a resolution of 1024×768 pixels for stimulus presentations, and to a keyboard used to transmit the manual responses. ERTS was used for event scheduling and response registration.

Stimuli and procedure. These were the same as in Experiment 2, with the following exceptions: First, in addition to the "chin" stimuli (Figure 1c) as a reference, the "forehead" stimuli (Figure 1d) were tested. The stimuli measured 1.3×1.3 cm. Viewing distance was 120 cm. In each trial, 1, 6, or 12 facial stimuli were presented without overlap within an area of about 8.5×6.5 cm. Individual faces were presented on an imagined 4×3 (horizontal $\times$ vertical) position matrix. Mean distance between faces (centre-to-centre) was 2.4 cm. The stimulus positions were jittered by random displacement, as before.

Results

Slopes. Figure 5 shows the results. The ANOVA of the RT slopes with the variables stimulus (reference vs. critical), target presence (present vs. absent), and crowd valence (positive vs. negative) revealed a significant main effect for stimulus, $F(1, 11) = 9.1$, $p < .05$, indicating that searches through crowds of reference stimuli were more efficient than through critical stimuli (29 vs. 42 ms/item), and a main effect for target presence, $F(1, 11) = 27.5$, $p < .001$, reflecting the well-known effect of more inefficient searches in the target absent than in the target present trials (48 vs. 23 ms/item). The crowd effect was not significant, $F < 1$. The Stimulus × Presence interaction was significant, $F(1, 11) = 15.5$, $p < .01$, indicating that the target presence effect was weaker in the reference than in the critical stimuli. Importantly, the Stimulus × Crowd identity interaction was significant, $F(1, 11) = 26.2$, $p < .001$, revealing that search was more efficient through positive (17 ms/item) than negative crowds (41 ms/item) of reference stimuli, $t(11) = 4.09$, $p < .01$, although less efficient through positive (51 ms/item) than negative (32 ms/item) crowds of critical stimuli, $t(11) = 4.30$, $p = .001$. The three-way interaction was also significant, $F(1, 11) = 9.1$, $p < .05$, indicating that target presence had a stronger effect on the difference between positive and negative crowds for the critical stimuli than for the reference stimuli.

A corresponding ANOVA of the error proportions basically revealed the same results pattern except with regard to the three-way interaction, which was not significant: Stimulus, $F(1, 11) = 14.1$, $p < .01$; presence, $F(1, 11) = 19.6$, $p < .01$; Stimulus × Presence, $F(1, 11) = 5.0$, $p < .05$; Stimulus × Crowd, $F(1, 11) = 4.9$, $p < .05$; other Fs < 1. The effects were in the same direction as the RTs effects except for the effects involving target presence, which is

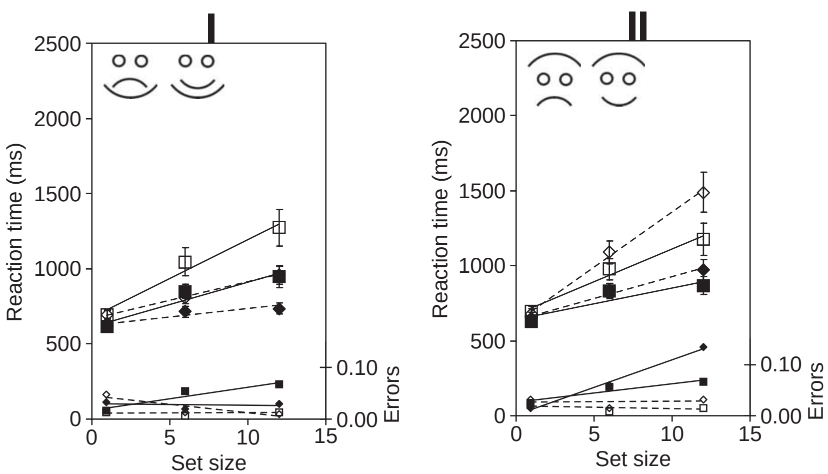

Figure 5. Mean correct RTs and error rates for each of the 24 conditions in Experiment 3. I (left panel), and II (right panel), provide the results for the chin stimuli, and the plate stimuli, respectively. Solid symbols represent target present trials and open symbols target absent trials. Diamonds code for negative face crowds with or without a positive face target, whereas squares code for positive face crowds with or without face negative targets. The figure also displays the linear trends obtained by linear regression analysis. Error bars show the standard errors of the mean for the RTs.

obviously due to the fact that participants missed some presented targets but rarely gave false alarms in crowd-only trials.

