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Attentional effects of negative faces: Top-down contingent or involuntary?

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Recent research has substantiated that schematic negative faces are found more efficiently than positive faces among crowds of distractor faces of varying set sizes. The present study asks whether this relative search asymmetry (RSA) is intention driven or due to involuntary attentional capture. To that aim, participants were first tested in a condition in which negative and positive faces were searched for, and then in a condition in which negative or positive schematic faces appeared at chance level at the position of the target (valid trials) or of a distractor (invalid trials), the faces thus being task irrelevant (the 1/*n* paradigm). The expected search benefit for valid negative-face target trials most clearly occurred when participants searched for a target defined by a conjunction of color and position; when the target was defined either by an orientation or color singleton, we found rather weak or no evidence for involuntary attention capture by negative faces. We see the results as being (1) evidence that the RSA is partly based on stimulus-driven factors that occur independently of the intention to search for a positive or negative face, and (2) consistent with the assumption that the effects are mainly due to a more efficient rejection of positive-face than of negative-face distractors, rather than being due to attentional capture by the target.

The hypothesis that affective stimulus characteristics—for example, the negative valence of angry facial expressions of emotion or the threat potential of spiders or snakes—are preattentively available and may even involuntarily capture attention has aroused the interest of researchers from such diverse research domains as perception (Eastwood, Smilek, & Merikle, 2001, 2003; Nothdurft, 1993; Purcell, Stewart, & Skov, 1996), psychophysiology (e.g., Lipp & Derakshan, 2005), social cognition (Hansen & Hansen, 1988; Öhman, Lundqvist, & Esteves, 2001), emotion (Calvo & Avero, 2005; Fox et al., 2000; Fox, Russo, Bowles, & Dutton, 2001; Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004, 2005; White, 1995), clinical psychology (e.g., Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005; Vuilleumier & Schwartz, 2001), and neuroscience (Vuilleumier, Armony, Driver, & Dolan, 2001).

The reasons for an interest in this possibility are manifold. For one, the identification of *basic features* in vision that are the building blocks for visual perception is an important research topic in vision research. Traditional theories of visual attention assume that only rather simple stimulus features such as color, brightness, or spatial frequency are computed before focal attention is directed to them, and some attention researchers specifically doubt that faces and facial expressions are among these preattentively available stimulus features (see, e.g., Wolfe & Horowitz, 2004). Evidence that facial expressions are preattentively available and can thus be used to guide attention would indicate the necessity of revising current thinking about preattentive and attentive processes.

Second, there has long been an interest in the causes of an involuntary orienting of attention (James, 1890), which has been the target of extensive research since the 1980s under the heading of *attentional capture*. In the attention literature, the term *involuntary capture of attention* normally refers to a shift in visuospatial attention, where a stimulus, which is outside one's current focus of attention, instigates a movement of attention to its location. The stimulus conditions of involuntary capture of attention, however, are heatedly debated. Some authors propose that perceptually salient stimuli automatically capture attention (e.g., Theeuwes, 1992), whereas others hold that only abrupt onsetting stimuli can capture attention, in a purely stimulus-driven fashion (e.g., Jonides & Yantis, 1988). Some researchers even deny the existence of truly involuntary capture of attention at all and instead assert that all shifts of attention ultimately depend on the intentions of the observer (i.e., *contingent capture of at-*

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tention; see Folk, Remington, & Johnston, 1992, 1993), except perhaps for expectancy-discrepant stimuli (Horstmann, 2002, 2005, 2006). None of these theories would predict, or could explain, the capture of attention by an angry facial expression.

Third, the hypothesized preattentive processing and automatic attentional prioritization of certain affective information can be connected to important assumptions in emotion research. Emotion theorists traditionally assume that the main causes of emotions reside in nonconscious processes (see, e.g., James, 1884; LeDoux, 1998; MacLean, 1949). The involuntary capture of attention by facial expressions or other emotional stimuli would be consistent with such a position, insofar as unattended stimuli may receive elaborate processing only because of their emotional value. What is more, attention researchers have developed experimental paradigms to test claims about preattentive processing and involuntary capture of attention. Thus, there are means for substantiating important ideas of emotion theory using the methodology of a field that is known for its rigorous experimental standards.

Claims for an involuntary capture of attention by threatening stimuli have been based on different kinds of data, such as visual search efficiency (e.g., Öhman et al., 2001; Williams, Moss, Bradshaw, & Mattingley, 2005), global–local interference (Eastwood et al., 2003), spatial interference (e.g., White, 1996), or reduced extinction in unilateral neglect (Vuilleumier & Schwartz, 2001). The diversity in the fields of research interested in the interaction between emotion and attention, however, also introduces some uncertainty in the classical concept of attention and, especially, attentional capture. For example, Vuilleumier and Schwartz (2001) inferred attentional capture from a study of a neurological patient with unilateral visual neglect, who showed reduced extinction of emotional faces as opposed to neutral faces or shapes in the neglected visual field. However, this interpretation advocates criteria for attentional capture that might not be universally accepted because in the attention literature, involuntary attentional capture has usually been diagnosed by implicit measures, such as response times (RTs) or accuracy, but not by explicit measures, such as conscious reports (Simons, 2000). Thus, although there is certainly an overlap between the concepts of attention and awareness, it is not quite clear to what extent the studies cited above conform to the classical notion of attention that is shared by most attention researchers, and thus how they add to the current body of attention research. In order to preserve a clear reference to the common understanding of attention and attentional capture, as well as a close correspondence to contemporary attention research, the discussion will henceforth concentrate on experiments that have employed implicit measures of attention.

But even in studies using implicit measures, attentional capture has not always been used in the same way, nor has it always been diagnosed using unambiguous criteria. For example, in one study, involuntary attentional capture was inferred from stronger global–local interference with negative than with positive faces (Eastwood et al., 2003): Participants needed more time to count the number of face components when faces were negative than when they were positive. Although Eastwood et al. (2003) used the term *attentional capture*, they also clarified that their data were indicative of changes of attentional focus within the same spatial location. In contrast, the literature on attentional capture typically deals with spatial shifts of attention, where attention is shifted from one spatial location to another (e.g., Folk et al., 1992; Posner, 1980). In another study, White (1996) presented one or two faces (emotional or negative) printed in blue or gray, the task being to detect the blue face. Responses were slowed when the gray face was a negative face, but not when it was a positive face. Such an interference effect, however, is not unequivocal evidence for attentional capture; for example, the negative face may have engaged attention longer than the positive face in trials where participants incidentally shifted attention to the gray face. Last but not least, the most commonly used experimental paradigm for investigating attentional effects by emotional stimuli is the visual search paradigm, where participants typically have to search for a negative-face target among positive-face distractors (or vice versa) and indicate the presence or absence of the target by pressing a key. More often than not, such studies have found a relative search asymmetry (RSA; e.g., Fox et al., 2000; Horstmann, 2007; Horstmann & Bauland, 2006; Horstmann, Scharlau, & Ansorge, 2006), with more efficient detection of negative-face than of positive-face targets (but see Nothdurft, 1993; Öhman et al., 2001; White, 1995; Williams et al., 2005). More efficient search for negative- than for positive-face targets has been interpreted by some authors as indicating either attentional guidance by preattentively available features (Eastwood et al., 2001) or involuntary attentional capture (e.g., Dolan, 2002; Williams et al., 2005).

The interpretation of a RSA as evidence for preattentive processing or attentional capture is not, however, without problems. First, according to the two most prominent theories of visual search, feature integration theory (Treisman & Gelade, 1980) and Guided Search 2.0 (Wolfe, 1994, 1998), an RSA is not taken to be evidence for preattentive processing[1] (with preattentive processing of a feature being the precondition for attentional capture of that feature). Rather, preattentive processing is inferred from efficient search or perceptual pop-out, which is implied by the result that detection latency for the target is independent of the total number of stimuli presented in a single display (set size). This pattern of results is usually taken to be evidence that attention can be immediately guided to the target location without an attentional scanning of the whole display. In contrast, if the latency to find a target increases with the number of distractor items, this is evidence that attention is also deployed to the distractors, resulting in *inefficient search*. In this case, the target cannot be attended to as the first item in the display; rather, target detection is the result of a serial deployment of attention (Treisman, 1982, 1988; Treisman & Souther, 1985).

Straightforward evidence for preattentive processing thus requires efficient search, but this result has rarely been found for affective faces. The majority of studies showed rather inefficient search, even for a negative-face target. This in turn suggests that postselectional processes (i.e., processes commencing after the attentional selection of the target and, in particular, of the distractors) may account for the RSA. Possible postselectional processes that contribute to the search asymmetry include processes of perceptual identification (feature binding; see, e.g., Treisman, 1982), or decisional processes (see, e.g., Theeuwes, 1992; Wolfe, 2001). Thus, a first important distinction with respect to the possible origin of search asymmetries is the difference between a *preattentive locus*, where the search asymmetry originates from early processes involved in the guidance of attention, and an *attentive*, or *postselectional*, *locus*, where later processes unrelated to guidance of attention (e.g., perceptual identification) account for the search asymmetry.

A second major problem of assessing attentional capture by RSAs consists in the fact that, in the classic search-asymmetry design, variations in search performance can be due either to the saliency of the target or to the ability of the observer to quickly categorize and reject distractors (distractor rejection, or grouping; see, e.g., Duncan & Humphreys, 1989). This is true because the classical search-asymmetry design confounds target identity with crowd identity (see, e.g., Eastwood et al., 2001): The display consists of either one positive-face target among several negative-face distractors or one negative-face target among several positive-face distractors. Therefore, participants can fulfill the task equally well by selectively filtering out the distractors or by tuning their attentional control settings to the target. Thus, the finding that negative-face targets can be detected more easily than positive-face targets could also indicate that positive-face distractors are rejected faster from search than negative-face distractors. In fact, search slopes are also steeper with crowds consisting entirely of negative-face distractors than they are with crowds consisting of positive-face distractors (see, e.g., Horstmann, 2007, in press; Horstmann et al., 2006). This result indicates that the differential speed with which distractors are rejected is probably the most important determinant of search asymmetries (see also Duncan & Humphreys, 1989; Rauschenberger & Yantis, 2006). Thus, a second important distinction with regard to the possible source of RSAs is the difference between target-mediated and crowd-mediated effects on search performance. Both target-mediated and crowd-mediated effects may modulate search performance on a preattentive level, so that attentional capture by the target or faster grouping of the distractors results in faster selection of the search target. Alternatively, target- or crowd-mediated effects may be based on later, postselectional processes—for instance, differences in perceptual identification processes in the case of target-based effects, or differences in processes of de-allocating attention from distractors in the case of crowd effects.

