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The Face in the Crowd Effect Unconfounded: Happy Faces, Not Angry Faces, Are More Efficiently Detected in Single- and Multiple-Target Visual Search Tasks

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Is it easier to detect angry or happy facial expressions in crowds of faces? The present studies used several variations of the visual search task to assess whether people selectively attend to expressive faces. Contrary to widely cited studies (e.g., Öhman, Lundqvist, & Esteves, 2001) that suggest angry faces "pop out" of crowds, our review of the literature found inconsistent evidence for the effect and suggested that low-level visual confounds could not be ruled out as the driving force behind the anger superiority effect. We then conducted 7 experiments, carefully designed to eliminate many of the confounding variables present in past demonstrations. These experiments showed no evidence that angry faces popped out of crowds or even that they were efficiently detected. These experiments instead revealed a search asymmetry favoring happy faces. Moreover, in contrast to most previous studies, the happiness superiority effect was shown to be robust even when obvious perceptual confounds—like the contrast of white exposed teeth that are typically displayed in smiling faces—were eliminated in the happy targets. Rather than attribute this effect to the existence of innate happiness detectors, we speculate that the human expression of happiness has evolved to be more visually discriminable because its communicative intent is less ambiguous than other facial expressions.

Keywords: face perception, attention, anger, emotional expressions, ecological psychology

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The human face conveys a rich array of signals. Emotional expressions are among the most ancient of these signals, often conveying messages with important—potentially dire—consequences for the receiver's fitness (Fridlund, 1994). For example, a smiling face says "approach me" and may offer affiliation, coalition building, warmth, and companionship, whereas an angry face says "back away," communicating displeasure and goal frustration on the part of the displayer and potentially warning of impending aggression and violence (Scherer & Wallbott, 1994). Today many theorists postulate that the human mind has mechanisms that automatically scan the environment for signs of danger and reallocate cognitive resources to deal with these proximate threats (Öhman & Mineka, 2001). Because facial expressions have been around since prehistoric times, it is not unreasonable to expect that the angry face is in this class of attentionally privileged objects and that it rapidly draws attention even when hidden in large crowds. Indeed, a growing literature purports to find such effects. Upon closer inspection, however, many of these results have alternative explanations that undermine strong inferences. One critical issue is that the method typically used in such demonstrations—the single-target visual search—is extremely sensitive to basic visual features such as lines and colors (Treisman & Gelade, 1980). Consequently, the method is susceptible to the criticism that low-level perceptual processes can drive attentional effects even if the emotional content of the expression is not perceived. How, then, can we distinguish between early perceptual mechanisms on the lookout for anger (which is what most authors are interested in and claim to find) and the efficient detection of simple visual features that are confounded with these more complex stimuli?

One way to show that anger indeed draws attention is to demonstrate that this occurs across a number of experiments and across a wide variety of stimulus sets, each containing multiple exemplars that are reliably identified as angry. Unfortunately, although some studies (to be reviewed shortly) do conclude that angry faces are more rapidly detected in a crowd of faces—the *anger superiority effect* (ASE; e.g., Hansen & Hansen 1988; Öhman, Lundkvist, & Esteves, 2001)—other studies have not found support for this idea (e.g., Hunt, Cooper, Hungr, & Kingstone, 2007; Purcell, Stewart,

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& Skov, 1996), and still others suggest that it is instead happy faces that are detected more efficiently (the *happiness superiority effect* [HSE]; e.g., Juth, Lundqvist, Karlsson, & Öhman, 2005). These differences may depend critically on the particular stimulus sets employed, which is problematic for any account that posits evolved threat detectors as the cause of the ASEs that are obtained.

We are not the first to systematically assess this literature. One recent review of the literature investigating visual searches for emotionally expressive faces (Frischen, Eastwood, & Smilek, 2008) concluded that there was evidence that expressive faces give rise to preattentional effects. That is, facial displays of anger can draw attention in even the noisiest environments (a functional equivalent of the cocktail party effect; Moray, 1959). This review is laudable in a number of respects, particularly in its attempt to make recommendations regarding how future experiments using the visual search task must be designed in order to make strong inferences about expressive face processing. However, in focusing on expressive faces in general, this review obscures one of the most important claims in the literature: that angry faces are preattentively detected. Whether this claim is made in its strongest form (that angry faces are detected equally fast regardless of the number of other faces in the crowd, i.e., that they "pop out" of crowds) or in the weaker form (that angry faces are merely more efficiently detected relative to happy faces), the ASE is one of the most widely cited effects in the emotion perception literature. Indeed, Frischen et al.'s (2008) review likely leaves most readers with the impression that anger superiority is broadly supported in the literature. Closer scrutiny, however, reveals a less consistent picture.

In the present work, we sought to provide a comprehensive picture of this literature and provide new empirical evidence that happy faces are more efficiently detected relative to angry faces. Importantly, the current research uses stimulus sets and experimental designs that move beyond the potentially confounded designs used in prior research. Additionally, the research employs a multitarget search design that affords stronger inferences about whether crowds are searched one face at a time (in a serial fashion) or whether all faces are simultaneously processed (in parallel), which is necessary if claims of preattentional availability are to be supported.

First, we provide an overview of the visual search method and consider strategies (including the suggestions made by Frischen et al., 2008) concerning how expressive faces should be used in this paradigm. Second, we provide a comprehensive review of the studies that have been used to support this claim. This review divides the relevant literature into those studies that used schematic (simple line drawing) faces and those that used photographs of real faces. The review also includes recent findings of HSEs and suggests that similar criticisms (i.e., perceptual confounds) may account for these effects. Third, we present several visual search experiments that use a number of design variations and stimulus sets, none of which reveal any evidence that angry faces are more efficiently detected. The results suggest that (a) realistic expressive faces are not preattentively detected and (b) the search asymmetry favors happy rather than angry expressions, persisting even when low-level visual confounds have been eliminated.

Search Asymmetries in the Visual Search Paradigm

The single-target visual search task (Treisman & Gelade, 1980; Wolfe, 1992) requires participants to search through arrays of objects for a target item, and can therefore reveal differences in the efficiency with which particular target classes can be found. The size of the array, and thus the number of distractors, is a key manipulation because it allows researchers to estimate search functions that relate the size of the array to the amount of time it takes to make a correct decision. These functions of search time and number of objects in an array quantify, as slopes, the effect of adding an object on search time. Greater slopes indicate a greater increase in search time for each additional distractor. Because target-absent trials require an exhaustive search of the entire array before participants can indicate that the target is absent, slopes for these trials provide an important baseline against which other slopes can be interpreted. If a target is present and appears equally often in each possible location within an array, then participants who search these arrays one item at a time and terminate the search when the target is found will find the target, on average, halfway through the search. The mean detection time for a target-present array will thus be half that of the exhaustive search, and so the slope will be about half that obtained in the target-absent condition. This has traditionally been called a *serial self-terminating search*. In contrast, another class of searches, known as *parallel searches*, is unaffected by array size. Here a target can be detected in the same amount of time regardless of the number of distractors, which suggests that preattentive mechanisms guide attention to the targets location (see Figure 1).

Although recent research has challenged the contention that searches can be neatly classified as either serial self-terminating or parallel (Wolfe, 1992; but see Thornton & Gilden, 2007, for new evidence of purely serial searches), these two broad classes of search remain useful anchors for thinking about performance in the visual search task. For example, although there is still considerable debate about what kinds of features reliably yield

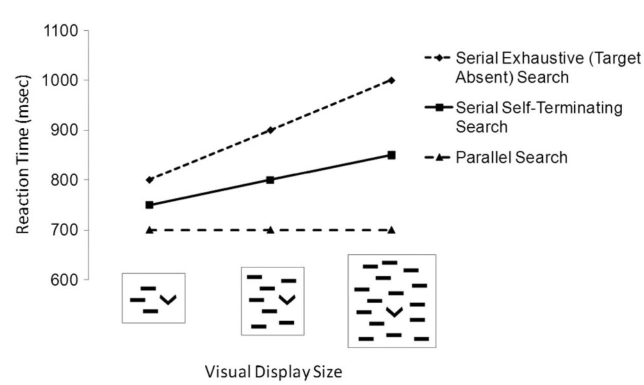


Figure 1. In the visual search task, participants must discriminate a target (V) from a set of distractors. The number of distractors is varied from trial to trial, allowing researchers to explore whether the search rate increases with more distractors, indicating serial exhaustive search strategies, or whether the slopes are flat, indicating that the target it is preattentively available.

search slopes near zero, single features such as color, size, line orientation, and motion generally do appear to pop out of arrays (Treisman, 1986). Even in the absence of pop-out effects, most searches likely involve both parallel and serial mechanisms (i.e., preattentive parallel processes that can isolate subsets of stimuli satisfying certain criteria, which can then initiate a postattentive serial search; Wolfe, 1998). This opens up the possibility that preattentive mechanisms operating in parallel might favor certain classes of objects over others, yielding search asymmetries in which these favored classes are more efficiently detected relative to other classes of stimuli (see Wolfe, 2001, for a review). However, questions have been raised about the single-target visual search task's ability to ground strong inferences about serial versus parallel searches, and many cognitive psychologists now favor a different paradigm—the multitarget search—where questions about preattentive availability are concerned (Thornton & Gilden, 2007). Surprisingly, the expressive face detection literature has not used this method. Because both methods have different inferential value, we use both of them in the empirical work below.

Theoretical Considerations Regarding the Use of Expressive Faces in the Visual Search Task

Before providing a more detailed review of the studies that specifically support ASEs and HSEs, it is useful to consider some theoretical issues that should inform the design and interpretation of studies that use angry and happy faces in the visual search task. The following discussion parallels Frischen et al.'s (2008) review of the uses of the visual search paradigm to investigate attention to emotionally expressive faces, but differs from their recommendations in several respects. Therefore we will augment these recommendations accordingly.

According to Frischen et al. (2008), the primary goal of their review was to answer the question "Are emotionally expressive faces processed preattentively and guiding attention in a visual search task?" (p. 655). The authors noted three criteria that must be satisfied by a design in order to provide a positive answer to this question:

1. Set size must be varied within subjects in order for slopes to be calculated, allowing for comparison of search efficiency between stimulus types. They further recommended that more than two set sizes be used, so that the linearity of the effects can be assessed. We suggest that for proper determination of search asymmetries, one not only needs multiple set sizes but also needs to assess the slopes for correct detections of targets relative to the target-absent searches. Analyses in terms of such search ratios are common practice in the bulk of the visual search literature (see Wolfe, 1992) and can disambiguate key findings when expressive faces are the targets (as we show below).

2. The content of the distractor crowds must be held constant across the different types of targets. If angry faces appear to be more efficiently detected relative to happy (or other expressive) faces, but the angry faces occur within happy crowds while the happy faces appear within angry crowds, target detection effects are confounded with search rates through different types of crowds. In other words, efficient detection of anger may reflect particularly fast searches through happy crowds and/or particularly slow searches through angry crowds. Frischen et al. (2008) advocated that nonexpressive faces be used as distractors for all target detection trials.[1]

3. Studies must be designed such that participants are consciously searching for a particular kind of expression. In support of this, Frischen et al. (2008) noted that searching for a specific expression sometimes yields more efficient detection relative to designs in which participants search for any discrepant expression. This criterion may be unnecessary in the present case, however, as any appeal to the adaptive nature of the ASE (e.g., Öhman & Mineka, 2001) should entail that signals of social threat, such as the angry facial expression, automatically draw attention to their presence regardless of the top-down goals of the perceiver.[2]

However, Frischen et al. (2008) may have neglected what are perhaps the most important criteria:[3]

4. For a study to demonstrate that emotionally expressive faces drive preattentional processes and/or efficient searches, it is critical to rule out low-level visual features that could account for the effect. For example, imagine that previous researchers have already noted that a V in an array of dashes can be detected more rapidly than a dash in a field of Vs. If new research employs a simple schematic angry target constructed such that one of its features is a V-shaped brow that is contrasted with happy targets constructed with a flat horizontal line for a brow, then any search asymmetry that favored the angry schematic face may entirely arise from the primitive properties of the visual system—feature detectors that have nothing to do with expression perception. Any sufficiently simple stimulus type has the potential to conceal such an alternative explanation.[4] Furthermore, researchers should take steps to ensure that distractors are selected to differ in equivalent ways from each of the possible targets. It is now widely conceded that when an item has more features than another item, this will give rise to a search asymmetry favoring the more complex item

[1] This raises the issue of what constitutes a nonexpressive distractor. Horstmann et al. (2006) have done several things to illustrate the theoretical perils and solutions to this dilemma, and we commend their work to the reader.