Intercepts. The ANOVA of the intercepts for the RTs revealed a significant main effect for target presence, $F(1, 11) = 15.8$, $p < .01$, reflecting a lower intercept in target present than in absent trials (628 vs. 660 ms), and a Stimulus × Presence interaction, $F(1, 11) = 10.7$, $p < .01$, reflecting that this effect was stronger for the reference than critical stimuli (10 vs. 53 ms). The other effects were not significant, $F < 2.3$. The ANOVA for the intercepts of the errors revealed no significant effects, Fs < 3.6.

Discussion

Experiment 3 reveals that the self-similarity or simplicity of facial stimuli is critical for the RSA observed with negative faces: The usual RSA for negative faces can only be observed when the facial outline segment is curved in the same direction as the mouth-line of positive faces; in contrast, when the facial outline segment is curved such that it is more similar to the mouth-line of negative faces, the usual RSA is reversed, showing more efficient search for positive faces among negative crowds than vice versa. This result pattern is consistent with the hypothesis that self-similar distractors can be rejected easier from search, which facilitates detection of the more dissimilar target face. In fact, we predicted this result on the assumption that it is the similarity between the discriminating feature of the target (i.e., the mouth) and a nondiscriminating feature of the stimulus (i.e., the facial outline segment) that is common to all stimuli is an important determinant of the RSA for affective faces.

Remarkably, self-similarity in Experiment 3 even modulated the RSA when the critical elements (i.e., facial outline segment and the mouth-line) were located farther away from each other, indicating that the classical RSA does not strongly depend on the spatial proximity of the critical elements.

RATING STUDY FOR EXPERIMENT 3

Proponents of the affective feature account may contend that the configuration change in Experiment 3 also altered the affective valence of the stimuli. In particular, it may be argued that perceptual factors could only modulate the RSA in Experiment 3 because the stimuli had lost their affective appeal, or because the affective appeal of the faces was covaried with changes in the configuration of the facial outline. In response to this possible objection, we conducted a rating study that asked for subjective judgement on three scales, these being activity (active–passive), pleasantness (pleasant–unpleasant), and potency (strong–weak). We chose these scales (cf. Osgood, Suci, & Tannenbaum, 1957) rather than a valence (positive–negative) scale because we regard a direct query in judging valence problematic in that it is pragmatically unclear whether the task is to judge the stimulus (the sign) or the designated object (the referent). A stimulus, however, can be more clearly judged as, for instance, pleasant or unpleasant. Note that pleasantness is the variable of prime interest; activity and potency are collected only for completeness (e.g., Lipp et al., 2009b). A secondary benefit from requiring three judgements is to obscure the research question, and to divert attention from the pleasantness judgement.

Method

Participants. These were 30 students (17 women), with a mean age of 26.4 years ($SD = 3.2$).

Procedure, stimuli, and design. Participants were given a five-page booklet. The first page included the instructions, "In the following, you will see one picture on each page, along with three scales concerning the contrasts passive–active, pleasant–unpleasant, and weak–strong. Please judge each stimulus on each of the three scales, by circling or crossing the corresponding scale point." After an example of the three scales with crosses at different points, the instruction continued: "Please always judge the first impression of the given picture", followed by prompts to indicate age and sex. Each 7-point scale ran from -3 over 0 to 3, with each of the scale points being labelled by the corresponding number. The poles of the three scales were labelled passive, unpleasant, and weak on the left side, and active, pleasant, and strong respectively, on the right side. The following four pages contained the four stimuli, one on each page, along with the three scales.

Results

Mean ratings are presented in Table 3. Analysis was conducted using three separate Facial emotion (positive vs. negative) × Stimulus type (critical vs. reference) ANOVAs. The ANOVA on activity revealed a main effect for

TABLE 3
Mean ratings for the four stimuli used in Experiment 5

	Activity		*Pleasantness*		*Dominance*	
	Critical	*Reference*	*Critical*	*Reference*	*Critical*	*Reference*
Negative	−0.567	−0.333	−1.733	−1.400	−0.400	−0.600
Positive	1.567	1.500	1.767	1.567	0.933	1.067

facial emotion only, $F(1, 29) = 47.7$, $p < .001$ (other Fs < 1), revealing lower activity ratings for the negative than for the positive face (-0.45 vs. 1.53). The ANOVA on pleasantness revealed a significant main effect for facial emotion, $F(1, 29) = 105.3$, $p < .001$ (other main effect $F < 1$), reflecting lower pleasantness ratings for the negative than for the positive face (-1.57 vs. 1.67). The two-way interaction approached significance, $F(1, 29) = 2.97$, $p < .10$, indicating that the difference was somewhat larger with the critical stimuli. Finally, the ANOVA on potency revealed a main effect for facial emotion only, $F(1, 29) = 19.2$, $p < .001$ (other Fs < 1), indicating lower strength ratings for the negative face than for the positive face.