The third and most critical problem of an attentional capture interpretation of the RSA is that the standard visual search task does not, in principle, test involuntary attentional capture. The 1990s saw an exhaustive discussion of the conditions necessary for inferring involuntary attentional capture from search experiments (e.g., Yantis, 1993; Yantis & Egeth, 1999; see also Becker, 2007), and these conditions have not been met by any of the published search experiments with faces. The reason is that the experimental tasks consistently required participants to search for an emotional face. As Yantis argued, participants in these experiments certainly have the intention of finding the target. Thus, even if the target can be found efficiently, one cannot conclude that the stimulus has involuntarily captured attention—that is, without or even against the intentions of the participants. In turn, the results are compatible with the (much weaker) hypothesis that the target could be detected efficiently because of top-down attentional control settings that specify the target. In order to infer involuntary attentional capture, it is necessary to ensure that the stimulus feature in question (e.g., facial expression) is entirely independent from the task to be accomplished. Involuntary capture by a given feature can then be inferred if the search slope is flat in trials where the test stimulus coincides with the target position (valid trials), but steep in trials where the target is presented at a distance from the test stimulus (invalid trials; see Yantis, 1993). As indicated above, this interpretation cannot be transferred directly to the RSA typically observed in search for emotional faces, because in these search tasks, search slopes are typically relatively steep across all conditions, which is a hallmark of inefficient search. Nevertheless, it is still possible to use the $1/n$ paradigm to investigate whether the RSA critically depends on the intention to find a negative versus a positive target face, or whether it is largely dependent on stimulus-driven processes that affect search performance independently of this intention. Depending on the search slope (or search efficiency), however, one might be more or less inclined to attribute differences in valid versus invalid trials to attentional capture (i.e., preattentive processes in attentional guidance), or to postselectional processes. Needless to say, better performance on valid than on invalid trials would be compatible with both target-mediated and crowd-mediated effects of facial affect, so we need to consider all possible combinations of the three pairs—"preattentive versus postselective," "target-based versus crowd-based," and "intention-driven versus stimulus-driven"—as potential sources of the search asymmetry. Note that although these three dimensions may determine visual search in any combination, attentional capture proper is normally understood to be one particular combination of preattentive, target-based, and stimulus-driven processes (e.g., Jonides, 1981; Jonides & Yantis, 1988; Yantis & Egeth, 1999).

The Present Experiments

The present experiments were designed to provide a critical test of the hypothesis that facial expressions involuntarily capture attention. In particular, we asked whether the RSA favoring negative-face targets in positive crowds can be plausibly explained by preattentive, target-based, and stimulus-driven processes.

We proceeded in two steps. First, we assessed the presence of a search asymmetry for a given pair of affective stimuli in a standard visual search task, where participants voluntarily searched for a negative- or positive-face target (Experiments 1A, 2A, and 3A). In the second step, we tested the same emotional faces in a different search task using the 1/*n* paradigm, where the emotional content of the faces was task irrelevant (e.g., Simons, 2000; Todd & Kramer, 1994; Yantis, 1993; Yantis & Egeth, 1999): a nose of a certain orientation (Experiment 1B), a particular conjunction of color and position (Experiment 2B), or a predefined nose color (Experiment 3B). In line with the requirements of testing involuntary attentional capture with the 1/*n* paradigm, the defining and the reported target features are both independently varied from the feature that is tested for involuntary attentional capture. For instance, in the present Experiment 1B, participants searched for a schematic target face among schematic distractor faces. The target face had either a rightward-pointing (>) nose or a leftward-pointing (<) nose, and distractor faces had an upward-pointing (∧) nose. The target face was thus defined by the left or right opening (as opposed to a bottom opening) of the nose. Participants reported the direction of the nose arrow (“>” or “<”) with a spatially congruent keypress (i.e., left when the arrow pointed to the left). Each crowd of faces comprised schematic positive or negative faces. All but one face showed the same expression—that is, each crowd contained an affective-singleton face. The affective-singleton face could be presented at the position of the target, in which case it would be a valid cue to the target’s position. Alternatively, the affective-singleton face could be presented at the position of one of the distractors, in which case it would be an invalid cue to the target’s position. Singleton and target positions coincided at chance level—that is, in only 1/*n* trials—with *n* being the number of stimuli in the display. Set size was also varied to allow an assessment of search efficiency.

Our predictions were as follows: First, on the basis of previous studies, we expected negative-face targets among positive-face crowds to be found more efficiently than positive-face targets in negative-face crowds in the standard search asymmetry task, where participants voluntarily search for an affective singleton (Experiments 1A, 2A, and 3A). Second, we reasoned that if this result is due to involuntary attentional capture of the negative faces, spatial attention should be quickly drawn to the location of the negative face, even when it is task irrelevant (the remaining experiments). In the 1/*n* paradigm, involuntary attentional capture is heralded by performance being much better in valid trials than in invalid trials. More specifically, if a negative-face singleton embedded in a positive crowd captures attention, search should be much more efficient with a negative-face singleton as a valid cue than with a negative-face singleton as an invalid cue, or with a positive-face singleton as either a valid or invalid cue, resulting in a three-way interaction of set size, singleton identity (negative vs. positive face), and cue validity (valid vs. invalid). In contrast, if the RSA is not due to involuntary attentional capture (but depends on the task-relevance of negative faces presented among positive distractors), there should be no differences between positive- and negative-face singletons when facial expression is irrelevant to the task. Parenthetically, we might obtain a search advantage on valid trials over invalid trials, if it is true that singletons are generally prioritized for attentional selection.

In addition to examining the question of voluntary versus involuntary processes, the design allows us to test the locus of the RSA with respect to attention. In particular, if the advantage for negative-face targets is due to preattentive processes, we expect flat search slopes in the standard search or the 1/*n* paradigm; if it is based more on postselectional processes than on preattentional processes, we would expect the search slopes to be quite steep in both tasks. Moreover, if the effects are postselective, validity effects in the 1/*n* paradigm should be considerably reduced or even eliminated when the target-defining feature can be found immediately. This prediction is tested in Experiments 3A, 3B, and 3C.

Finally, to test whether search asymmetries in the 1/*n* paradigm are due to target-mediated or crowd-mediated effects, Experiments 2C and 3C tested search performance with crowds of neutral distractor faces. If RT benefits for negative faces among positive crowds are due exclusively to the identity of the target, the same benefits should occur when the same target is embedded among a neutral crowd. If, on the other hand, the positive crowd accounts for the search asymmetry, differences between negative and positive singletons embedded in neutral crowds should be greatly attenuated or eliminated.

EXPERIMENT 1A

The aim of Experiment 1A was to replicate the more efficient search for negative-face targets in positive-face crowds than vice versa, as has been found in numerous studies with schematic stimuli. The replication of this RSA with the present stimuli is important for two reasons. First, it sets the stage for examining whether this effect is due to voluntary, top-down controlled factors, or whether it is due mainly to involuntary, stimulus-driven factors. Second, we must demonstrate that the modifications to the stimuli in Experiment 2B (i.e., adding the arrow-shaped noses) that were necessary for the test of involuntary attentional capture do not eliminate the attentional effects of the stimuli in a standard search task.

Method

Participants. The participants were 7 students (3 women), with a mean age of 21.7 years ($SD = 4.5$). One additional participant was tested but was not included in the analysis because of excessive errors (19% on average; this participant, however, would not have changed the results in any theoretically important respect).

Design. A 3 (set size: 1, 6, 12) × 2 (affective-singleton identity: positive, negative) × 2 (singleton presence: present, absent) design was employed. Each of the resulting 12 experimental conditions was

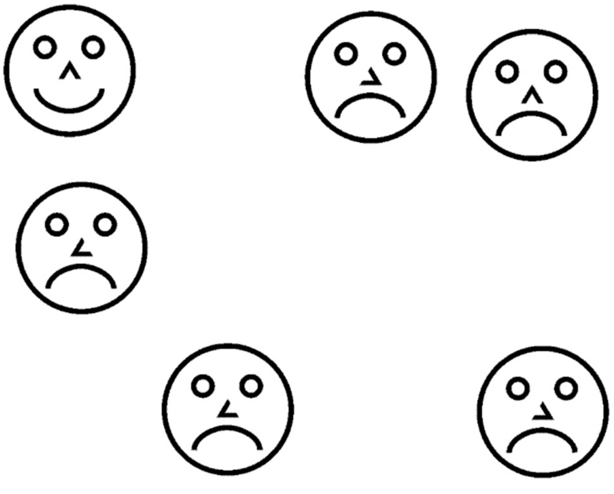

Figure 1. Sample display from Experiment 1A (set size 6, positive target present). The stimuli were presented in an imaginary 3 (rows) × 4 (columns) matrix. Average positions were altered by random displacement to weaken suprastimulus cues that could result from a regular arrangement (Duncan & Humphreys, 1989). Figure is not drawn to scale.

replicated 25 times. Affective singleton identity was varied between blocks of trials. Set size and singleton presence varied randomly from trial to trial within blocks. Dependent variables were mean correct RTs and error rates. Starting block (positive vs. negative target face) and judgment (target present vs. absent) to response (left vs. right response key) mappings were balanced across participants.

Stimuli. The stimuli were positive and negative faces that were differentiated by the orientation of the curve forming the mouth (pointing upward or downward). For reasons that are important only in Experiment 2, the faces also differed in the rotation of the nose, which was a "∧" with the open side either left, down, or right. Nose layout was chosen randomly for each individual face stimulus presented in a trial. The stimuli resembled the faces tested by White (1995) and Horstmann (2007), the one difference being that each of the present faces had a nose.

The faces 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. These were either all positive or all negative faces (target-absent trials) or contained one discrepant face (target-present trials). Individual faces were presented on an imaginary 4 × 3 (horizontal × vertical) position matrix. Mean distance between the positions (center to center) was 2.4 cm (see Figure 1). Average positions were altered by random jitter to eliminate the possible suprastimulus cues to the target that may result from a regular arrangement (Duncan & Humphreys, 1989). The stimuli were presented on a black background.

Procedure. Written instructions requested participants to indicate the presence or absence of a discrepant face by pressing one of two response keys. The instructions emphasized the importance of speed and accuracy. The participants worked on 20 practice trials, followed by two blocks of 150 trials each. When they searched for the positive face in the first block, they searched for the negative face in the second block, and vice versa.

The face stimuli were preceded by a 1,000-msec fixation cross and followed by the 1,100-msec empty-screen intertrial interval. The stimuli were presented until a response was made, but a trial was aborted if no response was registered within 6 sec. If participants pressed the wrong key, a 100-msec tone provided error feedback.

Apparatus. A computer connected to a high-resolution 19-in. color monitor for stimulus presentations and to a keyboard to collect the manual responses controlled the experiment.

Results

Anticipatory (<200-msec) or very long (>3,000-msec) responses were excluded from the RT analysis (<2%), as were false responses (2%). For the data analysis, mean correct RTs and proportions correct for each experimental condition were calculated (see Figure 2).

Mean correct RTs were analyzed by a 3 (set size: 1, 6, 12) × 2 (affective-singleton identity: positive, negative face) × 2 (affective-singleton presence: present, absent) ANOVA, rendering main effects of set size [$F(2,12) = 87.1, p < .001$], singleton identity [$F(1,6) = 4.7, p = .07$], and singleton presence [$F(1,6) = 83.9, p < .001$]. The main effect of set size revealed that RT increased as set size increased, with a slope of the linear function being 80 msec/item. The marginally significant main effect of singleton identity indicated that RTs were faster when participants searched for the negative singleton target among a positive crowd than when they searched for the positive singleton target embedded in a negative crowd (1,056 vs. 1,198 msec, respectively). The main effect of singleton presence reflected longer RTs for target-absent trials than for target-present trials (1,344 vs. 910 msec, respectively).