[2] Horstmann et al. (2010) have explicitly investigated this, showing that certain threat-relevant stimuli do not drive efficient search if their status as targets is based on other properties—like color and orientation—and conclude that it is hard to see the adaptive advantage of finding threatening faces if they do not grab attention in scenarios that have different top-down sets.

[3] Frischen et al. (2008) asked a similar question—"What properties of emotionally expressive faces influence search efficiency?"—but neglected to include this as an explicit criteria.

[4] We should note that Frischen et al. (2008) discussed at length the possibility that a single feature might drive efficient search and appeared open to the possibility that such primitive features might drive efficient search precisely because of their emotionality. Unfortunately, this position borders on being unfalsifiable: If one group of researchers claimed that the V is better detected because it is the sign vehicle for anger (as was suggested by Aronoff et al., 1992), and another group claimed that simple cells in the visual cortex designed to detect features that had nothing to do with anger fully explain the effect, how could a visual search experiment ever distinguish between these two possibilities? It is instead incumbent upon researchers to design studies that are decidedly about expression detection and strive to eliminate confounds at the level of simple perceptual features.

(Wolfe, 2001),[5] and this extends to the number of features that differ between the target items and the distractors.

5. Considerations of the potential for visual confounds suggests one additional criterion: If distractors are extremely homogeneous in form (and specifically if they are identical), then target detection effects can arise, because participants can learn to search for idiosyncratic featural differences between targets and distractors. One way to guard against this is to make sure that the distractor faces, while all bearing similar expressions and other qualities, do show some variability so that participants cannot learn a single identical feature that discriminates distractors from targets. Any finding that arises from a single stimulus target and single repeated distractor being used over and over again (e.g., the majority of studies reviewed below) should be interpreted with caution. Research in the visual search paradigm has shown that almost anything can come to be detected efficiently if enough trials are administered, because this gives participants an opportunity to find features in the repeated stimuli that can drive the efficient search without emotional processing coming into play at all (Cave & Batty, 2006; Schneider & Shiffrin, 1977). Ensuring that low-level visual confounds—whether in the targets or in the distractors—cannot account for expressive face visual search results is critical to making sound inferences about expressive face effects in the visual search arena.

Before moving on to our own review of the literature, we should draw attention to two of the conclusions of Frischen et al. (2008):

> We argue that (1) preattentive search processes are sensitive to and influenced by the emotional expression of faces; (2) search efficiency is influenced by the emotional meaning of facial expressions (*note that this is not incompatible with findings that perceptual characteristics also influence allocation of attention*) (p. 665, emphasis added)

It is our position that the first conclusion must be grounded in the second and that Frischen et al. have not done this for the ASE. Specifically, their parenthetic note conceals a critical assumption that cannot support strong inferences about the ASE if all such demonstrations are confounded with simple perceptual characteristics. This critical difference motivates the present work and leads to very different conclusions.

Claims of Selective Attention for Anger in the Visual Search

Hansen and Hansen (1988) were the first psychological researchers to claim that angry faces pop out of crowds. They used the visual search paradigm to demonstrate that angry faces could be detected faster than happy faces and that detection times for angry faces did not significantly rise with an increase in the number of distractors (from three to eight distractors). However, Purcell et al. (1996) subsequently demonstrated that confounds in the stimuli were popping out—it was not the expression of anger at all. Specifically, the image-processing technique used to convert the photographs to pixilated images inadvertently introduced a black blotch at the base of each of the angry faces. In a careful replication by Purcell et al., the pop-out effect vanished once this artifact was removed. Furthermore, these researchers then added a different artifact (a smaller, white blotch) and demonstrated that they could make the pop-out effect return. This initial foray into visual search for expressive faces is unfortunately all too typical of the subsequent work: Visual confounds were confused for psychological effects. We must therefore look elsewhere for unconfounded evidence that angry faces are efficiently detected in crowds. Although it is not difficult to find purported demonstrations, they are rife with inconsistencies, confounds, and alternative explanations to the threat detector hypothesis.

Evidence of the Anger Superiority Effect

Many studies are now cited in support of the contention that angry faces are efficiently detected in crowds of faces, and these studies fit into two broad classes: those that use schematic line drawings of expressions for stimuli and those that use photographs of real faces. The schematic studies can be further subdivided into those that use line drawings of faces whose only expressive cue is a frowning mouth and those that add downturned eyebrows to make the faces appear unambiguously angry.

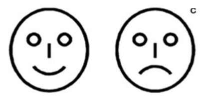
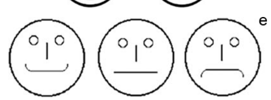
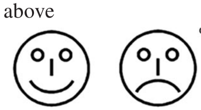
Schematic Demonstrations Without Eyebrows

Table 1 catalogs the schematic face studies and makes clear that the bulk of the demonstrations of an expression superiority effect use schematic faces without eyebrows. Although these stimuli may suggest that negative emotions capture attention, they are not strongly supportive of claims that anger captures attention. Indeed, Fox, Russo, Bowles, and Dutton (2001) reported that 16 of 20 participants identified their eyebrowless stimuli as "sad." It is difficult to see how the threat detection mechanisms postulated to underlie ASEs would be vigilant for signs of sadness, because such faces do not convey interpersonal threat. We therefore distinguish the effects demonstrated with these kinds of faces as sadness superiority effects.

Table 1 shows that the results of these studies are somewhat mixed and that many of these studies generally do not conform to the optimal strategies we discussed above, which opens up alternative explanations for the effects. For example, Horstmann, Scharlau, and Ansorge (2006; row 6 in Table 1) counter Eastwood, Smilek, and Merikle's (2001) results with their own design, which "highlights a major methodological requirement not met by the study of Eastwood et al. (2001) but met by the present research: Differences in the ease of distractor rejection caused by different amounts of perceived target–distractor similarity must be ruled out" (p. 1072). Despite positive findings with their better controlled distractor stimuli, Horstmann et al. have been increasingly critical of interpreting such results as supporting a facial threat detection adaptation, because other aspects of the results suggest that low-level stimulus features provide more parsimonious explanations of their results. Horstmann (2007) provided new empirical results comparing several of the stimulus sets used in previous research and concluded that despite a consistent negative face advantage, the searches were not particularly efficient, and so provided little evidence for preattentive search. In subsequent work, Horstmann (2009) compared performance with these stimuli in a within-subjects design and concluded that low-level stimulus

[5] Note that Wolfe (2001), after making this point, went on to point out that "not only are faces not basic, preattentive features, but basic features like curvature . . . can lose their ability to support efficient search if they form part of a face" (p. 384).

Table 1
Expression Detection Studies With Schematic Sad Faces

Experiment	Stimuli	*n*	Vary size	Neutral crowds	Top down	Vary distractors, targets	Effect
Eastwood et al. (2001): Experiment 1A	 [a]	11	7, 11, 15, 19	Yes	No	No, no	SSE
Eastwood et al. (2001): Experiment 1B	As above, but inverted	11	7, 11, 15, 20	Yes	No	No, no	SSE
Eastwood et al. (2001): Experiment 2A	As above for Experiment 1A	11	7, 11, 15, 21	Yes	No	No, no	SSE
Eastwood et al. (2001): Experiment 2B	As above, but inverted	11	7, 11, 15, 22	Yes	No	No, no	SSE
Eastwood et al. (2005)	As above	12	7, 11, 15, 19	Yes	No	No, no	SSE
Horstmann et al. (2006)	 [b]	12	1, 6, 12	Yes	Yes (blocked)	No, no	SSE
Horstmann (2007): Experiment 3	 [c]	8	1, 6, 12	No	Yes (blocked)	No, no	SSE
Horstmann (2007): Experiment 4	 [c]	8	1, 6, 12	No	Yes (blocked)	No, no	SSE
Horstmann (2009): Set A (White)	 [c]	20	1, 6, 12	No	Yes (blocked)	No, no	SSE
Horstmann (2009): Set B (Fox)	 [c]	20	1, 6, 12	No	Yes (blocked)	No, no	SSE
Horstmann (2009): Set D (Eastwood)	 [d]	20	1, 6, 12	No	Yes (blocked)	No, no	SSE
Horstmann (2009): Set E (Nothdurft)	 [c]	20	1, 6, 12	No	Yes (blocked)	No, no	SSE
Nothdurft (1993): Experiment 1.5	 [c]	10	Many	Yes	Yes	No, no	None
Suslow et al. (2003)	 [e]	30	2, 4, 6	No	No	No, no	SSE
Suslow et al. (2004)	As above	22	2, 4, 6	No	No	No, no	SSE
White (1995): Experiment 1	 [c]	14	2, 4, 6	No	No	No, no	*ns* HSE

(table continues)

Table 1 (*continued*)

Experiment	Stimuli	*n*	Vary size	Neutral crowds	Top down	Vary distractors, targets	Effect
White (1995): Experiment 2	As above, inverted	14	2, 4, 6	No	No	No, no	*ns* HSE
White (1995): Experiment 3	As above, plus neutral crowd	14	2, 4, 6	Yes	No	No, no	*ns* SSE
White (1995): Experiment 4	As above, inverted	14	2, 4, 6	Yes	No	No, no	*ns* SSE

Note. Although these studies appeared to provide evidence for a sadness superiority effect (SSE), they frequently failed to employ the design criteria that would have allowed us to rule out low-level confounds. HSE = happiness superiority effect.

[a] From "Differential Attentional Guidance by Unattended Faces Expressing Positive and Negative Emotion," by J. D. Eastwood, D. Smilek, and P. M. Merikle, 2001, *Perception & Psychophysics, 63,* p. 1006. Copyright 2001 by the Psychonomic Society. [b] From "More Efficient Rejection of Happy Than of Angry Face Distractors in Visual Search," by G. Horstmann, I. Scharlau, and U. Ansorge, 2006, *Psychonomic Bulletin & Review, 13,* p. 1070. Copyright 2006 by the Psychonomic Society. [c] From "Search Asymmetries With Real Faces: Testing the Anger-Superiority Effect," by G. Horstmann and A. Bauland, 2006, *Emotion, 6,* p. 195. Copyright 2006 by the American Psychological Association. [d] From "Visual Search for Schematic Affective Faces: Stability and Variability of Search Slopes With Different Instances," by G. Horstmann, 2009, *Cognition and Emotion, 23,* p. 363. Copyright 2009 by Psychology Press. [e] From "Detection of Facial Expressions of Emotions in Schizophrenia," by T. Suslow, C. Roestel, P. Ohrmann, and V. Arolt, 2003, *Schizophrenia Research, 64,* p. 141. Copyright 2003 by the Schizophrenia International Research Society.

idiosyncrasies of both targets and distractors accounted for all effects. In short, mounting evidence suggests that the eyebrowless variety of schematic stimuli generate effects that do not require expressive face detection advantages at all.