Discussion

The results of the rating study clearly support our assumption that the reference and the critical stimuli used in Experiment 3 do not differ with respect to their affective appeal. This bolsters our claim that the reversal of the RSA was indeed due to perceptual variations of the stimuli, and not to hidden variations of their emotional impact.

EXPERIMENT 4

The aim of Experiment 4 was to provide convergent evidence for the assumption that the RSA in intact faces (e.g., Experiments 1a and 1b) is due to the interaction between the curved line and the adjacent chin. In particular, Experiment 4 was designed to test whether the RSA can also be reversed by reversing the interaction between mouth and chin, when the spatial proximity between the mouth- and chin-line from the standard stimuli is preserved. This hypothesis was tested by mirroring the chin region from the standard stimuli, such that a local contrast in curvature between the mouth and the chin in the positive face stimulus was present, but absent in the negative stimulus. To preserve the impression of a schematic face, the facial outline was completely drawn, resulting in a facial stimulus with a "dent" in the chin region (see Figure 1e for an example). If the RSA in the standard face is indeed driven by the parallelism of mouth- and chin-line, then we would expect the RSA to be reversed in this experiment, where negative faces had parallel chin- and mouth-lines, whereas the chin- and mouth-lines of positive stimuli diverged.

Method

Participants. These were eight students (one women), with a mean age of 24.4 years ($SD = 2.4$).

Design, stimuli, and procedure. These were the same as in Experiments 1–2, except for the stimuli Figure 6 gives an example of the search display.

Results

Slopes. Figure 7 shows the grand means for RTs and errors. Table 1 summarizes the results of the ANOVAs, and Table 2 reports the mean slopes and intercepts. An ANOVA of the slopes for RTs and the errors revealed a significant main effect for target identity, reflecting that the slope in the positive target/negative distractor condition was less steep than in the negative target/positive distractor condition (61 vs. 101 ms/item). The main effect for target presence revealed the common result of steeper slopes in target absent than present conditions (51 vs. 112 ms/item). The corresponding analysis of the error slopes similarly revealed a steeper slope in target present than absent trials (0.006 vs. -0.001 errors/item), and a significant Stimulus $\times$ Presence interaction, revealing a very high slope in the condition where a negative face target was present among positive face distractors (see Table 1).

Intercepts. The ANOVA of the intercepts for RTs rendered no significant main effects. The corresponding ANOVA for the errors revealed a main effect for target identity, reflecting more errors with the negative stimulus, and a significant Stimulus $\times$ Presence interaction, revealing that

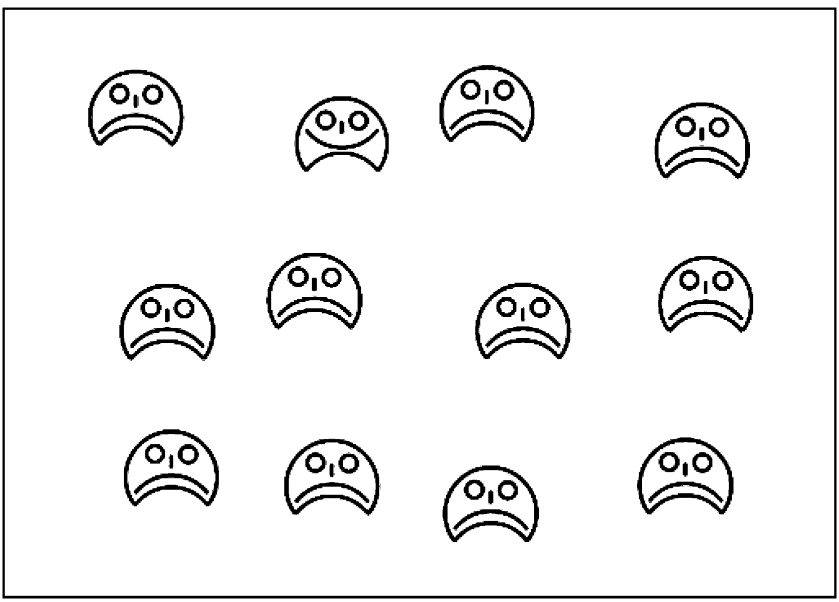

Figure 6. An example for the displays in Experiment 4, drawn to scale.