Two interactions were significant. The set size × singleton identity interaction [$F(2,12) = 16.4, p < .01$] revealed that the slope of the search function was shallower for negative singletons among positive crowds (60 msec/item) than for positive singletons among negative crowds (99 msec/item). Finally, the set size × singleton presence interaction [$F(2,12) = 48.6, p < .001$] indicates steeper

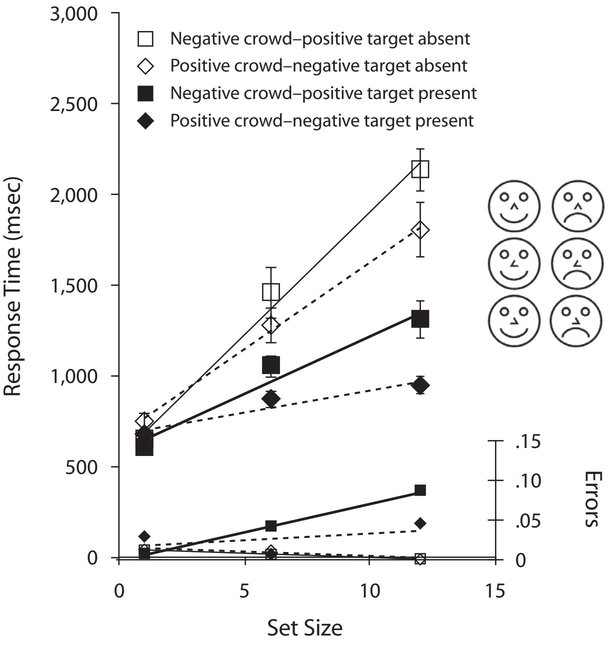

Figure 2. Mean correct response times (in milliseconds) in Experiment 1A for trials with and without a positive or negative singleton among negative or positive distractors, respectively, for set sizes 1, 6, and 12. Error bars depict the standard errors of the means. The straight lines are the slopes of the RT–set size function, as obtained by linear regression. The bottom of the figure shows the mean proportion of errors for each condition.

slopes for target-absent trials (115 msec/item) than for target-present trials (44 msec/item).

A corresponding error analysis revealed a main effect of stimulus presence [$F(1,6) = 10.0, p < .05$], a set size × singleton identity interaction [$F(1,12) = 5.4, p < .05$], and a set size × singleton presence interaction [$F(1,12) = 6.4, p < .05$] (other Fs < 3.1), with no indication of a speed–accuracy trade-off involving the valence of the singleton (see Figure 2).

EXPERIMENT 1B

After having demonstrated in Experiment 1A that the negative-face target is actually found more efficiently among positive-face distractors, Experiment 1B tests whether this effect reflects involuntary attentional capture or depends critically on the task relevance of the stimuli. As explained in the introduction, this test requires the proposed attention capturing stimulus attribute (affective valence) to be independent from the current task. In Experiment 1B, the task was to search for the single face that had a left-pointing (<) or right-pointing (>) angle serving as the nose and to respond with a direction-congruent keypress. Thus, the nose was both the defining and the reported attribute in Experiment 1B, and this attribute was independent from the affective valence of the face.

If the search asymmetry observed in Experiment 1A was due to involuntary attentional capture, the search slope should be reasonably flat when the negative face coincides with the target (valid trial), and search should remain inefficient in all other conditions (i.e., invalid trials with negative singletons, and valid and invalid trials with positive singletons), resulting in a significant three-way interaction between set size, singleton identity (positive, negative), and cue validity (valid, invalid). However, having observed that Experiment 1A actually failed to produce the corresponding three-way interaction between set size, singleton identity, and singleton presence, we should add the following prediction: If the effects observed in Experiment 1A can be exactly replicated in Experiment 1B, we should expect more efficient search with negative singletons among positive crowds than vice versa, but no differences in the validity effects between positive and negative singletons.

One might think that results from Suzuki and Cavanagh (1995) and Eastwood et al. (2003) should complicate predictions, because access to lower level features appears to be blocked by a higher level facial gestalt, in particular with negative faces. We doubt that global-to-local precedence applies here (see the General Discussion), but we would expect it to register in longer RTs when most stimuli are negative.

Method

Participants. Twelve students (7 women), with a mean age of 24.9 years ($SD = 6.3$), participated as paid volunteers, earning €2 each.

Design. A 2 (set size: 3, 6) × 2 (singleton identity: positive, negative face) × 2 (cue validity: valid, invalid) design was employed.[2] Because cue validity was, on average, at chance level, valid trials appeared less frequently than did invalid trials. In particular, for set size 3, 40 trials were valid and 80 trials were invalid; for set size 6, 40 trials were valid and 200 trials were invalid. This distribution was orthogonal to singleton identity, with positive and negative singletons being presented on half of the trials. The nose pointed to the left in half of the trials and to the right in the other half of the trials (orthogonal to the other variables). The variables set size, singleton identity, cue validity, and pointing direction of the nose varied randomly from trial to trial within blocks. Dependent variables were mean correct RTs and error rates (proportions correct).

Procedure. Written instructions were given prior to the experiment. The participants were told to search for the single face with a nose pointing to the left or to the right and to respond with the corresponding response key. The instructions emphasized the importance of speed and accuracy. Participants worked on 20 practice trials, followed by five blocks of 72 trials each.

Each trial began with a 1,000-msec fixation cross, followed by the face stimuli. The stimuli remained visible until a response was made, but a trial was aborted if no response was registered within 6 sec. If participants pressed the wrong key, a 100-msec tone provided error feedback. The intertrial interval was 1,100 msec.

Apparatus. The experiments were controlled by a computer connected to a 17-in. color monitor for stimulus presentations and to a keyboard to collect the manual responses.

Stimuli. The stimuli were the same as those used in Experiment 1A.

Results

Anticipatory (<200 msec) or very long (>3,000 msec) responses were excluded from the RT analysis (0.5%), as

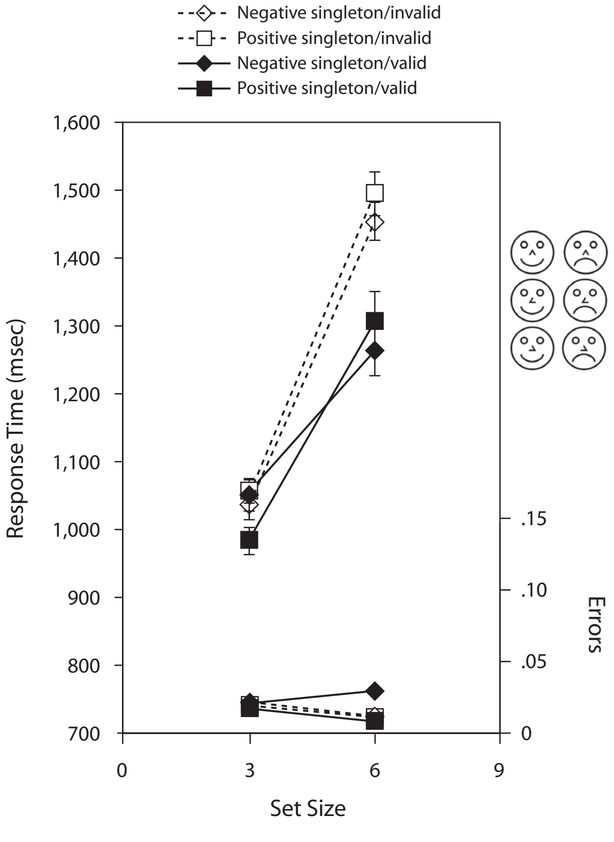

Figure 3. Mean correct response times (in milliseconds) and errors in Experiment 1B for trials with positive and negative singletons at the position of the target (valid) or at the position of one of the distractors (invalid), for set sizes 3 and 6.

were false responses (1.5%). For the RT analysis, mean correct RTs for each experimental condition were calculated (Figure 3).

Mean correct RTs were analyzed by a 2 (set size: 3, 6) × 2 (singleton identity: positive, negative) × 2 (cue validity: valid, invalid) ANOVA. The results revealed a main effect of set size [$F(1,11) = 488.2$, $p < .001$], reflecting faster RTs in the set size 3 condition than in the set size 6 condition (1,031 vs. 1,379 msec, respectively); a main effect of cue validity [$F(1,11) = 24.1$, $p < .001$], revealing faster RTs in valid than in invalid (1,151 vs. 1,260 msec, respectively) trials; and an interaction between these two variables [$F(1,11) = 32.4$, $p < .01$]. The interaction was due to a smaller set size effect with valid than with invalid (90 vs. 143 msec/item, respectively) singletons. Additionally, the interaction of singleton identity with set size was significant [$F(1,11) = 9.7$, $p < .01$], indicating that the set size effect was stronger with a positive versus a negative (127 vs. 105 msec/item, respectively) singleton. The three-way interaction approached significance [$F(1,11) = 2.8$, $p = .12$], reflecting that search efficiency was better with negative than with positive faces as valid cues (71 vs. 108 msec/item, respectively) [$t(11) = 2.7$, $p < .05$], but more similar for negative and positive faces as invalid cues (139 vs. 146 msec/item, respectively, $t < 1$). The two-way interaction of stimulus identity and validity was not significant [$F(1,11) = 1.7$, $p > .20$].

A corresponding analysis of the error proportions revealed no significant effects whatsoever (Fs < 3.0, $p > .10$). Thus, the interpretation of the RTs is not complicated by a speed–accuracy trade-off.

Discussion of Experiments 1A and 1B

Experiment 1A replicates the typical RSA observed for emotional faces: When participants searched for a negative target face among positive distractor faces, search was faster and less dependent on set size than vice versa. However, one should be cautious in interpreting this finding to be evidence for target-based effects—specifically, as indicating that negative faces guide attention. This is because on target-absent trials, search was also more efficient with a negative-face target than with a positive-face target. If negative-face targets could be found more efficiently by virtue of attentional capture by the target, we would have expected search benefits only in the target-present trials, resulting in a three-way interaction between set size, singleton identity (positive, negative), and target presence (present, absent). However, we found instead a significant two-way interaction between set size and singleton identity, reflecting that search for the negative-face target among positive-face crowds was generally more efficient, regardless of whether the negative face was present or absent. This indicates that the search asymmetry is driven more by the identity of the crowd than by the identity of the target, with more efficient search with a positive-face crowd than with a negative-face crowd (Horstmann et al., 2006).

Moreover, in both experiments, the search slope was quite steep, measuring roughly between 40 msec/item and 100 msec/item. This suggests that the search asymmetry is not based solely on differences in preattentive processing between positive and negative faces; rather, differences in the attentive or postselectional processing of facial expressions contribute substantially to the search asymmetry (see Horstmann et al., 2006).