Schematic Demonstrations With Downturned Eyebrows

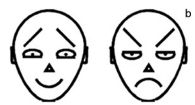
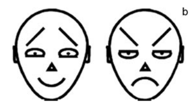
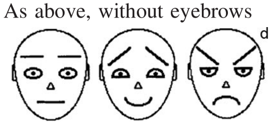
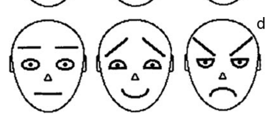
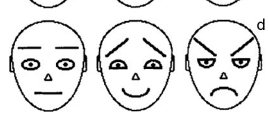
Other studies, summarized in Table 2, used schematic faces that are more clearly angry, but these additional features introduced additional confounds. The most cited example[6] is Öhman et al. (2001), despite its being questioned fairly frequently in the primary literature (e.g., Horstmann & Bauland, 2006). Their conclusions included a claim of pop-out for angry (and happy) faces in neutral crowds and a general superiority for angry detections. However, on closer inspection, it is clear that each experiment manipulating crowd size produced only very slight slope advantages for angry versus happy targets (e.g., 3-ms slope for angry targets vs. a 4-ms slope for happy targets in Experiment 2). Furthermore, as Horstmann and Bauland (2006) noted in their review of this work, "a search asymmetry with pop-out for angry or threatening faces was not found, search was clearly inefficient, and only the error data may be interpreted as revealing an advantage of angry targets in happy crowds" (p. 195). An even more important criticism is that Öhman et al. found that their angry schematic face was better detected even when presented upside down. Superior detection of an inverted face is a sign that facial or expression perception does not drive the effect, because inversion disrupts facial processing and thus makes expression perception more difficult (Farah, Tanaka, & Drain, 1995). This suggests that simple visual features, and not the expression of anger, drove the reported ASE. Indeed, Purcell and Stewart (2002) pinpointed a perceptual feature that could drive the superior detection of schematic angry faces: The eyebrows and corners of the mouths radiate outward from the center of the face. This would allow very simple feature detectors in the visual cortex to detect these schematic faces even when presented upside down.

It is important to note that not all attempts to use schematic displays of facial anger have yielded positive evidence for the ASE. Hunt et al. (2007) recently used eye-tracking technology to investigate this effect and failed to find evidence that angry schematic stimuli grab attention any faster than other (emotionally expressive or neutral) stimuli. Furthermore, as noted above, Horstmann (2007, 2009) has used all of these stimuli in more tightly controlled studies and has convincingly demonstrated both that these searches are not particularly efficient and that distractor homogeneity plays a bigger role than target discriminability. Moreover, these stimuli do not give rise to involuntary capture (i.e., they do not grab attention when another stimulus is being searched for; Horstmann, Becker, Bergman, & Burghaus, 2010), and the ASE to which they do give rise can be reversed by stimulus manipulations that leave the expressive components intact but change the outlines of the schematic faces (Horstmann et al., 2010).

In sum, studies using schematic faces of anger that include eyebrows as well as frowning mouths have produced evidence that

[6] Over 250 citations at the time this article was written.

Table 2
Expression Detection Studies With Schematic Angry Faces

Experiment	Stimuli	*n*	Vary size	Neutral crowds	Top down	Vary distractors, targets	Effect	Comments
Hahn et al. (2006): Experiment 1	 [a]	40	5, 10, 15, 18	Yes	No	No, no	ASE	Touch screen response
Hahn et al. (2006): Experiment 2	See above	28	6, 10, 14, 18	Yes	No	No, no	ASE	640 trials
Hahn et al. (2006): Experiment 3	See above	30	5, 10, 15, 20	Yes	Yes	No, no	ASE	1,680 trials
Hahn & Gronlund (2007): Experiment 1	See above	16	5, 10, 15, 21	Yes	No	No, no	ASE	600 trials
Hahn & Gronlund (2007): Experiment 2	See above	11	5, 10, 15, 22	Yes	Yes	No, no	ASE	1,680 trials, singleton design
Horstmann (2007)	 [b]	8	1, 6, 12	No	Yes	No, no	ASE	Horstmann concluded “not efficient”
Horstmann (2009)	 [b]	20	1, 6, 13	No	Yes	No, no	*ns*	Horstmann concluded “not efficient”
Fox et al. (2000): Experiment 1	 [c]	45	4	Yes	No	No, no	ASE	300 ms
Fox et al. (2000): Experiment 2	 [c]	30	4	Yes	No	No, no	ASE	800 ms
Fox et al. (2000): Experiment 3	 [c]	22	4	Yes	No	No, no	ASE	Inversion of above
Fox et al. (2000): Experiment 4	As above, without eyebrows	36	4	Yes	No	No, no	SSE	Removes eyebrows
Fox et al. (2000): Experiment 5	As above, without eyebrows	21	4, 8	Yes	No	No, no	SSE	Removes eyebrows
Öhman et al. (2001): Experiment 1	 [d]	20	9	Some trials	No	No, no	ASE	
Öhman et al. (2001): Experiment 2	 [d]	16	4, 9, 16, 26	Some trials	No	No, no	ASE	Consistent search
Öhman et al. (2001): Experiment 3	 [d]	16	4, 9, 16, 27	Some trials	No	No, no	ASE	Emotional crowds, inconsistent search

(table continues)

Table 2 (*continued*)

Experiment	Stimuli	*n*	Vary size	Neutral crowds	Top down	Vary distractors, targets	Effect	Comments
Öhman et al. (2001): Experiment 4	As above, but inverted	36	9	Some trials	No	No, no	ASE	Effect found despite inversion
Öhman et al. (2001): Experiment 5	 [e]	18	9	Some trials	No	No, no	ASE	

Note. Although these studies seemed to show anger superiority effects (ASE), they failed to employ the design criteria that would have allowed us to rule out low-level confounds. Nonvisual search studies using these stimuli have typically failed to provide evidence of attentional capture (e.g., Horstmann et al., 2010; Hunt et al., 2007). SSE = sadness superiority effect.
[a] From "Aging and Visual Search: Automatic and Controlled Attentional Bias to Threat Faces," by S. Hahn, C. Carlson, S. Singer, and S. D. Gronlund, 2006, *Acta Psychologica, 123,* p. 317. Copyright 2006 by Elsevier. [b] From "Search Asymmetries With Real Faces: Testing the Anger-Superiority Effect," by G. Horstmann and A. Bauland, 2006, *Emotion, 6,* p. 195. Copyright 2006 by the American Psychological Association. [c] From "Do Threatening Stimuli Draw or Hold Visual Attention in Subclinical Anxiety?" by E. Fox, R. Russo, R. Bowles, and K. Dutton, 2001, *Journal of Experimental Psychology: General, 130,* p. 687. Copyright 2001 by the American Psychological Association. [d] From "The Face in the Crowd Revisited: A Threat Advantage With Schematic Stimuli," by A. Öhman, D. Lundqvist, and F. Esteves, 2001, *Journal of Personality and Social Psychology, 80,* p. 382. Copyright 2001 by the American Psychological Association. [e] From "The Face in the Crowd Revisited: A Threat Advantage With Schematic Stimuli," by A. Öhman, D. Lundqvist, and F. Esteves, 2001, *Journal of Personality and Social Psychology, 80,* p. 391. Copyright 2001 by the American Psychological Association.

angry faces are more efficiently detected. However, almost all of these findings are subject to the criticism that perceptual processing, rather than emotional processing, drives the effects.

Demonstrations of the ASE With Images of Real Faces

Given the problems with schematic stimuli, it is crucial to look for evidence that angry faces grab attention when more realistic stimuli are used. Table 3 details the studies that we believe have the greatest potential to reveal a real and unconfounded expression superiority effect. Before proceeding, it is crucial to note that there are several ways in which low-level perceptual effects might give rise to misleading results when using real faces. First, many studies use angry targets that have an open mouth, which, relative to a close-mouthed neutral expression, yields a simple visual feature—a dark patch at the base of the face—that would be expected to drive efficient search, particularly if the same stimulus target was used across many trials. Of course, happy faces with exposed teeth also have this kind of potential confound (discussed further below). Another problem is that many researchers neglect to compare target-present search rates with target-absent search rates. If angry targets yield shallower search rates relative to happy targets, but the exhaustive search rates are also shallower for happy crowds, this suggests that the results have more to do with ease of rejecting happy distractors than ease of finding angry targets. For example, Horstmann and Bauland (2006) produced evidence of what may appear to be an ASE, but when exhaustive search slopes are taken into account, there are slight advantages for happy expressions. Finally, we again need to be wary of any finding that arises from using the same stimulus target repeatedly (e.g., the 1,280 trials in Experiments 1 and 2 of Williams, Moss, Bradshaw, & Mattingley, 2005), as the repeated exposures allow participants to identify features unrelated to emotional processing that nonetheless facilitate efficient search.

This leads us to a more significant challenge to the generality of the ASE that arises in studies using realistic stimuli: Several studies have now demonstrated that happy faces are efficiently detected relative to angry faces. For example, Juth et al. (2005) reported an HSE with photographic stimuli, but these stimuli failed to yield any ASE (they did report an ASE in Experiment 4B by reverting to the schematic stimuli used in Öhman et al., 2001). Likewise, Williams et al. (2005) found that photographs of happy faces in neutral crowds were more efficiently detected.

Transitional Summary and Overview of the Current Empirical Research

In reviewing the prior literature that purports to show that expressive faces generate search asymmetries— or indeed, pop-out effects—there seems to be little unconfounded evidence for either ASEs or HSEs in the visual search task. However, given that the weaknesses in the extant literature are due to stimulus problems and design issues, the present research aims to provide more compelling (and less confounded) evidence that the visual search paradigm still has something to reveal about attention to facial expressions. The following experiments were designed in accordance with the five criteria we outlined above: Set sizes were varied, content of the distractors was controlled, top-down search strategies were encouraged, studies were designed to eliminate (or at least lessen) the influence of low-level visual features, and the crowds were composed of faces with varying identities. This research employs photographs of real faces and realistic-looking computer-generated stimuli, which are an alternative to simple schematic faces that provide a good balance of feature control and realistic complexity. Additionally, the research uses not only a traditional single-target visual search but also a multiple-target visual search, which has the potential to discriminate between serial and parallel search processes in ways that the single-target visual search does not (see Thornton & Gilden, 2007, discussed in greater detail below). These results systematically converge on the conclusion that angry faces are not efficiently detected in visual search tasks but that there does appear to be a search asymmetry favoring the detection of happy faces. In the general discussion, we suggest that this search asymmetry reveals something about the evolution of the expressions themselves rather than perceptual mechanisms innate in the human mind.

Experiments 1A and 1B

The first pair of experiments compared the relative detection advantage of happy and angry expressions in a crowd of neutral distractors, thus addressing Criteria 1–3. Note that although Experiment 1A uses the standard Ekman and Friesen stimulus set that we have already criticized as confounded (the happy expressions bear exposed teeth), it is included so that a comparison can be made with the results when the confound is removed by erasing the lower half of the faces in Experiment 1B.

Method: Experiment 1A

Participants. Twelve men and 12 women participated in exchange for course credit. One man and one woman were excluded from the analyses for having accuracy more than 2.5 standard deviations below the grand participant mean. In this and all studies that follow, participants were treated in accordance with the American Psychological Association guidelines for the ethical treatment of human subjects.