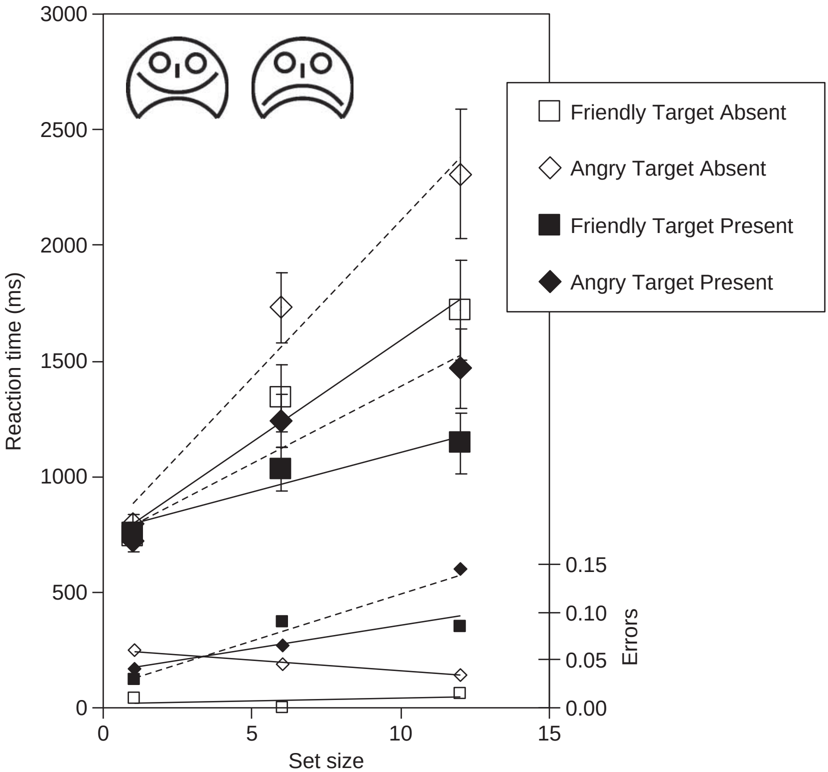

Figure 7. Mean correct RTs and error rates for each of the 12 conditions in Experiment 4. See also Figure 2.

many more negative face targets than positive face targets were missed; the false alarm rates were rather low for both stimuli (see Table 1).

Discussion

The final experiment revealed that a simple mirror reversal of the chin part of the face reversed the RSA. This result was predicted on the assumption that certain perceptual interactions between the mouth and the adjacent part of the face's outline are responsible for the commonly observed RSA.

Search was clearly inefficient, and even more inefficient than in Experiments 1–3. Horstmann (2009) observed that search for affective faces is generally more efficient with less complex faces. Arguably, the chin inversion renders the face's shape more complex and possibly less easy to process. There might be also more crowding of the facial features with some complex faces, rendering segregation of the critical component difficult.

RATING STUDY FOR EXPERIMENT 4

We conducted a rating study for Experiment 4 that corresponded to that for Experiment 3.

Method

Participants. These were 30 students (17 women), with a mean age of 26.7 years ($SD = 5.7$). Participants were not the same as in the rating study for Experiment 4.

Procedure, stimuli, and design. These were the same as in the previous rating study with the difference that only two stimuli were judged, which were the stimuli from Experiment 4.

Results and discussion

The negative stimulus was judged as less pleasant than the positive stimulus (−1.97 vs. 1.9), $t(29) = 14.32$, $p < .001$, less active (−1.00 vs. 1.03), $t(29) = 6.84$, $p < .001$, and less strong (−0.30 vs. 1.20), $t(29) = 3.64$, $p < .001$. The results clearly show that the smiling stimulus is regarded as pleasant and the frowning stimulus as unpleasant, confirming our assumptions.

