Visual Search of Emotional Faces

Eye-Movement Assessment of Component Processes

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Abstract. In a visual search task using photographs of real faces, a target emotional face was presented in an array of six neutral faces. Eye movements were monitored to assess attentional orienting and detection efficiency. Target faces with happy, surprised, and disgusted expressions were: (a) responded to more quickly and accurately, (b) localized and fixated earlier, and (c) detected as different faster and with fewer fixations, in comparison with fearful, angry, and sad target faces. This reveals a happy, surprised, and disgusted-face advantage in visual search, with earlier attentional orienting and more efficient detection. The pattern of findings remained equivalent across upright and inverted presentation conditions, which suggests that the search advantage involves processing of featural rather than configural information. Detection responses occurred generally after having fixated the target, which implies that detection of all facial expressions is post- rather than preattentional.

Keywords: facial expression, emotion, eye movements, attention, efficiency

Neuropsychological, cognitive, and developmental studies have provided evidence that faces are a special kind of stimulus for perception (see Farah, Wilson, Drain, & Tanaka, 1998). Faces convey information with an important adaptive function for social interaction (e.g., a person's identity, age, etc.). This importance is further increased for emotional expressions. They can reveal the motivational state and intentions of other people, and therefore indicate what we can expect from them and how we should adjust our own behavior. In the current study, we explored visual search differences between six emotional facial expressions (anger, happiness, sadness, fear, surprise, and disgust). The main purpose was to investigate the cognitive mechanisms responsible for the detection advantage of some expressions. Particularly, we were interested in whether such an advantage involves: (a) preattentive parallel search, (b) early, but serial, selective orienting of overt attention, or (c) later enhanced processing efficiency upon fixation.

Detection of emotional facial expressions has usually been investigated with the visual search paradigm, in which a discrepant emotional target face has to be searched in an array of neutral or expressive context faces. An angry-face superiority has been found in studies using *schematic* faces as stimuli. Schematic angry expressions are typically detected faster than neutral or happy expressions (Calvo, Avero, & Lundqvist, 2006; Eastwood, Smilek, & Merikle, 2001; Fox et al., 2000; Juth, Lundqvist, Karlsson, & Öhman, 2005; Lundqvist & Öhman, 2005; Öhman, Lundqvist, & Esteves, 2001; Schubö, Gendolla, Meinecke, & Abele, 2006; Tipples, Atkinson, & Young, 2002). However, the external validity of schematic faces as stimuli is controversial and the generalizability of the findings to real faces can be questioned (see Horstmann & Bauland, 2006). In fact, results have been less consistent with *real-face* stimuli (i.e., digitized photographs). The pioneering study by Hansen and Hansen (1988) found evidence of an angry-face superiority. However, when Purcell, Stewart, and Skov (1996) removed some artificial spots from the angry faces used by Hansen and Hansen, the advantage disappeared. Two recent studies (Fox & Damjanovic, 2006; Horstmann & Bauland, 2006) have replicated the original angry-face superiority. In contrast, Juth et al. (2005) obtained opposite results, that is, a happy-face advantage, with happy expressions being detected more quickly and accurately than angry and fearful targets. Williams, Moss, Bradshaw, and Mattingley (2005) found an advantage of both angry and happy faces (with no consistent difference between them) over sad and fearful faces. Byrne and Eysenck (1995) reported a happy-face superiority for a low-anxious group, with no differences between angry and happy faces for a high-anxious group.

This review suggests that there is no definite evidence that photographic angry faces are detected faster than happy faces or vice versa. It is not clear whether the consistent facilitated search of angry schematic faces applies to real faces. The low number of different stimuli that have been used in many previous studies might reduce the generalizability of the findings and underlie some of the inconsistencies. For schematic faces, there is usually a single prototype of each expression. In studies using real-face stimuli, less than 10 different models have been often used (Fox & Damjanovic, 2006; Hansen & Hansen, 1988; Horstmann & Bauland, 2006; Purcell et al., 1996). Twelve models were employed by Byrne and Eysenck (1995) and Williams et al.

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(2005), and 60 by Juth et al. (2005). In addition, in most cases, only two or three different emotional expressions, that is, angry and happy, were presented, except in the Juth et al. (2005) study (happy, angry, and fearful) and the Williams et al. study (happy, angry, sad, and fearful). In the current study, we attempted to overcome these limitations. We compared all six basic facial expressions within the same design. Also, to increase the variability and representativeness of the stimulus sample, we used photographs of 28 different individuals.