It is interesting to note that search in Experiment 1A was less efficient than in Horstmann (2007), where the stimuli were basically the same, except that they did not have a nose. Obviously, the presence of the irrelevant nose slowed search, possibly because the nose rendered the stimuli less simple, which made stimulus identification more difficult (Rauschenberger & Yantis, 2006). It is also possible that the three variants of noses contributed to distractor–distractor dissimilarity, which is known to slow search (Duncan & Humphreys, 1989).

In Experiment 1B, we tested whether the RSA was predominantly due to top-down or stimulus-driven factors of attentional control. If the search asymmetry is completely due to top-down attentional control settings, search advantages for the negative face should disappear completely when it is task irrelevant and thus does not help with the task of finding the target. In contrast with this prediction, Experiment 1B revealed a significant interaction between singleton identity and search efficiency: Search was more efficient when the singleton was a negative face (105 msec/item) than when it was a positive face (127 msec/item). The finding of a difference between the faces (although facial expression was completely irrelevant to the task) indicates that the advantage in search for a negative face does not depend exclusively on top-down-induced task demands.

However, analogous to the results of Experiment 1A, the results of Experiment 1B are also not in line with the hypothesis that negative faces capture attention. On this hypothesis, we would have expected efficient search when the negative-face singleton coincided with the target position (valid trials), but inefficient search in all other conditions. In contrast, more efficient search in the presence of a negative-face singleton occurred on both valid and invalid trials—that is, independently of whether the singleton was at the position of the target or of a distractor. Again, this pattern of results indicates that the main factor modulating search efficiency may be not the identity of the singleton, but the identity of the crowd, with more efficient search within positive-face rather than negative-face crowds. The finding that facial valence of the singleton had a spatially nonspecific effect on search efficiency is in line with the explanation of the search asymmetry in Experiment 1A—namely, that it is generally easier to search through crowds consisting of positive faces than to search through crowds consisting of negative faces (e.g., Horstmann, 2006; Horstmann et al., 2006).

Also in line with Experiment 1A, the search slopes in Experiment 1B were very steep, even for valid trials with negative singletons (71 msec/item). Evidently, the affective-singleton face did not immediately capture attention to its position, because if this had been the case, search should have been efficient (i.e., approximately 0 msec/

item). If anything, the affective-singleton face may have received *some* attentional priority and weakly attracted attention to itself (attentional misguidance effect; Todd & Kramer, 1994).

The finding that search remained largely inefficient both when affective-singleton faces were task relevant (Experiment 1A) and when they were task irrelevant (Experiment 1B) is probably most parsimoniously explained by proposing that threatening stimuli are not preattentively available—that is, available in parallel over large parts of the visual field. This accounts for inefficient search when affective-singleton faces are task relevant and explains why they did not capture attention in a strict sense—that is, immediately, and by initiating distance-bridging shifts of attention—when they were task irrelevant.

One result of Experiment 1B complicates the interpretation as evidence for an attentional effect of negative or threatening emotional information: Benefits for valid over invalid trials were not confined to the negative face, but were also present with the positive face, albeit to a lesser extent. The finding that search was generally more efficient when the target coincided with a positive- or negative-face singleton than when the singleton was presented away from the position of the target might be taken as an indicator of stimulus-driven attentional capture by salient stimuli (e.g., Theeuwes, 1992). Another possible explanation for faster RTs on valid trials may be that singletons could attract attention because participants adopted a "singleton search mode" in the experiment: Because the target was the only face with a different nose, participants may have used the strategy to search for an "odd man out" to detect the target (Bacon & Egeth, 1994). Accordingly, the face singleton may have received attentional priority as a side effect of the task-relevant attentional settings for a feature singleton (see Folk et al., 1992). This hypothesis gains some plausibility when we consider that the defining feature (nose) and the irrelevant feature (mouth) were also not completely dissimilar, and were located in close physical proximity. Thus, it is also conceivable that the irrelevant face singleton guided attention to its position by virtue of its similarity or physical proximity to the target-defining feature (Duncan & Humphreys, 1989; Folk et al., 1992; Yantis, 1993).

Experiment 2A was devised in order to replicate the earlier findings while simultaneously eliminating the similarity between irrelevant and target-defining features. To that end, a more typical conjunction search task was used, where all stimuli shared both of two colors and the defining feature was the actual configuration of the two colors. This had the advantage of decreasing the probability of the use of a singleton search strategy.

Finally, we note that there was no evidence for a stronger global-to-local precedence with negative faces (Eastwood et al., 2003) in Experiment 1B, which would have resulted in generally slower RTs when most faces were negative. This is probably due to the different construction of the stimuli as compared with that in the previous studies, as explained in the General Discussion.

EXPERIMENT 2A

The stimuli presented in Experiments 2A through 2C were different from those presented in Experiments 1A and 1B. In particular, they were very similar to the positive- and negative-face stimuli used by Eastwood et al. (2001), which were composed of a circle as the head's outline, two dots for the eyes, and a curved line for the mouth. As explained below, they had two additional features—the target-defining feature and the reported feature in Experiments 2B and 2C. As in the previous set of experiments, Experiment 2A tested the very stimuli from the critical experiment (2B) in an ordinary facial singleton search task, to ensure that the additional (reported) feature would not eliminate any effect that could be attributed to an attentional capture by affective stimulus attributes.

Method

Participants. The participants were 8 students (3 women), with a mean age of 25.5 years ($SD = 6.1$).

Design. A 3 (set size: 1, 6, 12) × 2 (affective-singleton identity: positive, negative) × 2 (singleton presence: present, absent) design was employed. We used the same design as was used in Experiment 1A.

Stimuli. The stimuli were positive and negative faces that were differentiated in the orientation of the curve forming the mouth (upward or downward pointing). For reasons that become important in Experiment 2B, the faces were half yellow and half brown and were tilted 15º to the left or to the right. Tilt (left, right) and side of yellow coloration (left, right) were assigned randomly for each individual stimulus. The other details were the same as those in Experiment 1A.

Procedure and Apparatus. The procedure and apparatus were the same as those used in Experiment 1A.

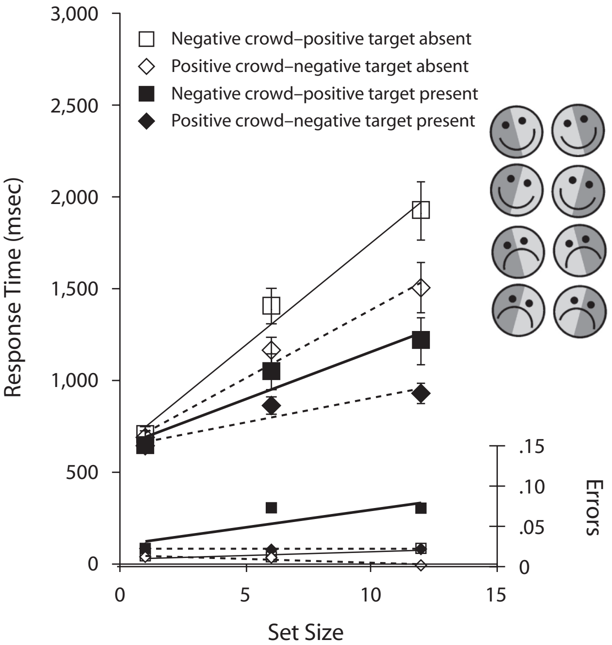

Figure 4. Mean correct response times (in milliseconds) in Experiment 2A for trials with and without a positive or negative singleton among negative or positive distractors, respectively, for set sizes 1, 6, and 12 (see also Figure 2).

Results

Data treatment followed the same rules as before. Very short or very long responses were excluded from the RT analysis (<1%), as were false responses (2%). For the data analysis, mean correct RTs and proportions correct for each experimental condition were calculated (see Figure 4).

Mean correct RTs were analyzed by a 3 (set size: 1, 6, 12) × 2 (affective-singleton identity: positive, negative) × 2 (affective-singleton presence: present, absent) ANOVA, rendering main effects of set size [$F(2,14) = 66.3$, $p < .001$], singleton identity [$F(1,7) = 20.3$, $p < .01$], and singleton presence [$F(1,7) = 57.4$, $p < .001$]. The main effect of set size revealed that RT increased as set size increased, with a slope of the linear function being 65 msec/item. The main effect of singleton identity revealed that RTs were faster for negative singletons within positive crowds than for positive singletons within negative crowds (889 vs. 1,230 msec, respectively). The main effect of singleton presence revealed longer RTs for target-absent trials than for target-present trials (1,155 vs. 964 msec, respectively).

Two interactions were significant. The set size × singleton identity interaction [$F(2,14) = 23.4$, $p < .001$] revealed that the slope of the search function was shallower for negative singletons within positive crowds than for positive singletons within negative crowds. Slopes in target-present trials were 26 msec/item for negative singletons and 51 msec/item for positive singletons; slopes in target-absent trials were 73 msec/item for negative singletons and 110 msec/item for positive singletons. Finally, the set size × singleton presence interaction [$F(2,14) = 33.3$, $p < .001$] indicated steeper slopes for target-absent trials than for target-present trials. The set size × singleton identity × singleton presence interaction was not significant [$F(2,14) = 1.50$, $p > .20$].

A corresponding error analysis revealed a similar (albeit weaker) pattern of results [for set size, $F(1,7) = 11.0$, $p < .05$; for singleton presence, $F(1,7) = 5.7$, $p < .05$; for singleton identity, $F(1,7) = 2.6$, $p = .11$; for set size × singleton identity, $F(1,14) = 1.7$, $p = .21$; for set size × singleton presence, $F(1,14) = 5.1$, $p = .06$; other Fs < 2.3], with no indication of a speed–accuracy trade-off involving the valence of the singleton.

Discussion

Experiment 2A replicated the more efficient search of negative faces in positive crowds than vice versa, as has been found in numerous studies with schematic facial stimuli, as well as in Experiment 1A. Thus, the stimuli modifications that were necessary for the test of involuntary attentional capture in the next experiment (Experiment 2B) did not eliminate the attentional effects of the stimuli. Search in Experiment 1A was much more inefficient than in the present experiment, which used faces very similar to (but nontilted and noncolored) faces used by Eastwood et al. (2001) and Horstmann (2007). A plausible explanation is that the present stimuli were more complex and more heterogeneous than those used in Eastwood et al. (2001).

EXPERIMENT 2B

Experiment 2A showed an RSA for the selected stimulus set when participants actively searched for negative- or positive-face targets. Experiment 2B tested whether the observed search asymmetry was intention driven or stimulus driven. To that end, Experiment 2B required participants to search for a specific conjunction of color and position; the valence of facial expressions was rendered irrelevant to the task. All stimulus faces had a yellow-brown-colored border transecting the face on its vertical meridian, as in Experiment 2A. The target was the one face with a yellow left side and a brown right side (the distractors were brown on the left side and yellow on the right side). All faces were tilted 15º to the left or to the right, and the direction of the tilt was the reported feature. That is, participants had to report with a keypress the direction of the tilt in the target face (tilted left vs. tilted right). The other details corresponded to those in Experiment 1B.

Method

Participants. Twelve students (9 women), with a mean age of 24.1 years ($SD = 2.3$), participated as paid volunteers, earning €2 each.

Stimuli. The stimuli were the same as those used in Experiment 2A.