GENERAL DISCUSSION

The central result of the present study is the reversal of the RSA in Experiments 3 and 4. Experiments 1a and 1b showed that the commonly observed RSA favouring negative faces can be replicated with the present procedure and type of stimuli. Experiment 2 revealed that the RSA still occurs when a large portion of the facial outline is deleted, leaving only the "chin" part of the face's outline. Experiment 3 and 4 were devised to further test the assumed crucial role of the concordance/discordance of the mouth and the chin. For this reason, Experiment 3 tested the stimulus pair of Experiment 2 as the reference stimulus, and a modified version of this pair where the visible and invisible parts of the facial outline were rotated by 180° as the critical stimulus. Results showed the typical RSA in the reference stimuli, but a reversed RSA in the critical stimuli. Crucially, a rating study confirmed that the affective valence of the critical stimulus pair was no different from the reference stimulus pair. Thus, the RSA was reversed with a very simple modification of the stimuli while holding affective valence constant, strongly suggesting that the change in the direction of the RSA was due to the perceptual modification of the stimuli, but not of the affective valence. Finally, Experiment 5 used a different manipulation to test whether the concordance/discordance of the mouth–chin ensemble is causally responsible for the direction of the RSA. In Experiment 4 the chin part of the face was inverted, such that the curvature of mouth and the chin were concordant in the negative stimuli and discordant in the positive stimuli. Visual search with these faces was more efficient when the target face had a discordant mouth–chin ensemble, although in Experiment 4, this was the positive face. Again, ratings secured that the affective meaning of the faces was retained even after the radical change in the stimulus outline: The smiling faces were perceived as more positive than the frowning faces.

The present results support the perceptual factors hypothesis that the RSA for schematic affective faces can be explained by perceptual factors. It is important to emphasize that the perceptual manipulations were not chosen ad lib. Rather, the manipulated characteristics (i.e., concordance/discordance of the mouth chin–ensemble) are widely acknowledged to result in a possible perceptual confound (e.g., Frischen et al., 2008). The present experiments thus strongly suggest that the direction of the RSA in typical schematic faces is in fact dependent on this perceptual factor.

The affective feature hypothesis, however, is not supported by the present data. In particular, the reversed RSA in Experiment 3 and 4 is contrary to what the affective feature hypothesis predicts. However, it should also be clear that the present experiments were not designed to test the affective feature hypothesis in the first place: This would have required the variation of affective valence while holding constant perceptual appearance (e.g., Beatty et al., 2005; Gerritsen et al., 2008). But even so, the present results weaken the support for the affective feature hypothesis, because the RSA favouring negative schematic faces is a cornerstone in the evidence for the affective feature hypothesis. The present results, in turn, show that this RSA can be explained by a purely perceptual account: The direction of the RSA in the present experiments is apparently determined by the concordance/discordance of mouth–chin ensemble, and not by the positive or negative valence of perceptually concordant or discordant faces.

We propose that Gestalt-like interactions between the discriminating feature and the constant context are the key for an understanding of the prevalent search advantage for negative face targets. It is interesting to note that, in the standard schematic faces, the mouth-line of positive faces is parallel to the chin, but differs largely from the forehead-line, whereas for negative faces, this configuration is reversed (i.e., the mouth-line is parallel to the forehead-line, but runs contrary to the chin-line). Why is it the case that similarity to the chin seems to be more important than dissimilarity to the forehead of the same stimulus? We suspect that mouth–chin similarity is more important than mouth–forehead similarity because (a) mouth and chin are spatially more proximate than mouth and forehead, and (b) mouth and chin are not separated by additional objects, whereas mouth and forehead are separated by eyes and nose. In Experiments 3, however, the constant element is presented either in the chin or in the forehead position alone, and was thus the only salient curved line apart from the mouth. Therefore, this was the most salient curved feature with which the other salient curved feature (the mouth) interacted. It should be noted here that the perceptual factors driving the RSA with emotional schematic faces may not be responsible for the RSA observed with more complex and more realistic stimuli (e.g., photographic images). This, however, does not question the value of the present experiments, because studies using schematic stimuli similar to those used in the present experiments are the centrepiece of existing evidence favouring the threat-advantage hypothesis (see introduction). In fact, studies assessing search efficiency for photographic faces have yielded results inconsistent with the threat-advantage hypothesis (e.g., Lipp et al., 2009b). In particular, realistic faces from the KDEF (Karolinska Directed Emotional Faces; Lundquist, Flykt, & Öhman, 1998) typically show a happy face advantage (e.g., Calvo & Nummanmaa, 2008). Calvo and Nummenmaa (2008) arrived at the conclusion that the search advantage is due to perceptual factors, in particular to the visual saliency of the happy-face typical smile, which was determined using the Itti and Koch (2000) model (see also Lipp et al., 2009a, 2009b).