Our major aim had an explanatory nature. We wanted to investigate the cognitive mechanisms responsible for the visual search advantage of any emotional face over the others. Three mechanisms were examined: Preattentive parallel processing, serial but biased overt attentional orienting, and detection efficiency following fixation. The issue of whether there is *preattentive* processing (i.e., detection prior to attentional selection) of emotional faces has been addressed by studies manipulating set size, that is, the number of distractor faces in the array (for a review, see Horstmann, 2007). Generally, it is assumed that, if a target can be detected preattentively, increasing the number of distractors will have minimal impact on search times. A search slope of 10 ms or less, that is, an increase of 10 ms or less in search performance per each additional distractor, is considered as an indication of preattentive processing. Prior results regarding preattentive processing are heterogeneous for both real and schematic faces. Some studies have shown nearly flat slopes (i.e., less than 10 ms) for negative emotional expressions (e.g., Hansen & Hansen, 1988; White, 1995), whereas others have found steeper slopes (e.g., Williams et al., 2005; Öhman et al., 2001). We used an alternative procedure to explore this issue, by assessing the probability of correct detection responses prior to (vs. during or after) an eye fixation on the target face. If a target is detected preattentively, the search will be performed in parallel rather than serially, and no eye fixations will be necessary.

Alternatively, if the mechanism is not preattentional, a serial search would require attention to the target face prior to detection. This would involve two processes: Early attentional orienting, with selective overt attention to (i.e., eye fixations on) the target face, and then decision making whether the fixated target is different from the distractors. The question is whether angry or happy (or any other) target faces are detected faster because they attract overt attention earlier or because, once fixated, they are more efficiently discriminated from the distractor context faces. To address this issue, we recorded participants' eye movements. Attentional orienting was assessed by the probability of first fixation on a target face in the array, as well as the time prior to this fixation, following the onset of the stimulus display. Detection efficiency was assessed by means of the number of fixations on the target face and the time since first fixating the target until the response. If there is privileged search of any particular facial expression due to selective attentional orienting, this will be reflected in facilitated localization of the target (i.e., earlier first fixation). If the effect is due to detection efficiency, there will be reduced resource demands after having located the target face (i.e., fewer or shorter fixations). Typically, more global performance measures such as response accuracy and reaction times are collected in visual search tasks. With the eye-movement measures, we aim to extend prior research by distinguishing between the different processes that underlie the search performance.

The current study also had two secondary aims. One is concerned with whether attentional span differs as a function of emotional expression, that is, whether some facial expressions are more readily detectable than others at more eccentric locations of the visual field. To this end, the eccentricity of the face stimuli in the array was varied. The faces appeared either in parafoveal or peripheral vision (3.2° or 5.1° away from the central fixation point). This also represents a novel contribution, as the target eccentricity has not been manipulated previously in relation to emotional face search. Yet, it may be important to explore this issue, given that the emotional valence of scenes depicting people can be recognized beyond the foveal area of vision (Calvo, 2006; Calvo & Nummenmaa, 2007). The other secondary aim is concerned with whether the search advantage of some expressions involves configural processing (i.e., encoding the structural relationship between facial features) or featural processing (i.e., detecting single distinctive features, e.g., upturned lip corners, open eyes, frowning, etc.) (Calder, Young, Keane, & Dean, 2000). To this end, we presented the faces either in an upright or an inverted position, thus allowing for configural and featural encoding (upright), or disrupting configural but not featural encoding (inverted) (see Farah, Tanaka, & Drain, 1995). This issue has been addressed to some extent by prior research, although generally limited to angry and happy faces, and with discrepant results (Fox & Damjanovic, 2006, vs. Horstmann & Bauland, 2006).

Experiments 1 and 2

Arrays of one emotional target face and six neutral context faces (or seven neutral or emotional faces) of the same individual were presented. Participants decided whether the array contained a discrepant facial expression or not. In Experiment 1, the faces appeared parafoveally in relation to the central fixation point; in Experiment 2, the faces were presented peripherally. The parafoveal-peripheral manipulation is relevant to the issue of whether there is a broadened functional field of view for some faces. As the participants belonged to the same undergraduate pool and were randomly assigned to the parafoveal or the peripheral conditions, the two experiments will be presented together, and their analysis will be combined.

Method

Participants

Fifty-four (27 for each experiment) psychology students (42 women) participated for course credit. They ranged from 19 to 22 years; 47 were right-handed.

Stimuli

One hundred ninety-six digitized color photographs were selected from the Karolinska Directed Emotional Faces (KDEF; Lundqvist, Flykt, & Öhman, 1998) for the experimental trials. The face stimuli depicted 28 different individuals (14 women: KDEF no. 01, 02, 03, 05, 07, 09, 11, 13, 14, 19, 20, 26, 29, 31; and 14 men: 03, 05, 06, 08, 10, 11, 12, 13, 14, 17, 23, 29, 31, 34) each posing seven expressions (neutral, happy, angry, sad, disgusted, surprised, and fearful), gazing directly at the viewer. Four additional models (2 women; 28 photographs) were used for practice trials. The models were amateur actors between 20 and 30 years of age, with Caucasian origin. A sample of pictures is shown in Figure 1.