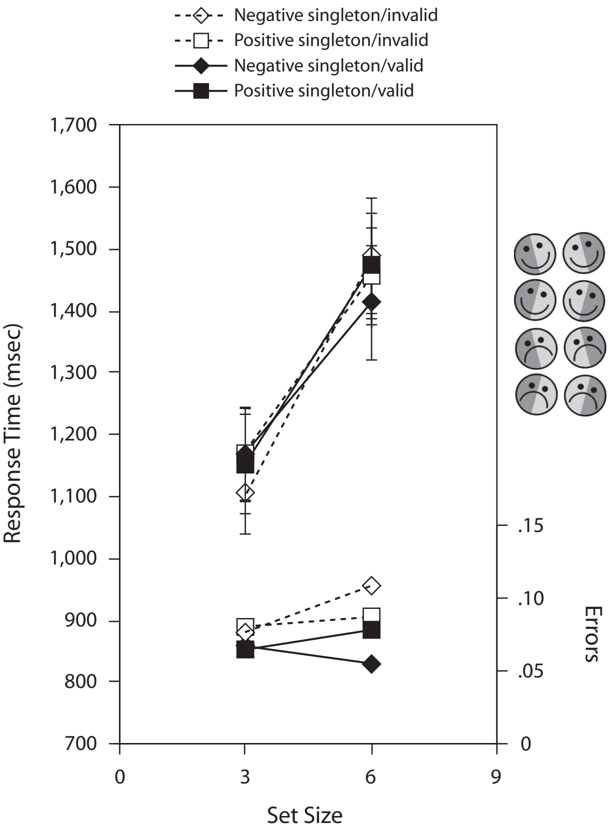

Figure 5. Mean correct response times (in milliseconds) in Experiment 2B for trials with positive and negative singletons at the position of the target (valid) or at the position of one of the distractors (invalid), for set sizes 3 and 6.

Design, Procedure, and Apparatus. The design, procedure, and apparatus corresponded to those in Experiment 1B.

Results and Discussion

The analysis was analogous to that in Experiment 1B (2% errors, <1% long or short RTs occurred). The main results are reported in Figure 5.

The ANOVA of the mean correct RTs revealed a significant main effect of set size [$F(1,11) = 97.7, p < .001$], indicating faster RTs with set size 3 than with set size 6 (1,140 vs. 1,454 msec, respectively), and a significant set size × singleton identity × singleton validity interaction [$F(1,11) = 9.8, p < .01$]. This interaction reflected the result that the set size effect with a negative singleton was smaller in valid (83 msec/item) than in invalid (129 msec/item) trials [$t(11) = 2.5, p < .05$], whereas the set size effect with a positive singleton was similar in valid (108 msec/item) and in invalid (97 msec/item) trials [$t(11) < 1$]. The other main effects and interactions were not significant (Fs < 2.0, ps > .18).

The analysis of the errors revealed no significant main effects or interactions, although the main effect of validity and the three-way interaction approached significance. The marginally significant main effect for validity [$F(1,11) = 4.7, p = .05$] revealed more errors with an invalid than with a valid (.08 vs. .06, respectively) singleton. The marginally significant three-way interaction [$F(1,11) = 3.5, p = .09$] showed roughly the same pattern of results as that of the RTs (see Figure 5).

To summarize, the first important finding of Experiment 2B is a pattern of results that is largely consistent with the assumption that negative (but not positive) faces capture attention: The validity effect pertained only to negative-face singletons; it was absent for positive-face singletons. However, it is also consistent with the notion that postselectional processes contributed to the effect, because search remained rather inefficient, even for the valid negative-face singletons. A second important finding is that the pattern of results from Experiment 2A, showing a clear crowd effect (faster scanning of positive-face crowds, with or without a negative-face target, than vice versa), is not reflected in Experiment 2B, in which the valence of the faces was completely irrelevant to the task. In Experiment 2B, there was no general search advantage for positive crowds (i.e., for displays consisting mostly of friendly faces). Instead, search for a conjunction target commenced more efficiently when the target was a negative-face singleton, whereas there were no differences between the invalid negative-face singleton condition and the valid and invalid positive-face singleton condition. These results support the assumption that negative faces can (mis)guide attention to their location. Discouraging a singleton search strategy by demanding a conjunction search might be the reason why, unlike in Experiment 1B, more efficient search in valid than in invalid trials pertained exclusively to the negative face. This result is consistent with the assumption that it is specifically the negative face that has an impact on attention shifts or postselectional processes. With this, the results of Experiment 2B, strictly speaking, do not match the results of Experiment 2A, where no corresponding search advantage for the target-present condition in search for the negative-face singleton emerged. Despite this, we should not dismiss the hypothesis that crowd effects contributed also to the outcome of Experiment 2B, and that the search asymmetry in Experiment 2A can be explained by the involuntary attentional guidance processes revealed in Experiment 2B.

Because of the ambiguity that is introduced by swapping the *singleton–nonsingleton* assignment (a positive-face singleton is always embedded in a crowd of negative-face nonsingletons, and vice versa), it is still possible that crowd effects also contributed to the attentional guidance effect by negative faces, as was observed in Experiment 2B. To test this possibility, Experiment 2C was conducted. In particular, we were interested in whether the observed effects were completely dependent on the singleton type (positive or negative face), or whether the context (crowd) would prove to be an important part of the conditions under which a validity effect can be observed. Therefore, Experiment 2C used crowds of neutral faces. If the observed guidance effect is due to negative-face targets guiding attention to their location, the same search benefits should also occur in Experiment 2C with neutral crowds. On the other hand, if the guidance effect critically depends on the crowd or on the relationship between the singleton and the crowd, there should be no differences in search efficiency between negative- and positive-face targets among neutral crowds.

EXPERIMENT 2C

Experiment 2C was a modified replication of Experiment 2B, the only difference being that the distractors were always neutral in Experiment 2C. Neutral distractors were constructed by superimposing positive and negative facial stimuli.

Method

Participants. Eight students (6 women), with a mean age of 22.8 years ($SD = 3.0$), participated as paid volunteers, earning €2 each.

Stimuli. The stimuli were the same as those used in Experiments 2A and 2B, but with the addition of four new "neutral" stimuli (see the introduction).

Design, Procedure, and Apparatus. The design, procedure, and apparatus were the same as those used in Experiment 2B, except that the distractors were always neutral.

Results

The analysis corresponded to that in the previous experiments (3.3% errors; 4.4% out-of-range RTs occurred). The main results are reported in Figure 6.

The ANOVA of the mean correct RTs reveals a significant main effect of set size [$F(1,7) = 375.2, p < .001$], reflecting faster RTs with set size 3 than with set size 6 (1,126 vs. 1,465 msec, respectively) and a significant main effect of validity [$F(1,7) = 14.3, p < .01$], reflecting 101 msec faster RTs in valid than in invalid trials. The other effects were not significant (Fs < 1.4).

A corresponding analysis of the error proportions revealed only a significant main effect of validity [$F(1,7) =$

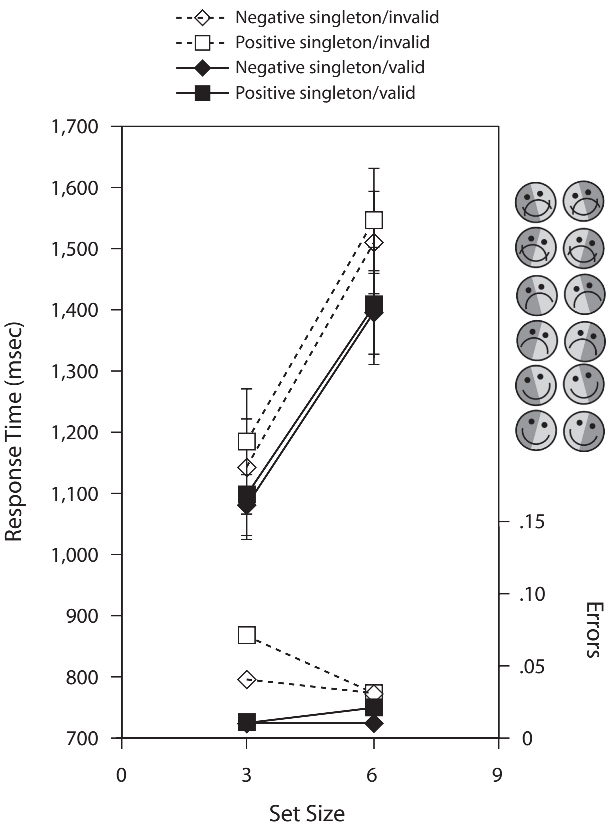

Figure 6. Mean correct response times (in milliseconds) in Experiment 2C for trials with positive and negative singletons at the position of the target (valid) or at the position of one of the distractors (invalid), for set sizes 3 and 6.

12.7, $p < .01$], indicating that more errors were made in invalid than in valid trials. The other main effects or interactions were nonsignificant (Fs < 3.1, ps $> .12$).

Discussion

As in the previous experiments, search slopes were far from being efficient in either valid or invalid trials, which indicates that neither positive nor negative facial expressions strongly captured attention. Most important, however, negative-face singletons no longer had an advantage over positive-face singletons. Evidently, the crowd is an important variable for the negative-face advantage.

The results still show an advantage for valid over invalid trials, which, however, did not interact with set size or target type. At a first glance, this validity effect may seem to imply attentional guidance by singletons (e.g., Theeuwes, 1992). However, participants probably did not actively search for featural singletons, because they performed a conjunction search task, not a singleton search task (Todd & Kramer, 1994). Moreover, the results do not support an attentional guidance (or misguidance) explanation, because in this case, the valid conditions should exhibit a shallower slope (i.e., reduction in the set size effect), but not an advantage that is additive to the set size effect. Thus, the validity effect is probably best explained by costs incurred in the invalid conditions; for example, rejecting a new distractor is more difficult than rejecting a stimulus that has already been repeatedly rejected.

In sum, the finding that the validity effect for negative-face singletons among positive-face crowds is eliminated in neutral-face crowds strongly suggests that crowd identity plays an important role also in search tasks in which the valence of facial expressions is irrelevant to the task. This, in turn, indicates that the validity effect in Experiment 2B is also crowd mediated. Two causes that immediately come to mind are (1) that positive crowds may facilitate attentional selection of the target by allowing more efficient grouping and immediate rejection as a structural unit (see, e.g., Duncan & Humphreys, 1989), and (2) that positive faces facilitate postselectional processes, possibly involved in perceptual identification or de-allocation of attention from already selected distractor items (see, e.g., Fox et al., 2000). Note that more efficient grouping and rejection (of positive-face distractors) would probably impede performance in invalid trials with a negative-face singleton (and, hence, a positive-face target), because the positive-face target would be inadvertently rejected by this process. Thus, the stimulus-driven effects revealed in Experiment 2B may well account for the RSA observed in Experiment 2A, indicating that advantages in searching for negative faces do not require actively searching for a predefined emotional face.