In the introduction, we reviewed two hypotheses regarding the mechanism that explain the influence of concordance/discordance on the RSA. Both hypotheses build in particular on distractor rejection as an important process determining inefficient search. First, Rauschenberger and Yantis (2006) suggested that stimulus redundancy (the inverse of complexity) renders distractor rejection quite efficient. Unfortunately, redundancy is not easily defined or operationalized. In their empirical work, Rauschenberger and Yantis used the reflections & rotations (R&R) heuristic, which consists in counting the number of different stimuli that result from reflections about the vertical and horizontal axes and 90° rotations. If the number of different stimuli that result from these R&R transformations is small, the stimulus is highly redundant. In contrast, if the number is high, then the stimulus is highly nonredundant or complex. Evidently, positive and negative faces do not differ in redundancy as determined by the R&R heuristic. However, as Horstmann, Scharlau, and Ansorge (2006) pointed out, self-similarity, that is the resemblance of components of a complex stimulus, may be an aspect of redundancy. On this account, the more self-similar (concordant) distractors were more quickly processed than the less self-similar (discordant) distractors.

Another account can be derived from attentional engagement theory (Duncan & Humphreys, 1989). According to this view, the rejection of one distractor leads to spreading inhibition of similar stimuli. A possible problem with the positive targets (except those in Experiments 3 and 4) is that they are defined by a discriminating feature (mouth) that is similar to a nondiscriminating feature (circle segment). The rejection of a negative distractor may lead to the inhibition of the positive mouth because of the spreading inhibition from the outline circle to the spatially adjacent and similarly curved mouth. When, as in Experiment 3, not a full circle but only a segment is displayed as a nondiscriminating feature, proximity is no longer important—as in the "forehead" stimuli, probably because forehead-curvature gains salience due to the omission of the lower face (relative to the full-circle outline, in Experiment 1a and 1b)

The exact causal structure underlying the RSA and its reversal is not yet understood, and unveiling it further presents an important challenge for future research. Based on our results, we regard our similarity-based account as highly successful in accounting for the RSA. However, it is probable that other perceptual factors add to the RSA, and that the contribution of factors depend on the particular design of the facial stimuli. For example, it might be noted that the eyes–nose–mouth ensemble itself has a simpler Gestalt in the positive than in the negative face, due to the fact that the configuration in the positive, but not the negative face, reveals closure (note, however, that Schubö, Gendolla, Meinecke, & Abele, 2006, did find faster searches for negative than positive faces with facial outline, but no difference without the facial outline, indicating that the facial outline is crucial for the negative face advantage). We view the present research, however, as a sound step forward in emphasizing the importance of perceptual factors in cognitive tasks with affective stimuli. Importantly, the present experiments show that the RSA can be reversed by simple perceptual changes of the stimuli that, however, leave the affective valence relatively unchanged. Thus, the direction of the RSA varies with perceptual changes, but not with the emotion implied by the face.

Discussion of problems of interpretation

The current conclusions might be contested on several grounds, which shall be discussed in the following. First, the present study might be criticized for using a common variant of the visual search task that, however, differed from the task of other authors (e.g., Eastwood et al., 2001; Öhman et al., 2001). In particular, search for specific targets is blocked, instead of being randomly intermixed within blocks. However, it is difficult to see how the blocked design could present a problem for our interpretation. Horstmann

(2006) found virtually no differences in results when displays were presented once in the blocked design as used here and once with a random variation of targets. The reason we opted for this design is that it allows measuring the deployment of attention under more controlled conditions, without interference from individual search preferences. More specifically, the disadvantage of a nonblocked (randomly intermixed) presentation is that it cannot be excluded that participants impute search priority on one of the targets, supporting more efficient search for this target.