Materials. Six male faces from the Ekman and Friesen (1976) Pictures of Facial Affect stimulus set were used (identified in the database as EM, JJ, JB, WF, PE, and GS). Each actor portrayed each emotion (anger, happiness, and, for the distractors, neutrality). In all the experiments, E-Prime was used to create the experimental displays and record reaction times. The experiments were run on Dell desktop computers with Pentium 4 processors and identical hardware specifications.

Design. There were three crowd sizes: two, four, and six. Each array was constructed so that none of the component faces were of the same individual, increasing the ecological and external validity of these crowds.

Each face in the visual display was approximately $2.5° \times 3.3°$ of visual angle and appeared in one of 12 possible locations in a 4×3 array that filled the screen. The locations of faces (both target and distractor) were counterbalanced across trials so that, for a given array size, each face and each expression appeared in each position. Each individual's happy and angry expression appeared an equal number of times. Faces never appeared directly next to one another in the array (i.e., the cells of the array above, below, and on either side of a face were always empty). Half the trials had a target expressive face, and in the other half the target was absent.

Procedure. Participants were greeted and seated so that their eyes were approximately 60 cm from the computer monitor. The basic task was explained, and they were told that their continued participation would constitute their consent that the data could be used in published research. Participants were told that their task was to search for a discrepant emotional expression as quickly as possible. They were instructed to strike the *D* key if there was an expressive face in the crowd or the *5* key on the number pad if all the faces were neutral. Additional text instructions presented on the computer monitor reiterated the verbal directions.

Participants completed two blocks, each consisting of 48 trials at each array size for a total of 288 trials. Each trial began with a fixation point (a cross presented in the middle of the screen for 1 s). Next, the array was displayed and remained visible until the participant responded or 10 s elapsed. Finally, the participants received feedback regarding their accuracy and speed, which remained visible for 1 s and was followed by the next trial.

Method: Experiment 1B

Experiment 1B was identical to the design of Experiment 1A, but with a critical alteration to the stimuli: The lower half of each face was erased. Removing everything below the nose eliminated the confound of exposed teeth that had potentially driven earlier demonstrations (e.g., Juth et al., 2005). Any evidence of an HSE by such unconfounded stimuli would be far more compelling than previous demonstrations (i.e., Juth et al., 2005; Williams et al., 2005). It should be noted that because many have argued that the brow is the primary signal of anger (as was suggested by Aronoff, Woike, & Hyman, 1992), this manipulation stacks the deck in favor of seeing an ASE.[7]

Participants. Six men and 19 women participated for course credit.

Materials. The stimuli were created by erasing the lower half of the image starting just below the nose (see Figure 2).

Procedure. This study was very similar to Experiment 1A. Participants were explicitly instructed to look for an emotional brow in a crowd of neutral brows. All other aspects of the design mirror Experiment 1A.

Results: Experiment 1A

Reaction times. Median correct reaction times for the target-present and target-absent results were calculated for each participant at each array size. These were then entered into a repeated measures analysis of variance (ANOVA) to test the principal hypotheses.

A 2 (target emotion: angry, happy) $\times$ 3 (crowd size: two, four, six) within-subjects ANOVA was conducted on the target-present results. The crowd size factor was treated as a linear contrast (quadratic components were examined and were found to be nonsignificant; all Fs < 1). There was a main effect of target emotion, with happy faces being detected faster than angry faces, $F(1, 20) = 28.80$, $p < .001$, $\eta_p^2 = .597$. The linear contrast of crowd size was also significant, $F(1, 20) = 129.77$, $p < .001$, η_p^2

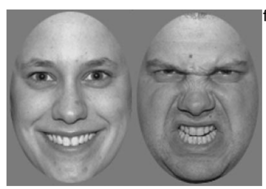
[7] Horstmann and Bauland (2006) used isolated images of eyes and mouths as well and did not find an ASE for the eyes, though it should be noted that they used only two stimuli.

Table 3
Expression Detection Studies With Photographs of Faces

Experiment	Stimuli	*n*	Vary size	Neutral crowds	Top down	Vary distractors, targets	Effect	Comments
Hansen & Hansen (1988): Experiment 3	 [a]	14	4, 9	Some trials	No	No, no	ASE	Widely repudiated
Hampton et al. (1989): Study 1	Unavailable	19	9	No	No	No, no	HSE	Slower searches through angry crowds
Hampton et al. (1989): Study 2	Unavailable	12	4	No	No	No, no	No expression advantage	Slower searches through angry crowds
Hampton et al. (1989): Study 3	Unavailable	10	9	No	No	No, no	HSE	Slower searches through angry crowds
Byrne & Eysenck (1995)	Unavailable	25	12	No	No	Yes, yes	HSE	Included 13 participants high in anxiety
Purcell et al. (1996): Study 1.1	 [b]	37	4, 9	No	No	No, no	*ns* HSE	No confound, no ASE
Purcell et al. (1996): Study 1.2	 [c]	36	4, 9	No	No	No, no	HSE	No confound, no ASE
Purcell et al. (1996): Study 2	 [a]	31	4, 9	No	No	No, no	Trivial HSE	Confounded stimulus, return of ASE
Juth et al. (2005): Experiment 1	 [d]	32	8	Some trials	No	Yes, yes	HSE	16 anxious participants

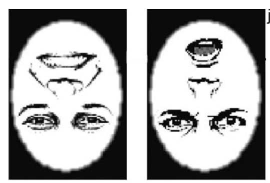
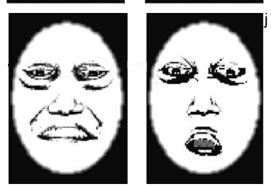
(table continues)

Table 3 (*continued*)

Experiment	Stimuli	*n*	Vary size	Neutral crowds	Top down	Vary distractors, targets	Effect	Comments
Juth et al. (2005): Experiment 2	As above	32	8	Some trials	No	Yes, yes	HSE	17 anxious participants
Juth et al. (2005): Experiment 3	As above	15	8	Some trials	No	Yes, yes	HSE	Phobic patients
Williams et al. (2005): Experiment 1 (happy vs. neutral)	 e	12	4, 8	Yes	Yes	No, no	HSE	1,280 trials; effect persists under inversion
Williams et al. (2005): Experiment 2 (sad vs. neutral)	Unavailable	12	4, 8	Yes	Yes	No, no	SSE	1,280 trials; effect persists under inversion
Williams et al. (2005): Experiment 3A (happy, angry [sad, fearful])	 f	12	4, 8	Some trials	No	Yes, yes	ASE, HSE	
Williams et al. (2005): Experiment 3B (happy, angry [sad, fearful])	 f	12	4, 8	Some trials	Yes	Yes, yes	ASE, HSE	
Horstmann & Bauland (2006): Experiment 1	 g	16	1, 6, 12	No	Yes	No, no	ASE	Authors noted that ASE is a function of distractor rejection speed, not target detection
Horstmann & Bauland (2006): Experiment 2	 h	23	1, 6, 12	No	Yes	No, no	ASE	Slope ratio favors HSE
Horstmann & Bauland (2006): Experiment 3A	 i	18	1, 6, 12	No	Yes	No, no	ASE	Slope ratio favors HSE

(table continues)

Table 3 (*continued*)

Experiment	Stimuli	*n*	Vary size	Neutral crowds	Top down	Vary distractors, targets	Effect	Comments
Horstmann & Bauland (2006): Experiment 3B		8	1, 6, 12	No	Yes	No, no	ASE	Slope ratio favors HSE
Horstmann & Bauland (2006): Experiment 4A	 [j]	16	1, 6, 12	No	Yes	No, no	ASE	Slope ratio favors HSE, faces inverted
Horstmann & Bauland (2006): Experiment 4B	 [j]	16	1, 6, 12	No	Yes	No, no	ASE	Slope ratio favors HSE, faces Thatcherized

Note. Although many studies showed anger superiority effects (ASE), others showed happiness superiority effects (HSE). These studies failed to employ the design criteria that would have allowed us to rule out low-level confounds. SSE = sadness superiority effect.

[a] D. Purcell, personal communication, June 7, 2011. [b] From "It Takes a Confounded Face to Pop Out of a Crowd," by D. G. Purcell, A. L. Stewart, and R. B. Skov, 1996, *Perception, 25,* p. 1099. Copyright 1996 by Pion. [c] From "It Takes a Confounded Face to Pop Out of a Crowd," by D. G. Purcell, A. L. Stewart, and R. B. Skov, 1996, *Perception, 25,* p. 1101. Copyright 1996 by Pion. [d] Adapted from "Looking for Foes and Friends: Perceptual and Emotional Factors When Finding a Face in the Crowd, by P. Juth, D. Lundqvist, A. Karlsson, and A. Öhman, 2005, *Emotion, 5,* p. 381. Copyright 2005 by the American Psychological Association. [e] From "Look at Me, I'm Smiling: Searching for Threatening and Nonthreatening Facial Expressions," by M. A. Williams, S. A. Moss, J. L. Bradshaw, and J. B. Mattingley, 2005, *Visual Cognition, 12,* p. 35. Copyright 2005 by Psychology Press. [f] From "Look at Me, I'm Smiling: Searching for Threatening and Nonthreatening Facial Expressions," by M. A. Williams, S. A. Moss, J. L. Bradshaw, and J. B. Mattingley, 2005, *Visual Cognition, 12,* p. 42. Copyright 2005 by Psychology Press. [g] From "Search Asymmetries With Real Faces: Testing the Anger-Superiority Effect," by G. Horstmann and A. Bauland, 2006, *Emotion, 6,* p. 198. Copyright 2006 by the American Psychological Association. [h] From "Search Asymmetries With Real Faces: Testing the Anger-Superiority Effect," by G. Horstmann and A. Bauland, 2006, *Emotion, 6,* p. 199. Copyright 2006 by the American Psychological Association. [i] From "Search Asymmetries With Real Faces: Testing the Anger-Superiority Effect," by G. Horstmann and A. Bauland, 2006, *Emotion, 6,* p. 201. Copyright 2006 by the American Psychological Association. [j] From "Search Asymmetries With Real Faces: Testing the Anger-Superiority Effect," by G. Horstmann and A. Bauland, 2006, *Emotion, 6,* p. 203. Copyright 2006 by the American Psychological Association.

= .866; however, these findings were qualified by a significant interaction of target emotion and crowd size, $F(1, 20) = 20.37$, $p < .001$, $\eta_p^2 = .505$, indicating that the slope for the detection of happy faces across different crowd sizes was significantly shallower than for angry faces.

Accuracy. A parallel ANOVA was conducted on the accuracy for the target-present results. There was a main effect of crowd size, with accuracy declining as the crowd size increased, $F(2, 19) = 3.86$, $p = .044$, $\eta_p^2 = .280$. There was no effect of target emotion ($F < 1$), nor did crowd size interact with target emotion, $F(2, 19) = 1.88$, $p = .18$.

Slope ratios. An examination of the ratios of target-present to target-absent slopes suggested that angry target detections demonstrate serial self-terminating searches (i.e., the ratio was not significantly different from 0.5), $t(21) = 1.39$, $p = .18$. The mean slope ratio for happy face detections was, however, significantly less than 0.5, $t(21) = -2.69$, $p = .014$. Happy face slope ratios were also significantly less than the angry face slope ratios, $t(21) = 4.26$, $p < .001$, $d = 0.77$.

Results: Experiment 1B

Median reaction times and mean accuracies were calculated for each participant for each factorial combination of crowd size and target type. The mean reaction times across these participant medians can be seen in Table 4.