The selected photographs were cropped: Nonfacial areas and those not conveying facial expression (e.g., hair, neck, etc.) were removed by applying an oval-shaped mask (see Williams et al., 2005). Stimulus displays were arranged in a circle, such that each array contained six faces surrounding a central face (see Figure 2). Each face subtended a visual angle of 3.2° × 2.4° at a 60 cm viewing distance. The center of the central face coincided with the starting fixation point. The center of all the surrounding faces was located at the same distance from this point and from the two adjacent faces (3.2° or 5.1°, in the parafoveal or the peripheral presentation conditions). Face stimuli appeared against a dark background. The display of specific interest included one discrepant emotional target face among six neutral context faces (144 trials). The central face was always neutral and the target appeared in one of the six surrounding locations. Two additional types of arrays included either seven neutral faces (48 trials) or seven emotional faces with the same expression (24 trials).

Apparatus and Procedure

The stimuli were presented on a 21-in., 120-Hz monitor, connected to a Pentium IV 3.2-GHz computer. Participants' eye movements were recorded with an EyeLinkII tracker (SR Research Ltd., Mississauga, Ont., Canada), connected to a Pentium IV 2.8-GHz host computer. The sampling rate of the eyetracker was 500-Hz and the spatial accuracy was better than 0.5°, with a 0.01° resolution in the pupil-tracking mode. A forehead and chin rest was used to keep viewing distance constant (60 cm).

Each participant was presented with 216 trials in three blocks, randomly. Each trial started with a central drift correction circle (0.8° of diameter). When the participant fixated this circle, the stimulus display appeared and remained visible until the participant pressed one of the two buttons, to indicate that there was no discrepant target (i.e., all faces identical) or that there was a discrepant face.

Design and Measures

Each experiment involved two within-subjects factors for displays with one discrepant target: Emotional expression (happy vs. angry vs. sad vs. disgusted vs. surprised vs. fearful) and location (left vs. middle vs. right) of target face. For the combined analysis of results, eccentricity (parafoveal: 3.2° vs. peripheral: 5.1°) was added as a between-subjects factor. Each target face appeared once in each of the six surrounding locations, and each participant saw each face only. To explore lateralization effects, we averaged scores for the two locations leftwards from the central face, the two rightwards locations, and the central upwards and downwards locations (see Williams et al., 2005).

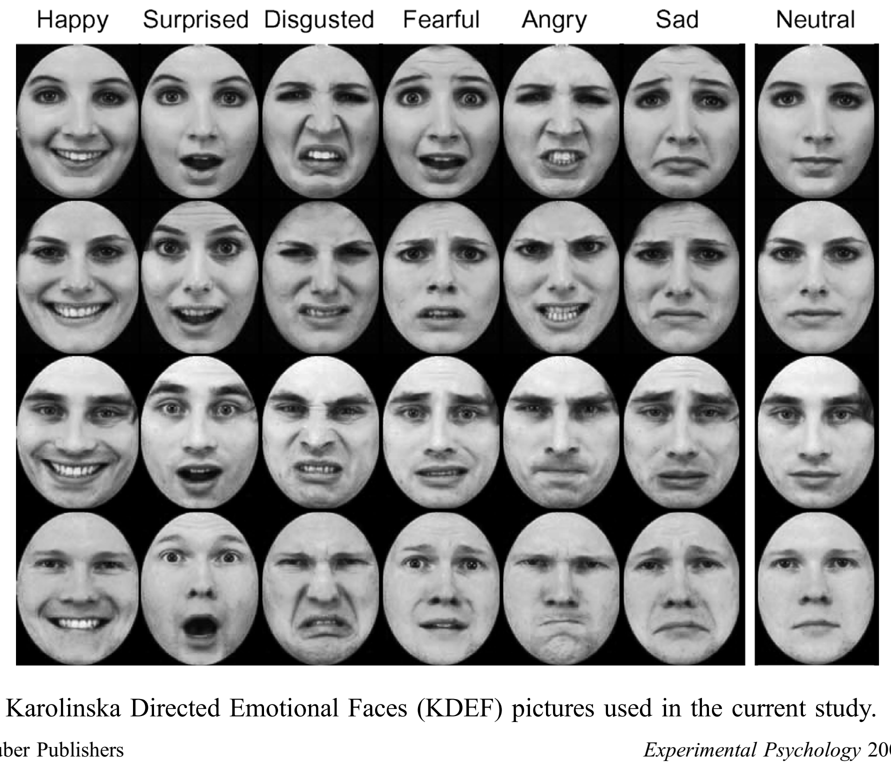

Figure 1. Sample Karolinska Directed Emotional Faces (KDEF) pictures used in the current study.