Second, we used the classical asymmetry design where targets and distractors change roles, rather than the constant-distractor design, where different targets have to be searched for among constant "neutral" distractors. This classical asymmetry design has, however, been criticized because it confounds effects of the targets and effects of the distractors (Eastwood et al., 2001). We would like to offer two replies: (a) The constant-distractor design suffers from the yet unsolved problem of choosing the correct (perceptually) neutral stimulus (see introduction). (b) The effect of the distractors is not unknown in the search asymmetry design but can be estimated from the data. Horstmann (2009) found that mean performance in the target absent trials predicted mean performance in the target present trials almost perfectly. The same computation can be performed on the present data, by representing each experimental condition as a point, where x is mean search efficiency in target present trials and y is mean search efficiency in the corresponding target absent trials. These 12 points align nicely around a line described by the equation $y = 1.70x + 15.49$, which accounts for a variance of $R^2 = .87$, corresponding to a correlation of $r = .93$. This means that distractor rejection accounts for almost 90% of the variance in search efficiency, not leaving much room for attentional guidance by the target in a narrower sense. That the amount of explained variance in the present data set is somewhat lower than in Horstmann might be attributed to the larger variety of stimuli, where other processes affecting search efficiency contributed to different degrees (e.g., partial rescanning of the crowd due to uncertainty in target absent trials). In addition, Horstmann used a within participants design, which controls for between-participants variations.

Third, proponents of the affective feature hypothesis could argue that the visual search paradigm is inadequate at all to reveal attentional guidance by affective features, because it yields the strong affordance to use perceptual features, so that participants in turn are lured to use perceptual features. Such a response to the presented experiments, however, would mark a turning point in research on affective features, since the visual search paradigm was hitherto the backbone of this research. This is also reasonable, because the appeal of the affective feature hypothesis lies in the analogy between preattentive processing of, for example, colour and the hypothesized affective feature. In order to safeguard the affective feature hypothesis, its proponents would have to specify in which way attentional guidance by affective features should be conceptualized if not in analogy to attentional guidance by, for example, colour.

Fourth, another possible criticism concerns the question whether perceptual changes in the faces might have been confounded with their emotional impact. For instance, in Experiment 3, the chin of the face was removed, rotated, and included as a forehead arc. However, from an emotion theorists standpoint, the forehead arc could be alternatively interpreted as eyebrows, which has been proposed to influence emotion perception (Lundquist & Öhman, 2005; Öhman et al., 2001). According to Öhman and colleagues, with the implied position of eyebrows, the negative face could be interpreted as sad (as opposed to angry). The possibility that the negative stimuli in Experiment 3 are perceived more as sad than as angry gains some support from the activity and potency judgements that were lower for the negative than for the positive stimulus in the first rating study: Sadness is usually seen as low in activity and potency, whereas anger is seen as high in activity and potency. Importantly, however, this result pertained to all stimuli in Experiment 3, not only to the critical stimuli with the altered perceptual features. Because Experiment 2 and the corresponding condition in Experiment 3 found the typical RSA pattern, the question of whether the negative stimuli look angry or sad is irrelevant for the present study. Moreover, the only reliable difference between the reference stimuli with the "chin" and the critical stimuli that had a "forehead" pertained to judged pleasantness; however, the difference between the positive and the negative stimulus was even smaller for the standard reference stimuli than for the critical stimuli.

In a similar vein, it might be critically noted that the face stimuli in Experiment 4 were deformed, and thus it may appear debatable to assume equivalence to the traditionally used sketchy faces. However, stimuli that were used in previous studies (e.g., Eastwood et al., 2001; Fox et al., 2000; Nothdurft, 1993; Öhman et al., 2001; White, 1995) violated some morphological and biomechanical constraints of real faces as well (cf. Horstmann, Borgstedt, & Heumann, 2006; see also Horstmann & Ansorge, 2009). Real faces are not circular shaped; when the mouth is moved in smiling, the upper lip is raised; in anger, the jaw is lowered; eyebrows are not tilted on a central pivot. This reveals two points. First, schematic faces in general are not realistic representations of faces, and they reduce real faces to some essential iconic properties (Horstmann, 2002b). Second, criticizing our stimuli for their deformation is ad hoc if at the same time other strongly reduced stimuli from previous studies are interpreted as support for the affective features hypothesis. In addition, the novel stimuli were not deformed beyond recognition: The rating study confirmed that the negative face stimulus is still judged as more unpleasant than the positive face stimulus.

Fifth, although the novel stimuli may still be viewed as positive or negative, they may no longer be perceived as faces. It might be argued that the deletion or change of the facial outline might have altered "facedness", which in turn might be important for the excitation of face specific modules in the brain. We like to offer three arguments. First, it should be noted that previous research has used even more simple faces, for example, compiled from only three differently oriented round brackets, and that results that appeared consistent with the affective features hypothesis have been interpreted as supporting this view (e.g., Eastwood et al., 2003). Second, imaging studies show that even alienated stimuli like Mooney faces, which consist of irregularly black and white areas, clearly activate the fusiform face area (FFA; Kanwisher, Tong, & Nakayama, 1998). Third, the face sensitivity of humans is so prevalent that it is extremely difficult to get around it. We found it almost impossible to create stimuli from the components of facial expressions that do not look like faces; for example, even with five, or with no, eyes, schematic faces look like faces. In a similar vein, the artists F. Robert and J. Robert (2005) photographed mundane objects, which exhibit strong impressions of facedness.