Reaction times. A 2 (target emotion: angry, happy) × 3 (crowd size: two, four, six) repeated measures ANOVA was conducted on the target-present trials. There was a main effect of target emotion, with the detection of angry faces taking longer than happy faces, $F(1, 23) = 9.92$, $p = .004$, $\eta_p^2 = .301$. There was the expected effect of crowd size, $F(2, 22) = 138.92$, $p < .001$, $\eta_p^2 = .858$. There was also an interaction of these factors, $F(2, 22) = 6.04$, $p = .022$, $\eta_p^2 = .208$, indicating that the slope for happy brow detections was significantly lower than the slope for angry brow detections.

Accuracy. There was a main effect of crowd size, with accuracy decreasing as crowd size increased, $F(1, 22) = 7.55$, $p = .003$, $\eta_p^2 = .407$. There was no effect of target emotion ($F < 1$), and the factors did not interact, $F(1, 22) = 1.65$, $p > .20$. It is noteworthy that mean accuracy for the happy brows in the six-face crowds was slightly better (91%) than for the angry brows (89.25%), which rules out the possibility that a speed–accuracy trade-off compromises the faster search rate for the happy brows.

Slope ratios. An examination of the ratios of target-present to target-absent slopes found both angry and happy target detections looking like serial self-terminating searches (i.e., neither was significantly different from 0.5). Happy face slope ratios were, however, significantly less than the angry face slope ratios, $t(21) = 2.34$, $p = .028$, $d = 0.49$.

Figure 2. An example of the cropped stimuli used in Experiment 1B to eliminate the confound of exposed teeth.

Discussion: Experiments 1A and 1B

The results of Experiment 1A do not suggest that facial displays of anger are preattentively available. Indeed, happy targets were both more rapidly and more accurately detected, and the slopes for these detections were significantly shallower than those for angry targets. Moreover, slopes for happy face detections were shallower than would be expected if the search was serial self-terminating. This suggests that searches are better for happy faces, though even these do not pop out, and are not even particularly efficient, according to the criteria suggested by Wolfe and Horowitz (2004).

Although the HSE in Experiment 1A replicates Juth et al. (2005) and Williams et al. (2005, Experiment 3), it also replicates the confound that renders those experiments questionable: Exposed teeth in smiling faces may provide a high-contrast, low-level feature that is capable of driving efficient search. In contrast, the results of Experiment 1B demonstrate that the previous null findings for the ASE were not simply due to the ease with which participants were able to detect open-mouthed smiles on happy faces because those features were eliminated. More importantly, although it is plausible that exposed teeth or other simple visual features could have led to the HSEs in the previous studies, erasing this feature only slightly attenuated the effect (Cohen's *d* was 0.49 relative to 0.77 in Experiment 1A). Indeed, the slope for the happy brow detections was still significantly shallower than for angry brow detections. This experiment therefore provides unconfounded evidence that happy faces are more efficiently detected than angry faces in the face in the crowd paradigm.

Experiment 2

The experiments thus far are suggestive. However, Öhman et al. (2001) have leveled a criticism at the use of pictorial stimuli that must be reckoned with. Let us quote their motivation for using the simple schematic line drawings:

> [One] problem concerns individual variability in posing different types of emotional facial expressions. Virtually everyone can provide a reasonably convincing friendly smile, but fewer persons can produce a convincing threatening, angry expression on command. As a result, a threatening crowd is necessarily more heterogeneous than a friendly or a neutral crowd is. Because distractor homogeneity is an important determinant of visual search efficiency . . . , the larger variability of threatening faces runs the risk of confounding comparisons between threatening and friendly crowds when several stimulus individuals are used. . . . However, to avoid this problem by using the same individual for all positions in a crowd . . . may introduce other problems. First, idiosyncrasies of the particular individuals chosen may introduce confounds . . . , and, second, it provides a loss of ecological validity, because crowds of clones so far are exceedingly rare in real life. (p. 382)

Öhman et al. (2001) adopted the strategy of using schematic faces because the distractor variability is reduced to zero. The obvious problem with such a strategy is that the simpler the schematic representation of an emotional expression, the greater the likelihood that some single feature or configuration of features will be more efficiently detected for reasons that have nothing to do with the emotional content of the expression. So how does one answer Öhman et al.'s concern without introducing potential con-

Table 4
Mean Correct Reaction Times (in Milliseconds) and Error Rates (Percent) for Different Target Faces

	Crowd size							
	2		4		6			
Target	RT	ER	RT	ER	RT	ER	Slope	Slope ratio
			Experiment 1A: Full face					
Angry	861	4.9	1,149	9.0	1,286	12.1	106	0.54
Happy	789	6.3	972	6.8	1,051	8.3	66	0.33
Absent	889	3.7	1,325	5.2	1,713	3.9	206	
			Experiment 1B: Upper face only					
Angry	1,027	3.5	1,337	4.3	1,633	9.4	151	0.59
Happy	979	7.1	1,307	5.0	1,429	8.0	113	0.43
Absent	1,130	1.6	1,731	2.6	2,153	4.0	256	

Note. RT = reaction time; ER = error rate.

founds even more grievous than the crowd heterogeneity problem?[8]

Fortunately, there have been significant advances in computer modeling tools in the last several years that can now produce realistic faces with all the control necessary to avoid the heterogeneity problems that may plague certain photographic stimulus sets. The next experiment leverages the strength of such technology by using realistic computer graphic faces that precisely control the intensity between the posed expressions and across the many exemplars of these expressions. Critically, the happy expressions were constructed with close-mouthed smiles, providing another test of the HSE without the confound of exposed teeth.

Method

Participants. Twelve men and 18 women participated in exchange for course credit.

Materials. A new set of faces was created with five male and five female prototypes from Poser 4, a software package widely used in the graphic arts for its ability to create lifelike figures (see Hugenberg & Bodenhausen, 2003, 2004, for other uses of Poser stimuli in psychological research). Independent controls allowed the deflection of the mouth and brows such that the expressions were clearly identifiable as angry and happy, and the magnitude and number of changes (from neutral) needed to create the two expressions were identical (see Figure 3 for examples of these faces). The stimuli had no hair or other features discriminating the sexes aside from those of facial morphology, and the direction and intensity of lighting varied across individuals but was consistent across each individual's facial expressions.

Twenty-two participants (none of whom participated in the visual search study) identified these expressions as bearing the intended expression with 100% accuracy, and did so in the context of the photographic stimuli, and also other expressions (fear, surprise, and disgust), suggesting that the computer-generated expressions of happiness and anger were not at all ambiguous. Twenty-four additional participants rated these faces on a 9-point scale with 1 identified as *angry*, 5 identified as *neutral*, and 9 identified as *happy*. Angry faces elicited a mean rating of 2.86 (SD = 0.81), neutral faces elicited a mean rating of 4.90 (SD = 0.67; note that this was not significantly different from the neutral anchor point of 5; $t < 1$), and happy faces elicited a mean rating of 7.16 (SD = 0.93). Each participant received difference scores contrasting the angry or happy face ratings with those for neutral faces, and a matched-pairs t test compared the magnitude of these differences. This analysis did not reveal a significant difference in the degree to which angry and happy faces differed from neutral, $t(23) = 1.09$, $p > .20$, suggesting that the expressive intensity of the angry and happy exemplars was equivalent.[9]

Design. In this experiment, participants were prompted to look for a specific target expression (either angry, happy, or neutral) in a heterogeneous crowd of faces displaying one of the other emotions. Note that this afforded us the ability to estimate exhaustive (target-absent) search slopes separately for angry and happy targets in neutral crowds. Each type of search occurred equally often, and the targets were present 50% of the time. Target and distractor faces were randomly assigned to one of 18 possible locations on the screen (see Figure 4 for an example). Because there were at most 10 faces in any given display, the particular crowd arrangement had considerable variability from trial to trial. Each participant saw each individual face as a target an equal number of times, yielding 240 trials in all.

Procedure. The procedure was very similar to that of Experiments 1A and 1B, with two exceptions. First, each expression could appear in crowds of either of the remaining expressions.

[8] It should be noted that it may be unfair to claim that the faces in an angry crowd show greater heterogeneity because the people posing these expressions have difficulty posing angry expressions. In fact, the Ekman and Friesen stimuli used up to this point are composed of expressions posed by well-trained individuals. But let us suspend this counterpoint for the moment, because it may accurately characterize the stimulus set that these authors used and likely describes many other stimulus sets in common use.

[9] In fact, although the means show a very weak trend for angry faces being more similar to neutral exemplars, the greater variability in the ratings of the happy faces yields a standardized measure of difference (Cohen's d) that trends in the opposite direction, suggesting that happy faces are more similar to neutral faces.

Thus, participants now also had to search for angry faces in happy crowds as well as happy targets in angry crowds. Second, at the beginning of each trial, participants were directed by a written prompt to look for a particular target expression (i.e., "Look for an angry face"). The prompt was visible for 500 ms prior to the onset of the array.

Results

Three participants in the experiment had accuracies below 70% and were eliminated from the following analyses. For each participant, medians for the correct reaction times and mean accuracy were computed for each crowd size within each crowd type. Crowd size was treated as a linear contrast (and verified that this consumed all the variance explained by crowd size), and so report numerator degree of freedom as 1 in those tests. Table 5 shows mean reaction times and error rates for Experiment 2.

Target-absent trials. For correct reaction times, for the computer-generated faces, the expected linear contrast for crowd size was significant, $F(1, 27) = 297.00$, $p < .001$. There was no main effect of crowd emotion, $F(2, 26) = 1.17$, $p > .20$, and there was no significant interaction of the linear contrast of crowd size and expression ($F < 1$). Further analyses subdividing the exhaustive search results by the type of target searched for produced no statistically significant effects. These slopes were all essentially equivalent.

For accuracy, the linear effect of crowd size was statistically significant, $F(1, 27) = 5.18$, $p = .031$, $\eta_p^2 = .161$, and there was a significant effect for crowd expression, $F(1, 27) = 21.15$, $p < .001$, $\eta_p^2 = .619$, with angry crowds eliciting lower accuracy. There was a marginally statistically significant interaction of the linear contrast of crowd size and expression, $F(1, 26) = 3.21$, $p = .084$, $\eta_p^2 = .106$, with accuracy to angry crowds falling off at a steeper rate (relative to others) as crowd size increased. It is also worth noting that participants showed very high false alarm rates when searching for neutral targets in angry crowds, but this effect should not influence any of the following target-present results, nor did it appear to impact correct reaction times.

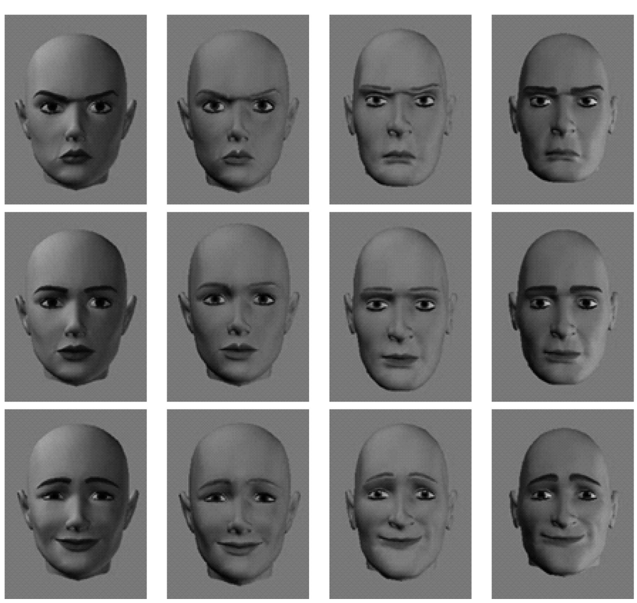


Figure 3. Examples of the angry, neutral, and happy expressions used in Experiment 2 (complete stimulus set available in the supplemental materials to this article).