Why did the negative-face singleton lead to more efficient search on valid than on invalid trials in Experiment 2B, whereas Experiment 1B showed only a general advantage for searching for a negative face over searching for positive faces? This difference may in part be due to using a more demanding conjunction search task in Experiment 2B. As can be seen by comparing the mean RTs, search for the conjunction of color and position was somewhat more difficult than search for the orientation singleton in Experiment 1B, which presumably involved slowed distractor rejection and longer attentional processing of the distractors. This in turn allows distractor identity to have a stronger effect on search performance, which may account for the differential effect of emotional valence on search performance. Alternatively (or additionally) it should be observed that the task-relevant stimulus in Experiment 2B was the position of a colored half-face and, thus, the task-relevant stimulus was superimposed over the irrelevant facial expression. Allocating attention to color and position may in turn have promoted attentional processing of facial valence, which could then exert stronger effects on search performance.

The next experiment was designed to test the hypothesis that the task and the construction of task-relevant stimuli can modulate processing of the facial valence of the stimuli. If unintentional processing of negative and positive facial expressions is completely independent of task difficulty, the valence of facial expressions should modulate search performance, even when the target can be found very efficiently. In contrast, if involuntary processing of irrelevant facial affect somehow depends on in-depth attentional processing of the distractors, differences between negative and positive faces should be reduced or even completely eliminated when the target can be found efficiently.

EXPERIMENT 3A

Experiment 3A was a second conceptual replication of Experiments 1A and 2A. This time, all stimulus faces looked like stage clowns, with a colored circle for the nose and two pairs of steep strokes near the eyes, one above and one below each eye. As in Experiment 1, the target-defining feature was the nose, and the target face was defined as the face with the yellow nose (and the distractors as the faces with the green nose); thus, the task was clearly a singleton search task. The two pairs of strokes were tilted 15º either to the left or to the right; these were the reported features. In Experiment 3B, which was the critical test for attentional capture, participants pressed the left key if the strokes were tilted to the left and the right key if the strokes were tilted to the right. Choosing a singleton search task additionally tests whether facial threat is a preattentively available stimulus dimension. For example, Bacon and Egeth (1994) hypothesized that even though irrelevant color singletons do not involuntarily capture attention when the target is a nonsingleton, they may do so when the target is also a featural singleton. This would be the case because if the target is defined by a featural singleton (e.g., a circle among rectangles), participants may enter singleton search mode, in which they look for any featural singleton. The irrelevant singleton is thus selected for attentional processing as a side effect of the search for a relevant singleton. By analogy, the affective singleton may receive attentional priority as a side effect of a singleton search task, given that facial affect is a preattentively available feature. In this case, we would expect more efficient search on valid than on invalid trials in Experiment 3B, which should occur regardless of whether a positive or negative singleton coincides with the target position.

As has already been indicated, Experiment 3A ensures that the usually occurring advantage of negative-face targets in positive-face crowds over positive-face targets in negative-face crowds is also found with the present stimuli. Experiment 3B is a critical test involving valenced distractors, and Experiment 3C is a critical test involving neutral distractors.

Method

Participants. Eight students (4 women), with a mean age of 26.1 years ($SD = 4.5$), participated as paid volunteers, earning €2 each.

Stimuli. The construction of the stimuli was described in the introduction to Experiment 3A. The size of the stimuli was the same as in the previous experiments.

Design, Procedure, and Apparatus. The design, procedure, and apparatus were the same as those used in Experiments 1A and 2A.

Results and Discussion

The analysis corresponded to that in the previous experiments (4.5% errors; <1% high and low RTs, respectively). The main results are reported in Figure 7.

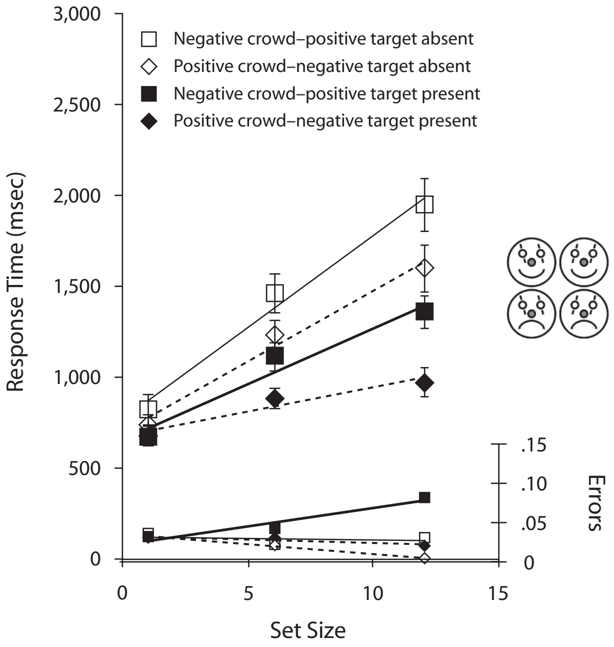

Figure 7. Mean correct response times in Experiment 3A for trials with and without a positive or negative singleton among negative or positive distractors, respectively, for set sizes 1, 6, and 12 (see also Figure 2).

Mean correct RTs were analyzed by a 3 (set size: 1, 6, 12) × 2 (affective-singleton identity: positive, negative) × 2 (affective-singleton presence: present, absent) ANOVA, rendering main effects of set size [$F(2,14) = 104.0$, $p < .001$], singleton identity [$F(1,7) = 8.8$, $p < .01$], and singleton presence [$F(1,7) = 89.9$, $p < .001$]. The main effect of set size revealed that RT increased as set size increased, with the slope of the linear function being 67 msec/item. The main effect of singleton identity revealed that RTs were shorter for negative singletons within positive crowds than for positive singletons within negative crowds (1,025 vs. 1,234 msec, respectively). The main effect for singleton presence revealed shorter RTs for target-present trials than for target-absent trials (953 vs. 1,307 msec, respectively).

Two significant interactions were found. The set size × singleton identity interaction [$F(2,14) = 9.9$, $p < .01$] revealed that the slope of the search function was shallower for negative singletons within positive crowds (53 msec/item) than for positive singletons within negative crowds (82 msec/item). Finally, the set size × singleton presence interaction [$F(2,14) = 60.8$, $p < .001$] indicated steeper slopes for target-absent trials (90 msec/item) than for target-present trials (45 msec/item).

A corresponding error analysis revealed a set size × singleton identity interaction only [$F(1,14) = 12.2$, $p < .001$] (all other Fs < 0.32, ps $> .12$). The interaction reveals that whereas errors increased with set size when the singleton target was a negative face, errors decreased with set size when the singleton target was a positive face. Thus, there was a moderate speed–accuracy trade-off in the present data—which, however, does not appear to be strong enough to explain the entire RT pattern.

To summarize, Experiment 3A revealed the same robust pattern of results as Experiment 1A and 2A, with more efficient search with a negative-face target than with a positive-face target.

EXPERIMENT 3B

Method

Participants. Twelve students (9 women), with a mean age of 22.8 years (SD = 4.2), participated as paid volunteers, earning €2 each.

Stimuli. The stimuli were the same as those used in Experiment 3A.

Design, Procedure, and Apparatus. The design, procedure, and apparatus were the same as those used in Experiments 1B and 2B.

Results and Discussion

The analysis corresponded with those in Experiments 1 and 2 (1.8% errors; no high or low RTs occurred). The main results are reported in Figure 8.

The ANOVA of the mean correct RTs revealed a significant main effect of set size [$F(1,11) = 83.6$, $p < .001$], reflecting faster RTs with set size 3 than with set size 6 (797 vs. 879 msec, respectively) and a main effect of singleton identity [$F(1,11) = 17.5$, $p < .01$], reflecting 19-msec longer RTs with a negative singleton than with a positive singleton (848 vs. 829 msec/item, respectively). The singleton identity × singleton validity interaction approached significance [$F(1,11) = 4.0$, $p = .07$], reflecting a tendency toward longer RTs in valid than in invalid trials for negative-face singletons (855 vs. 840 msec, respectively), but a tendency for shorter RTs in valid than in invalid trials for positive-face singletons (819 vs. 839 msec, respectively). A corresponding analysis of the error proportions revealed only a marginally significant main effect of set size [$F(1,11) = 4.1$, $p = .07$], indicating that more errors were made with set size 3 than with set size 6 (2.7% vs. 1.5%, respectively). The other main effects or interactions were nonsignificant [Fs < 2.7, ps $> .13$]. Thus, the set size effect may have been partially due to a speed–accuracy trade-off, which, however, is unproblematic here, because the set size effect alone is of no special interest for the present investigation.

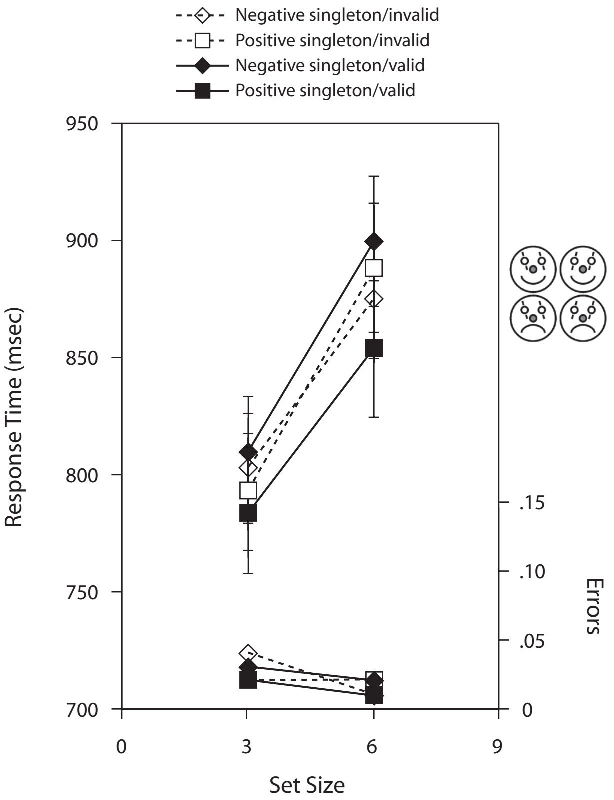

Figure 8. Mean correct response times (in milliseconds) in Experiment 3B for trials with positive and negative singletons at the position of the target (valid) or at the position of one of the distractors (invalid), for set sizes 3 and 6.

To summarize, search was much more efficient (27 msec/item) than in the previous experiments, indicating that the color search task in this experiment was much easier than the orientation and conjunction search tasks of Experiments 1B and 2B, respectively. More important, the present results show a strong dissociation between voluntary search for facial singletons (Experiment 3A) and involuntary capture by facial singletons (Experiment 3B), indicating that the task demands and the construction of the task-relevant stimulus are important determinants for the RSA and involuntary guidance effects by facial expressions. Whereas Experiment 3A showed the robust finding of the RSA (see Figure 7), the indications for involuntary guidance by negative faces were completely absent (see Figure 8). Remarkably, negative-face singletons affected search performance in a directly opposite way than in previous experiments: Search performance was impaired with a negative singleton, especially when it was presented at the position of the target (valid trials).