Sixth, proponents of the affective feature hypothesis might demand an explanation for the finding that anxious persons (e.g., with social phobia) exhibit a stronger RSA for negative faces than nonanxious persons (e.g., Eastwood et al., 2005): The modulation of the RSA by anxiety strongly suggests that affective processing plays a role in the RSA. However, we contend that it is unclear whether the results show that anxious persons are particularly sensitive for, or whether they are particularly responsive to feared stimuli. For one, anxious persons might be more motivated to search for the feared stimuli. Moreover, it is important to note that the modulation of search efficiency by affective content may reflect that anxious persons have problems in disengaging attention from fear-provoking stimuli when they constitute the distractors.

CONCLUSION

How could we now theoretically analyse the case of the hiker in the woods spotting the snake (cf. LeDoux, 1998)? There are several established mechanisms that may be engaged in this situation. First, the hiker, cautious of the possible presence of certain dangerous animals, may have established an attentional set that guides attention towards certain movement patterns, or towards a certain colour, or whatever other simple attributes he believes characterized the feared animal (Ansorge & Horstmann, 2007; Ansorge, Horstmann, & Carbone, 2005; Folk, Remington, & Johnston, 1992; Horstmann & Ansorge, 2006; Yantis & Egeth, 1999). Note that in this case, he will probably miss other dangerous animals that fail to meet the searched-for specification (Mack & Rock, 1998). Alternatively, he or she may more generally search for salient stimuli, that is, for stimuli that differ in any of their simple perceptual features from their surrounds, for example, the curling movement of the snake against the stationary stimuli, or the light-green colour of the snake that differs from the dark-green moss (Bacon & Egeth, 1994). Note that in this case, the hiker's attention would be attracted to various salient stimuli in the woods, of which only a fraction are important. On the other hand, he or she would miss a camouflaged animal that is similar to its surround. Third, the hiker's attention may be attracted to expectancy-discrepant ("surprising") stimuli, such as a suspiciously coloured or moving stimulus encountered after a period of walking through a homogeneously coloured and motionless region (Horstmann, 2002a, 2005, 2006). Note that in this case, he or she might miss the moving green snake if he had previously encountered numerous moving green objects (e.g., frogs) that he had decided to ignore. Finally, some visually salient stimuli may involuntarily capture attention, such as looming objects, or fast-moving objects (Franconeri & Simons, 2003).[2] Given that all these mechanisms are established theories of attention, it is questionable whether we would additionally need a threat detector to explain the results: The assumption that threatening stimuli can be attended in virtue of their threat potential only seems to be justified if it is impossible to explain the observed effects on the basis of the existing and well-known factors and search mechanisms known to affect search performance. The present study strongly supports the view that the search asymmetry for negative schematic faces is due to perceptual factors and, thus, obviates the need to include such additional affective, attention-guiding factors.

To conclude, the RSA favouring negative schematic face targets among positive schematic face nontargets over the alternative mapping can be reversed by rather simple perceptual changes. Importantly, these changes were done to the effect that finally the negative face is characterized by a configuration of facial components that is normally associated with the

[2] The phylogenetic origin of some features of emotional expressions might indeed be rooted in an evolutionary process that selected for salient and conspicuous features, like high contrasts as in the eyebrows, or movement as in dynamic facial expressions, for which the perceptual system is already highly sensitive to. Horstmann and Ansorge (2009) and Horstmann and Bauland (2006) contrasted this perceptual bias hypothesis on the phylogenetic origin of facial signals with the original affective feature detector hypothesis (e.g., Öhman et al., 2001). The difference of the two hypotheses is that the perceptual bias hypothesis states that facial expressions evolved to fit the perceptual system, whereas the affective feature hypothesis states that perceptual system evolved to fit the demand of detecting facial expressions.

positive schematic face. Moreover, the changes do not strongly influence the perception of the stimulus as a face, nor does it strongly change the ease with which the stimuli can be categorized as pleasant or unpleasant. The results question the conclusions drawn from previous experiments with respect to alleged emotional influences on visual search efficiencies.

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