Target-present trials: Neutral crowds. For correct reaction times, happy faces were identified faster than angry faces, $F(1, 25) = 6.58$, $p = .017$, $\eta_p^2 = .210$. There was a significant effect of crowd size, $F(3, 23) = 13.57$, $p < .001$, $\eta_p^2 = .636$, and no interaction, $F(3, 23) = 0.99$, $p > .20$.

For accuracy, no effects were significant (all $ps > .20$).

Target-present trials: Emotional crowds. For correct reaction times, happy faces were identified more rapidly than angry faces, $F(1, 26) = 18.61$, $p < .001$, $\eta_p^2 = .417$. There was a significant effect of crowd size, $F(3, 26) = 32.66$, $p < .001$, $\eta_p^2 = .557$, and the slope for the happy target detections in angry crowds was significantly shallower than that for angry detections in happy crowds, $F(1, 26) = 4.21$, $p = .050$, $\eta_p^2 = .139$.

Accuracy decreased with crowd size, $F(1, 26) = 4.69$, $p = .040$, $\eta_p^2 = .153$, but no other effects were significant.

Discussion

In both neutral and emotionally expressive crowds, happy targets were detected more rapidly than angry targets. This detection benefit persisted even though the computer-generated faces were designed to (a) eliminate the open-mouthed smiles, (b) precisely equate the number of features making up anger and happiness, and (c) precisely equate the degree that each of the altered features was shifted away from the common neutral expression. To see these carefully constructed happy faces detected faster than angry faces in both neutral and expressive crowds lends more credence to the legitimacy of the HSE. And although the neutral crowd produced a slightly shallower slope for angry detections relative to happy expressions, the mean function was higher, so no angry face detection advantage can be claimed here, either. Indeed, the key difference was that angry targets were even more poorly detected in the smaller crowds, and this rendered these slopes shallower. Thus, although there is no evidence that angry faces grab attention, the results bolster the possibility that the HSE is a legitimate phenomenon, because it again occurs here in the absence of the confound of exposed teeth.

Experiment 3: Multiple-Target Search

The experiments presented thus far have all used the traditional visual search methodology, in which only a single target may be present. Such single-target searches can be criticized because they do not truly distinguish between serial searches and parallel searches (Townsend, 1972, 1974). Indeed, one of the main points that Frischen et al. (2008) made in their review was that because visual searches combine both parallel and serial processes, one can obtain evidence for preattention to anger without necessarily producing evidence of pop-out effects.

In contrast to the single-target visual search, multiple-target searches allow the discrimination between truly serial and limited-capacity parallel searches. Although multiple-target searches were initially investigated by van der Heijden (1975), Thornton and Gilden (2001, 2007) are responsible for the recent revival of

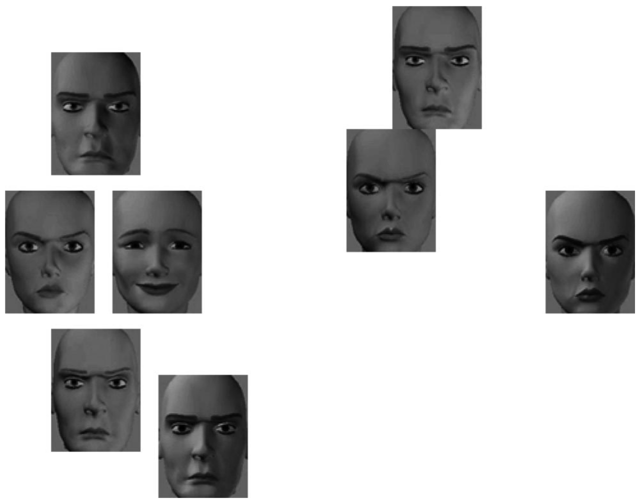


Figure 4. An example of the kind of display seen in Experiment 2.

interest in this method. The key difference in multiple-target search designs is that more than one target can satisfy the search criteria. With each additional target, a limited-capacity parallel search—that is, a search that picks up information from several or all target locations at once—should be able to accumulate evidence more rapidly that a target is present. The critical comparison is thus across set sizes in which every item satisfies the search criteria. If larger pure target arrays yield faster decisions than smaller pure target arrays, this is evidence of *redundancy gain* (i.e., that multiple targets redundantly satisfying the search criteria will simultaneously and in parallel contribute evidence to the decision processes that allow participants to make a target-present decision). Such a result strongly implies a parallel search process. A serial search, on the other hand, should show no such redundancy gain but rather give rise to equivalent reaction times across the pure target trials, because the first item that the serial process selects will always be a target.

Method

Participants. Thirty-six men and 36 women participated in exchange for course credit. Four participants with mean accuracy less than 2.5 standard deviations below the group mean were excluded.

Materials. The computer-generated faces from the previous experiment were used.

Design. Faces were presented in the middle of one of the four quadrants of the screen (the center of each image was approximately 7 cm away from the center of the screen). This is consistent with Thornton and Gilden's (2007) designs, which have small array sizes relative to those typically used in search paradigms—no more than four potential targets are presented to participants. Arrays consisted of either two or four faces. Each face in the visual display was approximately 4° × 3°. Crowds with two faces consisted of two faces arranged along one of the two diagonals of the four possible positions and could have one, two, or no targets (with equal probability). Crowds with four faces consisted of faces in each quadrant and could have one, two, four, or no targets (with equal probability). Targets were randomly assigned to locations, and distractors were always neutrally expressive faces. Note that each array was constructed so that none of the component faces were of the same individual.

Procedure. Participants were greeted and seated at a computer. The basic task was explained, and they were told that their continued participation would constitute their consent for the data to be used in published research. On each trial, participants were directed to search for either an angry or a happy target and were told that multiple targets may appear. They were told to press the *5* key on the number pad if a target was present and the *A* key if

Table 5
Mean Correct Reaction Times (in Milliseconds) and Error Rates (Percent) for Experiment 2

Expression		Crowd size									
		4		6		8		10			
Crowd	Target	RT	ER	RT	ER	RT	ER	RT	ER	Slope	Slope ratio
Target-absent searches											
Neutral	Happy	1,760	0.07	2,162	0.04	2,659	0.06	3,058	0.07	220	
Neutral	Angry	1,737	0.02	2,233	0.04	2,572	0.05	2,925	0.03	195	
Happy	Neutral	1,876	0.05	2,467	0.08	2,917	0.10	3,367	0.12	246	
Happy	Angry	1,628	0.05	1,964	0.02	2,383	0.02	2,755	0.01	190	
Angry	Neutral	2,332	0.21	2,835	0.24	3,554	0.28	3,767	0.37	251	
Angry	Happy	1,550	0.05	1,905	0.04	2,429	0.05	2,705	0.06	200	
Target-present searches											
Neutral	Happy	1,378	0.10	1,640	0.08	1,843	0.14	1,992	0.19	102	0.47
Neutral	Angry	1,639	0.09	1,810	0.10	1,993	0.07	2,100	0.11	78	0.40
Happy	Neutral	1,990	0.11	2,151	0.15	2,750	0.21	2,661	0.24	131	0.53
Happy	Angry	1,545	0.06	1,757	0.08	1,921	0.14	2,173	0.14	102	0.54
Angry	Neutral	1,895	0.19	2,253	0.15	2,570	0.19	2,926	0.19	171	0.68
Angry	Happy	1,383	0.07	1,739	0.12	1,640	0.10	1,801	0.09	58	0.29

Note. RT = reaction time; ER = error rate.

it was absent. Once the computer program was started, additional text instructions reiterated the verbal directions.

Participants completed 120 trials. Each trial began with a fixation point (a cross presented in the middle of the screen for 1 s). Next, the array was displayed and remained visible until the participant responded or 10 s elapsed. Finally, participants received feedback regarding their accuracy and speed, which remained visible for 1 s and was followed by the next trial.

Results

Redundancy gain. This contrast compared searches for angry or happy faces when the crowd was saturated with targets. Limited-capacity parallel searches should give rise to negative slopes—the redundancy gain—whereas serial searches should give rise to flat slopes. This analysis was thus a 2 (target expression: angry, happy) × 2 (pure target array size: two, four) within-subjects ANOVA.

The main effect of array size was not significant, $F(1, 66) = 3.11$, $p = .082$. Moreover, the trend showed a redundancy cost, which is in the opposite direction of the trend that would provide evidence for a parallel search. There was a main effect of target expression, $F(1, 66) = 50.71$, $p < .001$, $\eta_p^2 = .435$, with happy targets detected more rapidly ($M = 634$ ms) than angry targets ($M = 751$ ms). The interaction of target expression and array size was not significant, $F(1, 66) = 1.16$, $p > .20$ (see Figure 5).

For accuracy, there was only an effect of target expression, $F(1, 66) = 29.15$, $p < .001$, $\eta_p^2 = .306$, with happy targets detected more accurately ($M = 0.983$) than angry targets ($M = 0.916$). Neither the array size ($F < 1$) nor the interaction, $F(1, 66) = 1.63$, $p < .20$, was significant.

Single-target detection. The next analysis compares searches for a single angry or happy face when the crowd was composed of neutral faces. This analysis was thus a 2 (target expression: angry, happy) × 2 (array size: two, four) within-subjects ANOVA, and is the closest direct analog to the kinds of analyses used in the other experiments reported in this article.

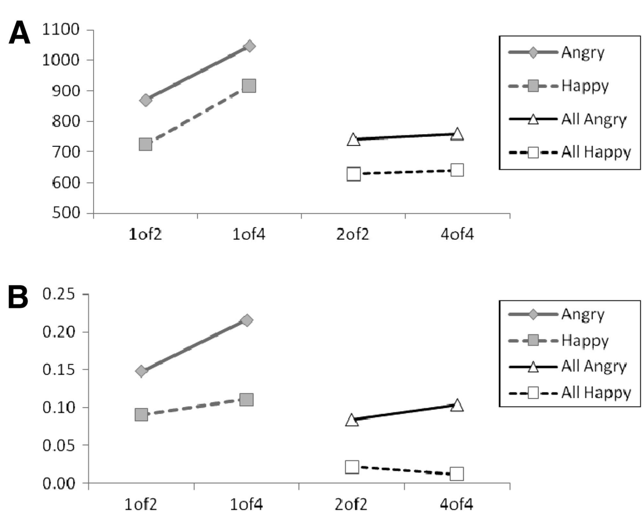


Figure 5. Correct reaction times (A; in milliseconds) and error rates (B) to identify single or multiple angry or happy faces in Experiment 3.

For correct reaction times, the main effect of array size was significant $F(1, 66) = 129.40$, $p = .001$, $\eta_p^2 = .428$. There was also a main effect of target expression, $F(1, 66) = 60.17$, $p < .001$, $\eta_p^2 = .477$, with happy targets detected more rapidly ($M = 820$ ms) than angry targets ($M = 959$ ms). The interaction of target expression and array size was not significant ($F < 1$).

For accuracy, the main effect of array size was significant $F(1, 66) = 5.80$, $p = .019$, $\eta_p^2 = .081$. There was a main effect of target expression, $F(1, 66) = 19.53$, $p < .001$, $\eta_p^2 = .228$. The interaction of target expression and array size was not significant, $F(1, 66) = 2.16$, $p = .146$.

Discussion

The multiple-target search methodology once again indicated an identification advantage for happy expressions relative to angry expressions. Both correct reaction times and accuracy results were consistent in this regard: Participants were faster and more accurate with happy faces.

This task showed no evidence of redundancy gain. If anything, there was a marginally significant redundancy cost. This strongly suggests that searching for expressive faces requires a serial search process and that previous demonstrations of pop-out for angry expressions (and the parallel searches they imply) were likely spurious. In the case of schematic stimuli, this probably arose from a low-level visual feature that had nothing to do with the expression. More realistic expressive face stimuli do not show any evidence that they pop out.