We attribute this result to the relatively high efficiency of distractor rejection in Experiment 3B, which was revealed by the relatively shallow search slopes. Under conditions of highly efficient distractor rejection (based on the color of the nose), distractors received little attentional processing; for this reason, distractor singletons did not interfere much during search. However, once the target face was located, attentional processing commenced, and the identity of the face therefore influenced RT, most probably by differentially hindering disengagement of attention (see, e.g., Fox et al., 2000).

EXPERIMENT 3C

Experiment 3C was a modified replication of Experiment 3B, the only difference being that the distractors were always neutral in Experiment 3C. The neutral distractors were constructed by superimposing positive and negative stimuli.

Method

Participants. Eight students (2 women), with a mean age of 23.8 years (SD = 5.1), participated as paid volunteers, earning €2 each.

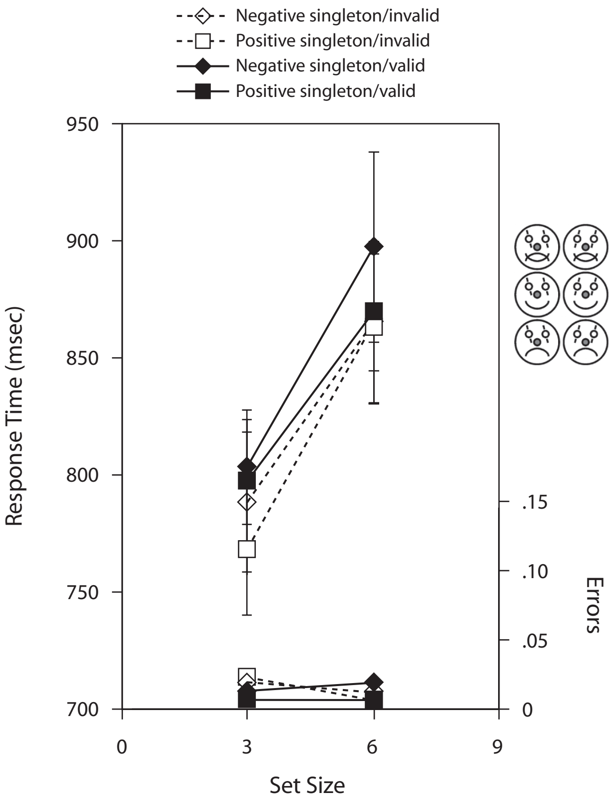

Figure 9. Mean correct response times (in milliseconds) in Experiment 3C for trials with positive and negative singletons at the position of the target (valid) or at the position of one of the distractors (invalid), for set sizes 3 and 6.

Stimuli. The stimuli were the same as those used in Experiments 3A and 3B, but with the addition of four new "neutral" stimuli (see the introduction).

Design, Procedure, and Apparatus. The design, procedure, and apparatus were the same as those used in Experiment 2C, except that the distractors were always neutral.

Results and Discussion

The analysis corresponded to those for the previous experiments (4.5% errors; $<$1% high or low RTs). The main results are reported in Figure 9.

The ANOVA of the mean correct RTs reveals a significant main effect of set size [$F(1,7) = 42.2$, $p < .001$], reflecting faster RTs with set size 3 (789 msec) than with set size 6 (874 msec). No other effect approached significance (Fs < 2.0, ps $> .19$).

A corresponding error analysis revealed no significant main effects or interactions (Fs < 3.5, ps $> .10$).

To summarize, under conditions of color singleton search and with neutral crowds, there was no evidence for attention capture by the negative-face singleton. This result implies that facial valence or facial threat is not a featural singleton that can be accessed preattentively and thus be used to guide attention to its location. This result is in line with numerous results from visual search experiments showing rather inefficient search for negative faces among positive faces.

It is interesting to note that the RSA for searching through positive-face or negative-face crowds could be observed when participants were required to search for an emotional face (Experiment 3A), but not when it was irrelevant to the task (Experiment 3B). In contrast, when participants searched for a color singleton, the valence of the crowds did not appear to be important. This was probably due to the fact that participants localized the target by looking for the target color (or, alternatively, simply for a color singleton), which did not require the processing of aspects of shape. Obviously, a faster scanning of positive crowds is not completely stimulus bound, but depends critically on the task of the participants—that is, on top-down contributions.

Another possibility is based on the observation that search for color targets was easier and also more efficient than that for the previously employed targets. Thus, it seems to be plausible that the failure of the search asymmetry for the negative-face target was due to more efficient search for the color target in Experiment 3B. According to this explanation, fast detection of the color target prevented emotional stimuli from exerting their typical influence on attention—for example, in engaging attention to their location for a longer time. This account of the observed effects could also be viewed as being close to horse race models: The elimination of the RSA could be due to the fact that the colored stimuli were processed faster than the emotional content of the task-irrelevant stimuli, so that attention was disengaged from the stimuli before the latter could be processed. As argued above, this would explain the RSA as well as provide a parsimonious explanation of the failure to replicate the effect in search for a color target.

GENERAL DISCUSSION

The present study tested whether threatening singleton faces capture spatial attention involuntarily, efficiently, and independently of the surrounding nonsingleton stimuli and whether this capture of attention may partly explain the advantage for negative-face targets in visual search, which was also replicated in Experiments 1A, 2A, and 3A.

A robust[3] attentional misguidance effect was observed in Experiments 1B and 2B, but not in Experiment 3B (see Table 1, in which the main results are summarized). Under conditions where the position of the singleton did not pre-

Table 1
Slopes (in Milliseconds per Item) for Negative- and Positive-Face Singletons in Invalid and Valid Trials for Experiments 1B, 2B, and 3B

Affective-Singleton Identity	Experiment 1B	2B	3B
Negative			
Invalid	139	129	32
Valid	71	83	30
Positive			
Invalid	146	97	24
Valid	108	108	23

dict the position of the target, and where there was thus no incentive to actively search for the singleton, the negative-face singleton apparently received attentional priority: Whether the singleton coincided with the target or with the distractor strongly affected search times for negative-face singletons, but less so for positive-face singletons. We refer to this effect as *attentional misguidance* rather than *attentional capture*, reserving the term *attentional capture* for instances where the attention-capturing item is, in fact, the first item attended to (see, e.g., Gibson & Jiang, 1998; Horstmann, 2002). This concept of attentional capture is not supported by the present results, where search was highly inefficient.

We discuss two principal alternatives, either of which could account for these misguidance effects. First, one could assume that the misguidance effect truly reflects the attentional priority of negative-face stimuli. The reason that only very weak effects are obtained could then be due to suboptimal stimulus conditions, where the underlying attention-drawing dimension is only weakly represented. Just as search performance does not fall into two clearly separable categories of efficient versus inefficient search (see Treisman & Gelade, 1980), but, rather, forms a continuum of search efficiency (see Wolfe, 1994, 1998), it is conceivable that items do not capture attention in an all-or-none fashion, and that the capacity to draw spatial attention is gradual. For instance, Todd and Kramer (1994) showed that a target letter among heterogeneous distractor letters could be found more quickly when it possessed a unique color than when one of the distractors was presented in the unique color; still, search remained inefficient across all conditions (see also Turatto & Galfano, 2001; Turatto, Galfano, Gardini, & Mascetti, 2004). These findings may be due to the fact that the stimulus captures attention on only a certain number of trials, or that attention is guided to the singleton only when attention is already directed to an item in the immediate vicinity of the singleton. We may suppose, for instance, that there is parallel processing of stimuli in a restricted area—probably the spatial focus of attention or its immediate surroundings—and that a singleton can draw attention to itself when the attentional focus approaches such a stimulus. In any case, the results strongly suggest that the position of the negative singleton was not available to the visual system at the beginning of the trial (hence the steep search slopes), but that the position of the singleton gained priority over the nonsingleton positions later in the trial, possibly once attention was focused in the vicinity of the singleton.

The second account for the misguidance effect pursues a completely different route, in that it focuses not on the target, but on the crowd. Two principal results indicate a major role of the crowd in the determination of search efficiency. First, a comparison of the target-present and target-absent trials in Experiments 1A, 2A, and 3A strongly suggests that the presence of the targets is not necessary for explaining the differences between positive-face and negative-face crowds. A crowd effect would suffice to explain all the differences in these three experiments. Second, a comparison of Experiments 2B and 2C reveals that a change in the crowds may alter the misguidance effect when affective valence is task irrelevant. Assuming that the locus of crowd effects is predominantly postselectional, these results suggest that stimulus-driven processes not only modulate preattentive processes concerned with attentional guidance (see Theeuwes, 1992), but also modulate processes after the attentional selection of a stimulus (i.e., postselectional processes). This is especially evident when one considers that negative crowds slowed search when the target could be found only by extensively scanning the crowd (see Experiments 1A, 1B, 2A, 2B, and 3A), but not when the target could be found with reasonable efficiency (see Experiment 3B). This indicates that the makeup of complex stimuli affects the speed of attentional processing foremost, and not the speed of attention shifts to the target, contrary to the assumption that stimulus-driven processes exert their main influence prior to attention shifts (see, e.g., Theeuwes, 1992).

This interpretation is consistent with the finding that singleton (or crowd) identity did not influence RTs in a consistent manner across all experiments. Specifically, it can account for the finding that crowd effects were restricted either to conditions in which the processing of facial expressions was task relevant (Experiments 1A, 2A, and 3A) or to conditions in which search for the target required attentional processing of distractor stimuli, which led to processing of their facial affect (Experiments 1A, 1B, 2A, 2B, and 3A). In Experiment 3B, the crowd presumably did not exert an effect, because participants generally engaged in a two-process strategy. First, participants searched for the target-defining feature, and during this stage, they did not automatically process the shapes that defined the positive or negative faces. Once they found the target, they processed the shape in order to identify the response-defining feature. Since only this latter stage required shape processing, the (irrelevant) shape of the face was processed only then, which in turn led to interference when the target position coincided with a negative face.

We may still ask why and how the identity of the crowd affects search performance. One account of a crowd effect has been advanced by Eastwood et al. (2003), proposing that access to a lower level feature is more difficult when the face is negative (see also Suzuki & Cavanagh, 1995). According to this view, slower distractor rejection in negative than in positive crowds may be due to the fact that access to lower level features is generally blocked by a higher level facial gestalt—in particular, with negative faces. However, we do not find this account convincing. It could have explained aspects of Experiments 1B, 2B, and 3B, assuming that the higher level gestalt of a negative expression blocked access to nose layout or vertical line orientation. This explanation, however, produces a dilemma when participants search for the higher level gestalt of a facial expression (Experiments 1A, 2A, and 3A). Either the mouth belongs to the higher level gestalt—in which case it is not necessary to access the mouth as a lower level feature in order to make the response—or the mouth is a lower level feature on which the response is based, in which case there is no basis for a global-to-local precedence to explain interference by negative valence.