Experiments 4A, 4B, and 4C

Experiment 3 provides the first use of the multiple-target search methodology for an investigation of the face in the crowd phenomenon. It is critical, however, to avoid basing inferences on a single small set of items. In the present case, it seems most informative to generalize this effect to real faces for reasons of ecological and external validity, but most photographic stimulus sets replicate the confound of exposed teeth for the happy faces and so are of little value in demonstrating the legitimacy of the HSE. Fortunately, the MacBrain stimulus set (or "NimStim"; Tottenham et al., 2009) includes several men and women making two varieties of happy and angry facial expressions: a close-mouthed version and an open-mouthed version (either a toothy grin or an expression of anger baring the teeth). The next studies use this stimulus set to test the generalizability of the HSE in three ways: (a) with close-mouthed expressions of anger and happiness in a small crowd of neutrally expressive distractors, (b) with open-mouthed expressions of anger and happiness in a small crowd of neutrally expressive distractors, and (c) with close-mouthed expressions of anger and happiness in a small crowd of distractors bearing fearful expressions.

Method: Experiment 4A

Participants. Eight men and 13 women participated in exchange for course credit.

Materials. In this variation, all expressive faces had close-mouthed expressions (specifically, exemplars numbered 30, 32, 33, and 37). The images measured 6 cm × 5 cm on the screen and, as in Experiment 3, were each presented in the center of one of the quadrants of the screen.

Design and procedure. The design and procedure were identical to those of Experiment 3.

Results: Experiment 4A

Redundancy gain. As in Experiment 3, this contrast compared correct reaction times for searches for angry or happy faces when the crowd was saturated with targets. This analysis is thus a 2 (target expression: angry, happy) × 2 (pure target crowd size: two, four) within-subjects ANOVA.

The main effect of array size, which had the potential to reveal redundancy gain and thus evidence of parallel searches, was not significant $F(1, 20) = 1.29$, $p > .20$, and trended in the direction of a redundancy cost for angry expressions. There was a main effect of target expression, $F(1, 20) = 6.57$, $p = .019$, $\eta_p^2 = .247$, with happy targets detected more rapidly ($M = 617$ ms) than angry targets ($M = 719$ ms). The interaction of target expression and array size was not significant ($F < 1$). Table 6 shows mean reaction times and error rates for Experiment 4A.

Accuracy results did not compromise the reaction time results; there was only an effect of target expression, $F(1, 20) = 9.33$, $p = .006$, $\eta_p^2 = 0.318$, with happy targets detected more accurately ($M = 0.972$) than angry targets ($M = 0.904$). Neither the array size nor the interaction had any effect (both Fs < 1).

Single-target detection. The following analysis compares searches for a single angry or happy face when the crowd was composed of neutral faces. This analysis is thus a 2 (target expression: angry, happy) × 2 (crowd size: two, four) within-subjects ANOVA, and is the closest analog to the kinds of analyses used in the other experiments reported in this article.

For correct reaction times, the main effect of array size was significant $F(1, 20) = 14.99$, $p < .001$, $\eta_p^2 = .661$. There was a main effect of target expression, $F(1, 66) = 9.41$, $p = .006$, $\eta_p^2 = .320$, with happy targets detected more rapidly ($M = 760$ ms) than angry targets ($M = 833$). The interaction of target expression and array size was not significant ($F < 1$).

For accuracy, neither the main effect of array size nor the main effect of target expression was significant (both Fs < 1), and the interaction of target expression and array size also failed to attain significance, $F(1, 20) = 2.57$, $p = .126$.

Method: Experiment 4B

Participants. Eight men and 13 women participated in exchange for course credit.

Materials. This variation used the same individuals from the MacBrain stimulus set but employed their open-mouthed exemplars of angry and happy expressions. Twenty-four participants rated these faces on a 9-point scale with 1 identified as *angry*, 5 identified as *neutral*, and 9 identified as *happy*. Angry faces elicited a mean rating of 1.45 ($SD = 0.52$), neutral faces elicited a mean rating of 4.81 ($SD = 0.46$), and happy faces elicited a mean rating of 7.89 ($SD = 0.78$). Each participant received difference scores that contrasted the angry or happy faces with the neutral faces, and a matched-pairs t test compared the magnitude of these differences. This analysis suggested that the open-mouthed angry expressions differed from neutral expressions (i.e., were more expressively intense) to a greater degree than happy faces, $t(23) = 1.98$, $p = .059$, which should make it easier for them to be discriminated from neutral distractor images.

Design and procedure. The design and procedure were identical to those of Experiment 3.

Results: Experiment 4B

Redundancy gain. This contrast compared correct reaction times for searches for angry or happy faces when the crowd was saturated with targets. This analysis is thus a 2 (target expression: angry, happy) × 2 (pure target array size: two, four) within-subjects ANOVA.

The main effect of array size was not significant ($F < 1$) and trended in the direction of a redundancy cost for both expressions. There was a main effect of target expression, $F(1, 20) = 6.56$, $p = .011$, $\eta_p^2 = .247$, with happy targets detected more rapidly than angry targets. The interaction of target expression and array size was not significant ($F < 1$). See Table 6 for mean reaction times and error rates.

Accuracy results did not compromise the reaction time results: There was only an effect of target expression, $F(1, 20) = 9.33$, $p = .006$, $\eta_p^2 = .318$, with happy targets detected more accurately than angry targets. Neither the array size nor the interaction had any effect (both Fs < 1).

Table 6
Mean Correct Reaction Times (in Milliseconds) and Error Rates (Percent) for Experiments 4A, 4B, and 4C

		Experiment 4A (closed mouth)				Experiment 4B (open mouth)				Experiment 4C (fearful crowd)			
		Angry target		Happy target		Angry target		Happy target		Angry target		Happy target	
Array size	Targets present	RT	ER	RT	ER	RT	ER	RT	ER	RT	ER	RT	ER
2	0	795	12	821	9	752	3	756	4	988	13	839	4
2	1	932	15	810	10	765	21	703	12	995	24	795	12
2	2	778	9	683	4	707	10	597	2	898	7	724	2
4	0	998	10	967	7	976	5	889	3	1,342	16	1,141	3
4	1	985	31	953	30	901	16	818	19	1,256	24	1,009	11
4	2	856	10	759	15	848	7	734	2	1,063	11	837	5
4	4	792	11	655	5	731	10	638	3	926	6	711	4

Note. RT = reaction time; ER = error rate.

Single-target detection. The next analysis compared searches for a single angry or happy faces when the crowd was composed of neutral faces. For correct reaction times, the main effect of array size was significant, $F(1, 20) = 14.99$, $p < .001$, $\eta_p^2 = .428$. There was a significant main effect of target expression, $F(1, 20) = 9.41$, $p = .006$, $\eta_p^2 = .320$, with happy targets detected more rapidly than angry targets. The interaction of target expression and array size was not significant ($F < 1$).

For accuracy, there was no effect of array size or expression (Fs < 1). The interaction of target expression and array size also failed to attain significance, $F(1, 20) = 2.57$, $p = .125$.

Method: Experiment 4C

Participants. Ten men and 20 women participated in exchange for course credit. Six participants (two men) had accuracy 2.5 standard deviations below the mean and were removed from the analysis.

Materials. For this variation, the open-mouthed exemplars of angry and happy expressions from the MacBrain served as targets, and the faces displaying fearful expressions (which also had open mouths) served as distractors.

Design and procedure. The design and procedure were identical to those of Experiment 3.

Results: Experiment 4C

Redundancy gain. This contrast compared correct reaction times for searches for angry or happy faces when the crowd was saturated with targets. This analysis is thus a 2 (target expression: angry, happy) $\times$ 2 (pure target array size: two, four) within-subjects ANOVA.

The main effect of array size was not significant ($F < 1$) and trended in the direction of a redundancy cost for angry expressions. There was a main effect of target expression, $F(1, 23) = 34.72$, $p < .001$, $\eta_p^2 = .602$, with happy targets detected more rapidly than angry targets. The interaction of target expression and array size was not significant ($F = 1.12$). See Table 6 for mean reaction times and error rates.

Accuracy results did not compromise the reaction time results: There was only a marginally significant effect of target expression, $F(1, 23) = 2.49$, $p = .128$, $\eta_p^2 = .098$, with happy targets detected more accurately than angry targets. Neither the array size ($F < 1$) nor the interaction ($F = 1.29$) had any effect.

Single-target detection. For correct reaction times, the main effect of array size was significant, $F(1, 23) = 15.52$, $p < .001$, $\eta_p^2 = .403$. There was a significant main effect of target expression, $F(1, 23) = 40.09$, $p < .001$, $\eta_p^2 = .635$, with happy targets detected more rapidly than angry targets. The interaction of target expression and array size was not significant ($F < 1$).

For accuracy, the main effect of expression was significant, $F(1, 23) = 21.05$, $p < .001$, $\eta_p^2 = .478$, with happy targets detected more accurately than angry targets. The interaction of target expression and array size was not significant ($F < 1$).

Discussion: Experiments 4A, 4B, and 4C

The multiple-target search results with real faces replicate the results with schematic faces. First, there was no evidence for anything other than serial search processes. No redundancy gain was observed, which rules out parallel search processes and any suggestion that expressive faces draw attention to their location prior to conscious and controlled movements of attention (see Figure 6). Second, happy faces continued to be detected more efficiently than angry faces, and no simple visual feature such as exposed teeth can be invoked to explain the effect. In Experiment 4A, all faces bore close-mouthed expressions, whereas in Experiments 4B and 4C all faces had open-mouthed expressions with visible teeth. Furthermore, the open-mouthed expressions of anger were rated as more expressively intense than those of happiness, suggesting that even when the signal of anger is strong, the greater detectability of happiness still prevails.

General Discussion

The idea that angry faces pop out of crowds is widely held and widely cited. Empirical demonstrations of the anger superiority effect have motivated many researchers and generated numerous publications, to the point that it might seem strange that anyone should quibble with the idea, especially given its intuitive appeal. Indeed, recent reviews like that of Frischen et al. (2008) are elevating the idea to an almost canonical status. But uncritical reviews risk concealing the great inconsistency in the results and the considerable controversy and debate that has been going on about the legitimacy of these effects, a debate that has been ongoing since they were first reported in Hansen and Hansen (1988). In the current article, we sought to critically review the literature on the ASE and then conducted a series of experiments designed to redress the shortcomings of previous studies. In these analyses, the ASE is far from supported. Indeed, it is happy faces that show a clear detectability advantage.

Our attempt at a comprehensive and unconfounded exploration involved several steps. The first step enumerated the design principles that should be employed when adapting expressive faces to the visual search paradigm using and augmenting past recommendations. The second step used these principles to evaluate the visual search literature. The bulk of the demonstrations of the ASE use simple schematic stimuli and are, therefore, susceptible to the criticism that low-level perceptual features drive the searches. This is not just a theoretical problem; there have been many demonstrations that expression detection effects actually boiled down to simple feature detection asymmetries. There was thus little consensus in the literature about any expression asymmetry, and the possibility existed that most results were confounded with low-level signal attributes that undermine strong conclusions about the adaptive detection of facial expressions of emotion.