We prefer a different explanation of the crowd effect, according to which *positive* and *negative* are regarded as semantic labels for perceptually distinct stimuli, with the perceptual differences accounting mainly for differences in search performance (e.g., Horstmann, 2007, in press; Horstmann et al., 2006). According to our explanation, the speed or efficacy with which different stimuli in a visual search array can be processed and rejected must be a function of similarity and complexity of the stimuli (Horstmann et al., 2006). Duncan and Humphreys (1989) hypothesized that the distractors can be rejected more easily as a group if they are dissimilar to the target and similar to each other. In an extension of this, Horstmann et al. noted that positive faces have a simpler perceptual organization than do negative faces and may even be regarded as self-similar because the mouth shape is similar to the adjacent chinline. Moreover, even if the chinline is disregarded, the mouth and eyes form a simple circular shape due to gestalt processes of grouping and closure. This is true to a lesser extent for the negative faces. Self-similarity and simplicity are roughly the converse of complexity, which has been assumed to be a determinant of encoding efficiency of distractors in visual search by Rauschenberger and Yantis (2006). Thus, according to our explanation, more efficient rejection of positive-face distractors than of negative-face distractors is due to the simpler perceptual organization of positive faces, which facilitates rejecting single positive faces, as well as rejecting them as a group (Duncan & Humphreys, 1989). If, in turn, positive-face distractors are rejected more efficiently than are negative-face distractors, a negative-face singleton could stand out as a distinct stimulus relatively well, which would explain the crowd effect or the valid–invalid difference in RTs. This account is preferable to the global-to-local interference explanation of crowd effects, because it parsimoniously explains many of the main results from the present experiments, draws on conceptions that have been identified to modulate search efficiency (i.e., similarity and complexity), and can also account for RSAs in tasks that do not involve emotional faces.

To summarize, the present study is apparently the first to test the threat-capture hypothesis with emotional faces using the 1/*n* paradigm, which is probably the most important design for testing involuntary attentional capture. Previous studies have used either unusual tests of involuntary attentional capture or standard visual search tasks, where efficient search cannot be taken to be evidence for involuntary attentional capture, because participants voluntarily search for the emotional target (e.g., Yantis, 1993). In the present Experiments 1B, 2B, 2C, 3B, and 3C, the hypothesized attention-capturing property (facial threat) had to be uncorrelated with the reported or the defining feature of the target. We have found support for the hypothesis that the effect of stimulus valence on attention is involuntary, rather than intentional, in the sense that facial valence affects performance, even when it is task irrelevant. However, we found no evidence that the locus of this effect is preattentive, given that search was very inefficient. Finally, we found considerable evidence favoring crowd-based rather than target-based effects, as discussed before. We propose that the difference between negative and positive faces mostly resides in processes that commence after attention has been shifted to a location, with negative faces slowing processes of perceptual identification or of disengaging attention more than positive faces.

This conclusion is also consistent with previous studies investigating the threat-capture hypothesis with other fear-provoking stimuli (e.g., Lipp & Waters, 2007; Miltner, Krieschel, Hecht, Trippe, & Weiss, 2004). In these studies, snakes and spiders constituted irrelevant distractors that could be either present or absent from the search array. In the study by Lipp and Waters, search for a bird or fish target among other animals (e.g., horses, cats) was slower in the presence of an irrelevant snake or spider distractor than when the distractor was absent. Lipp and Waters also included pictures of cockroaches and lizards as similar-looking (but less fear-provoking) control distractors for spiders and snakes, respectively. The results showed that search was slower in the presence of feared distractors (i.e., spider, snake) than in the presence of nonfeared distractors (i.e., cockroach, lizard), but that the presence of nonfeared distractors also significantly slowed search, compared with a distractor-absent control condition (Lipp & Waters, 2007). Additionally, the distractor effect of spiders and snakes was differentially larger in participants who were apprehensive of either spiders (but not snakes) or snakes (but not spiders). Lipp and Waters speculated that fear-relevant stimuli exert their effect both by preferentially attracting attention and by holding attention longer—that is, by creating difficulties in disengaging attention from fear-provoking stimuli (see also Lipp, 2006; Lipp, Derakshan, Waters, & Logies, 2004).

This interpretation is fully consistent with the interpretation presented in the present study. Although we wish to remain agnostic about the question of whether negative faces cause interference in postselectional processes because of their perceptual or emotional properties, the results of the present study suggest that differences between negative and positive faces in visual search (1) are independent of the intention to search for a negative or positive face; (2) are, to a large extent, mediated by the identity of the crowd, and not by the identity of the target; and (3) cannot be clearly attributed to preattentive processes concerned with guiding attention, but may well reflect processes located in the attentive or postselectional stage of processing.

The present results are also in line with numerous visual search studies that prevalently rendered inefficient search for negative faces among positive or neutral distractors. Clearly, if negative faces are not processed preattentively, it is logically impossible that they capture attention (in the strong sense). Second, and also in line with the previous experiments, the search advantage for negative faces over positive faces in Experiments 1A, 2A, and 3A was demonstrated to reside in more efficient rejection of positive-face than of negative-face distractors (e.g., Fox et al., 2001; Horstmann, in press; Horstmann et al., 2006). This is evident in the target-absent slopes, which showed the same search inequality as the target-present slopes. In fact, Horstmann showed that across five different pairs of stimuli, search efficiency in target-absent trials explained 96% of the variance in target-present trials. Third, some experiments revealed a stronger negative-target advantage for participants high in state anxiousness than for participants low in state anxiousness, suggesting an emotional bias (Fox et al., 2001). This effect does not necessarily indicate threat capture, but it is consistent with faster scanning through positive-face distractors, or slower disengagement of attention from positive-face distractors. Consistently, results by Fox, Russo, and Dutton (2002) and Rinck et al. (2005) have suggested that highly state-anxious participants may dwell longer on negative stimuli than do lower state-anxious participants. Fourth, the present results are consistent with an account given by Horstmann and Bauland (2006) to explain possible target effects for photorealistic faces. According to their sensory-bias hypothesis, negative faces may be searched for relatively efficiently, not because of the working of dedicated threat-detection modules, but because the signaling processes and structures have been molded by evolutionary processes to the effect that ecologically more urgent social signals (e.g., unfriendly intent) are perceptually more conspicuous than less urgent social signals (e.g., friendly intent). Here, it is not that the visual system has adapted in evolution to the facial signals (which is implied by, e.g., Öhman et al., 2001), but that facial signal programs have adapted to the capabilities of the visual system. This hypothesis implies that real facial expressions may have perceptual appearances that allow easy detection. The features that allow attentional guidance are still to be identified, but according to the research on so-called basic features, one would expect those features to be relatively simple perceptual characteristics, such as a particular contrast or spatial-frequency distribution (see Wolfe & Horowitz, 2004). The present results are consistent with the sensory-bias hypothesis, in that preattentive processing of facial affect is not required in order to account for target effects.

Finally, the hypothesized preattentive processing of angry faces has been connected to LeDoux's (1998) theory of dual pathways to the amygdala, which has been portrayed as the "hub in the wheel of fear." In particular, it has been suggested (e.g., Öhman et al., 2001) that facial expressions may be accessible to the amygdala by the "low road"—that is, via thalamo-amygdaloid connections. The results of the present study, however, do not suggest this connection. Even with negative valid singletons, search was very inefficient, strongly suggesting slow attentional processing, rather than "quick-and-dirty" noncortical processing. Complex emotional stimuli, such as faces, are more probably processed via the "high route" to the amygdala, where emotional relevance is determined (see LeDoux, 1998), with involvement of cortical processing capabilities, and not via the "low route," which involves the direct route from the sensory thalamus to the amygdala. As demonstrated by LeDoux, very simple stimuli may not need cortical processing for acquiring emotional significance by means of the amygdala. Faces, however, are probably not simple and would therefore require cortical processing (note that the affective response may not depend on a full cortical processing of the face; e.g., Vuilleumier et al. [2001] found that unattended facial expressions are not processed at the [cortical] fusiform gyrus, but at the [subcortical] amygdala).

We have suggested in the introduction that an uncertainty in the concept of attention might be the result of the diverse fields of research. We would like to conclude with a suggestion for more conceptual clarity with respect to shifts of attention. In our view, attention can be shifted voluntarily in accordance with an (often reportable) plan, or involuntarily—that is, *unplanned* or *spontaneous*. Second, differences in search performance can be based on preattentively available information or on postselectively available information that becomes available only after attention has been devoted to a stimulus. Both dimensions—intentionality and parallel processing—can be combined to form four categories. We doubt that facial expressions are processed in parallel (preattentively) in a way corresponding to classical basic features like color, contour, orientation, or abrupt onsets. However, in addition to an intentional search for certain facial expressions, faces and facial expressions, like many social stimuli, probably have a strong propensity to attract attention to themselves once their presence has been noticed (i.e., postattentionally), even in the absence of a specific intention (i.e., involuntarily).

AUTHOR NOTE

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NOTES

1. A strict distinction between efficient and nonefficient processes (see, e.g., Treisman & Souther, 1985) has been convincingly criticized (Wolfe, 1998), because search functions show a continuum of slopes, not a dichotomy. However, this critique does not imply that efficient search

is not a necessary criterion for preattentive processing; it just says that it is not sufficient (see, e.g., Wolfe & Horowitz, 2004).

2. Many visual search studies use more than two set sizes, which has the advantage that deviations from linearity can be easily detected. However, for the computation of the slope and intercept parameters of a linear function, two set sizes are sufficient. The reason we used only two set sizes was that in the 1/*n* paradigm, $n - 1$ invalid trials have to be presented for every valid trial. If we had added a set size 9, for example, for 40 valid trials, we would have had to present 320 invalid trials. We preferred to keep the experiment short to prevent fatigue and disengagement from the task, because the marginal utility is small. For the same reason, rather small set sizes were used.

3. Experiments 1B and 2B (but not Experiment 3B) showed similar patterns of results that are indicative of a weak attention capture effect of the negative-face singleton. For the friendly-face singleton, but not for the positive-face singleton, the set size effect was smaller in valid than in invalid trials. To explore this effect with enhanced power, we combined the data from all three experiments and conducted a conjoint analysis. Table 1 gives an overview of the search slopes of the corresponding Experiments 1B, 2B, and 3B. The ANOVA yields a significant main effect of validity [$F(1,35) = 9.6$, $p < .01$], reflecting faster RTs in valid than in invalid trials (1,094 vs. 1,133 msec, respectively), and a main effect of set size [$F(1,35) = 113.9$, $p < .001$], reflecting faster RTs with set size 3 than with set size 6 (989 vs. 1,237 msec, respectively). The main effect of singleton identity was not significant ($F < 1$). Of the two-way interactions, the validity × set size interaction was significant [$F(1,35) = 13.4$, $p < .001$]. The three-way interaction was significant [$F(1,35) = 8.7$, $p < .01$], reflecting that search efficiency was different in valid and invalid trials for the negative-face singletons (61 vs. 100 msec/item, respectively) [$t(35) = 4.1$, $p < .001$], but not for the friendly-face singletons (80 vs. 89 msec/item, respectively) [$t(35) = 1.3$, *p*s $> .10$]. The remaining interactions were not significant (*F*s > 2.0, *p*s $> .1$). An analysis of the error scores did not yield any significant effect (*F*s < 2.2). This analysis demonstrates a robust involuntary spatial guidance effect by the negative-face singleton in a positive crowd, but not by the positive-face singleton in a negative crowd, even though the effect was virtually absent in Experiment 3B.

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