These issues motivated us to conduct a series of experiments to properly ground inferences about the face in the crowd effect. The first set of experiments showed that real faces (taken from the Ekman and Friesen stimulus set) gave rise to an HSE and that exposed teeth could not entirely account for the effect because it occurred even when the lower half of the face was removed. The second set of experiments showed that highly controlled computer-generated happy faces were better detected than angry faces. Critically, these happy faces smiled with closed lips, eliminating the white contrast of the exposed teeth that plagues many other demonstrations of the HSE in the literature. The next set of experiments used a multitarget search design, which allows one to make stronger inferences about the kind of search strategy that expressive faces elicit. These studies revealed that expressive faces reliably elicited serial search strategies and corroborated the finding that searches for expressive faces were not particularly efficient. However, these studies continued to demonstrate that happy faces consistently gave rise to faster and more accurate detection relative to angry faces, effects that persisted across four different design and stimulus variations. This empirical work motivates two principal conclusions.

Principal Conclusions From the Present Studies

Facial expression does not preattentively seize attention in the visual search. Across the present experiments, there was no evidence that angry faces (or happy faces) drew attention to themselves prior to attention consciously being allocated to them in a controlled, serial search. Because certain authors (e.g., Frischen et al., 2008) maintain that the visual search may still provide evidence of parallel processes even when slopes are nonzero, four of our experiments used the multitarget search methodology (Thornton & Gilden, 2007), which has the potential to provide clear evidence for parallel processes in the form of redundancy gains when multiple targets were present. None of these studies produced evidence for parallel processing of expressive faces. We therefore disagree with Frischen et al. (2008), concluding that, at least with regard to anger and happiness, there is no evidence that expressive faces draw attention to themselves automatically. Of course, once these faces are seen, they may command attention and processing resources, resist attentional disengagement, and elicit enhanced encoding and memory processes. Expressive faces are clearly special and prioritized by cognitive processes; they are just not available preattentively.

Happiness is detected more efficiently than anger in visual search paradigms. Both the photographic stimuli and the schematic stimuli revealed several varieties of a happiness detection

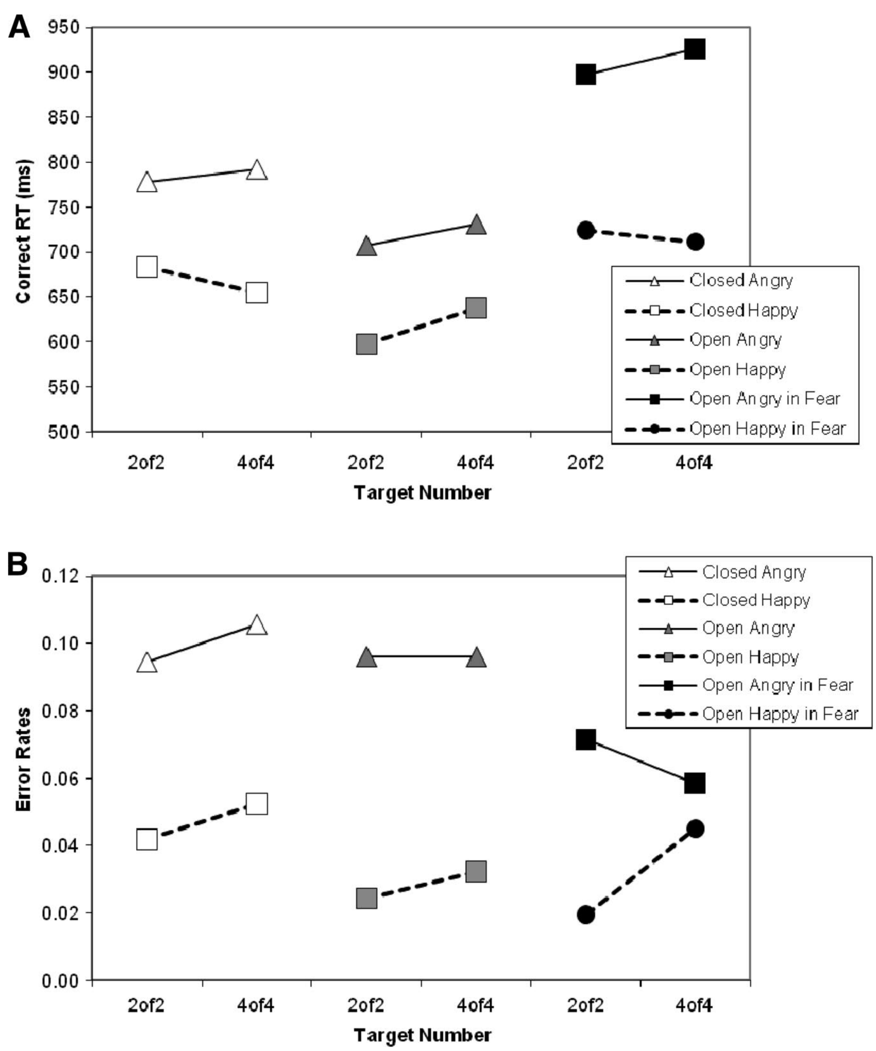


Figure 6. Correct reaction times (A) and error rates (B) in Experiments 4A, 4B, and 4C. These experiments again show no evidence of redundancy gain and continue to suggest an advantage for detecting happy expressions rather than angry expressions. RT = reaction time.

advantage. Happy faces were identified more accurately than angry faces, elicited faster decisions, and often resulted in shallower slopes and/or more efficient slope ratios. Although past demonstrations of this effect may have been caused by the exposed teeth of a full smile, a feature that could feasibly pop out given its contrast with the darker tones of the rest of the face, compelling evidence comes from the greater detectability of happy brows (in Experiment 1B) and from close-mouthed computer-generated happy expressions (in Experiments 2 and 3). Both of these findings reveal significantly faster searches relative to angry face detections, even when the high-contrast pop-out feature of exposed teeth has been eliminated. Furthermore, the HSE was replicated with photographs from the MacBrain stimulus set, with both close-mouthed and open-mouthed variations of angry and happy expressions, and it occurred regardless of whether neutral or fearful faces served as the distractors. Indeed, for the open-mouthed and bared-teeth expressions of anger employed in Experiments 4B and 4C, preratings indicated that the expressions of anger were more expressively intense than the same exemplars displaying happiness. This research therefore provides considerable evidence that happy faces are detected better than angry faces when all potential confounds have been removed or controlled for.

It is important to note that many demonstrations of HSEs that are confounded with exposed teeth (going back to Hager & Ekman, 1979) are not without value: They highlight the fact that the canonical form of the happy face seems designed to be detectable, which may hint at an adaptive function of these expressions. Horstmann and Bauland (2006) proposed a perceptual bias hypothesis to explain such results. They proposed that rather than reflect preattentive threat or friend detectors, emotionally expressive faces evolved to exploit extant processing capabilities within the visual system (a similar argument was made in Becker, Kenrick, Neuberg, Blackwell, & Smith, 2007). Exposing the teeth to express happiness would have ensured that friendly intentions could be detected rapidly and over great distances, and perhaps served as a way to de-escalate intergroup–intrasex threat. Indeed, recent psychophysiological evidence suggests that faster responses to happy (relative to angry) faces are caused by factors very early in processing. Using single stimuli and two-alternative forced-choice tasks, Leppänen, Tenhunen, and Hietanen (2003) found electrophysiological results in which the only differences in response latencies came from the earlier perceptual stages rather than the later motor stages. Such results are consistent with the idea that the happy expression evolved to be discriminable and to stand out in a crowd. It is critical to note, however, that the present demonstrations extend this line of thinking to displays of happiness that are not so obviously confounded, suggesting that the happy face evolved to be a clear and detectible signal even in the absence of exposed teeth.

As a more general speculation of why there might be a happiness detection advantage, given that most people are happy most of the time (Diener & Diener, 1996), it may be that facial expressions of this state are more accessible and that their detection is more practiced. Indeed, the greater frequency with which one encounters happy faces may engender a perceptual fluency akin to the word frequency effect (i.e., the finding that high-frequency words can be recognized faster than low-frequency words; Oldfield & Wingfield, 1965). Cacioppo and Berntson's (1994) evaluative space model specifically predicts that positive information receives preferential processing so long as negative affect is not overly aroused. This might suggest that manipulations that make participants feel negative affect (e.g., fear, a need for self-protection) would reduce the HSE and perhaps even elicit an ASE. Furthermore, given the importance that signs of social acceptance, approval, and affiliation had for our ancestors, another possibility is that happy expression detectors constantly scan attended objects for positive human affordances. The present results may provide preliminary evidence of such a mechanism.

Such speculations are preliminary, of course, and it may be more parsimonious to relegate the root of this effect to greater signal clarity rather than anything in the perceiver. Coevolutionary processes could have caused the facial expression of happiness to become more discriminable, by converging on signal forms that could make use of low-level feature detectors in human visual processing that existed long before the facial expression itself took on its present form. Because the communicative intent of happiness is relatively straightforward—one generally wants this signal to be perceived—selective pressures would have caused it to be more discriminable. Anger, on the other hand, carries with it mixed motives and very often does not want to be perceived. Indeed, if one wants one's anger to grab someone's attention, it is very often accompanied by threatening gestures and vocalizations (which again make use of preexisting feature detectors, not anger detection modules), and it is far more often the case that one is motivated to conceal one's anger, lest one invites interpersonal conflict. In this way, signaling intentions may underlie the eventual explanation of why happy expressions are more detectible relative to angry expressions.[10]

General Conclusions

Considering an earlier version of this article, one reviewer wryly observed, "The literature on visual search using face stimuli is a morass where the bold should fear to tread. Instead, the allure of faces, emotion, and evolutionary psychology continues to attract researchers like moths to the proverbial flame." We could not agree more. In the present article, we have tried to highlight the theoretical pitfalls that lead inferences astray and warn researchers less well versed in visual search methodology against the blind acceptance of previous demonstrations. The dangers are more serious than one might appreciate. For example, despite the very real possibility that the Öhman et al. (2001) stimuli have low-level visual confounds that account for their ASE results (which should have been evident in the inversion effect reported in the primary article), these stimuli have been reused in a number of studies that purport to find that threat detection is unimpaired in particular demographic groups that might be expected not to show robust threat detection (e.g., in participants with Asperger's syndrome, Ashwin, Wheelwright, & Baron-Cohen, 2006; and in the elderly, Mather & Knight, 2006). By using these stimuli, these researchers

[10] We are sensitive to the fact that many researchers are leery of such explanations, often identifying them as "just so" stories. However, the coevolution of signals and receivers is a well-studied topic in evolutionary biology, and it would be foolish to eliminate a whole class of explanatory models because of such prejudices. This explanation can lead to novel testable predictions and can be supported with computer simulations of coevolutionary processes (e.g., Enquist & Arak, 1994).

are actually showing only that simple feature detectors remain intact in these participants. Researchers who accept ASE effects uncritically thus risk wasting research efforts that might otherwise go toward finding real effects with legitimate diagnostic and/or therapeutic potential. We hope that the present efforts caution researchers against such erroneous conclusions in the future.

So why has the angry face in the crowd effect persisted in the literature despite repeated counterdemonstrations and theoretical critiques? It may simply be a case of a beautiful theory failing to be slain by an ugly fact. The idea that angry faces pop out and grab one's attention makes visceral sense. Of course, in the real world, the visceral reaction is to more than just a static display of anger: Enraged strangers growl, they bare teeth, and they approach—all things that do grab attention. Our results suggest that once one strips these signs of threat away, it is the static display of happiness that has the advantage.

One thing is certain: In the visual search paradigm, stimuli such as expressive faces (even schematic versions of them) introduce a host of potential confounds that can generate misleading effects, and so the tools of experimental psychology must be translated to the social realm with caution. This is particularly true of the visual search task, where detectability is a function not only of the target stimulus as it is holistically perceived but also of every feature that makes up the stimulus and of the array in which it is embedded. Researchers in this area should use multiple stimulus sets and multiple methods to verify that low-level, domain-general properties of perceptual systems do not account for the appearance of higher order, domain-specific perceptual effects.

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