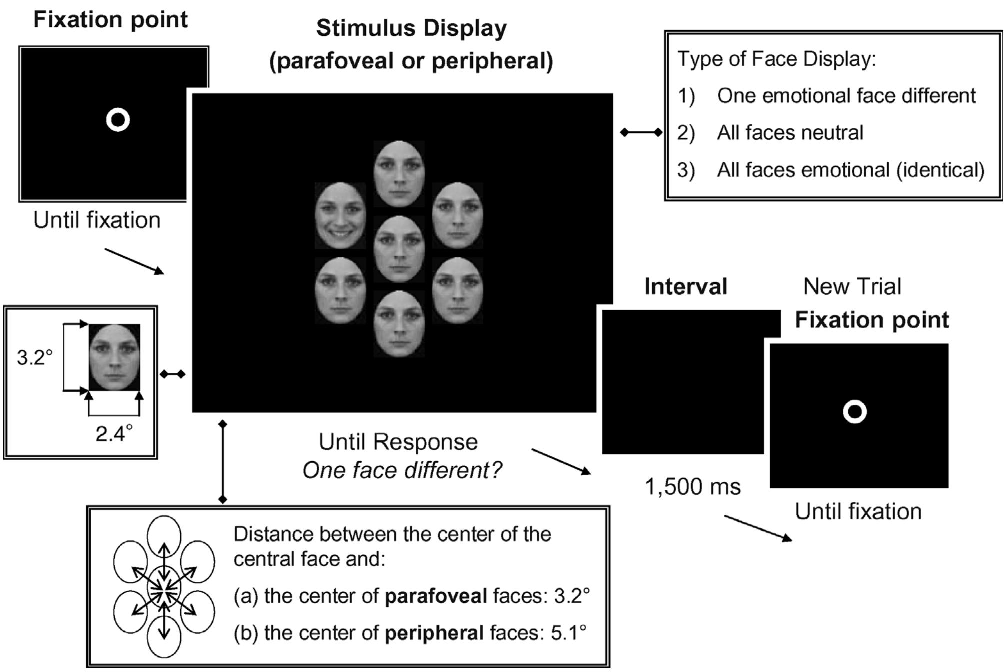

Figure 2. Sequence of events and overview of basic characteristics of a trial.

Three types of measures were collected. Visual search *performance* was assessed by (a) response accuracy and (b) reaction times from the onset of the stimulus display until the participant responded whether there was a discrepant face or not. The effects on attentional *orienting* were examined by three eye-movement measures: (a) probability of first fixation, that is, the probability that the initial fixation landed on the target face; (b) localization time, that is, the time from the onset of the stimulus display until the target face was initially fixated; and (c) rank order of the first fixation on the target face, that is, how many crowd faces were fixated before the target face. The effects on detection *efficiency* were examined by four measures: (a) decision time or the time since the target was initially fixated until the response; (b) number of fixations on the target before the response; and (c1) second-pass dwell time, that is, after first fixating away from the target and then refixating it, and (c2) number of looks-back to the target face after having exited it once, which would reveal the need of re-processing the stimulus.

Control of Low-Level Physical Features

On discrepant-target trials, one emotional face had to be detected in a context of six neutral faces. In visual search tasks, the more visually salient the discrepant objects are, the faster are the search rates (see Duncan & Humphreys, 1989). To rule out the possibility that differences in visual search were due to mere physical differences – rather than to facial expression per se – between target and context faces, we ensured that all emotional faces were equivalent in low-level visual properties when compared with the neutral faces. To this end, we assessed (a) mean luminance and (b) contrast density (RMS contrast, Bex & Makous, 2002) of each face stimulus by means of Adobe Photoshop. In addition, we assessed (c) color and (d) texture similarity each target (emotional) face and the corresponding context (neutral) face, by implementing a local pixel-by-pixel principal component analysis (PCA) with reversible illumination normalization (see Latecki, Rajagopal, & Gross, 2005). One-way ANOVAs (type of emotional expression) yielded no significant differences in luminance (p = .61) or RMS contrast (p = .35) among the emotional faces. No significant differences appeared between the various emotional expressions and the neutral faces in PCA-based color (p = .30) or texture (p = .35) similarity.

Results

Trials With All Faces Identical

When all faces in the display conveyed the same expression, a 7 (expression) × 2 (eccentricity) ANOVA yielded no significant effect on response accuracy. The mean probability of *correct responses* was equivalent for neutral (.866), happy (.872), surprised (.897), disgusted (.941), fearful (.922), angry (.897), and sad (.946) faces, and for the parafoveal (.911) and peripheral (.898) conditions. *Reaction times* varied as a function of expression, $F(6, 294) = 7.13$, $p < .0001$, $\eta_p^2 = 0.13$, and eccentricity, $F(1, 49) = 18.90$, $p < .0001$, $\eta_p^2 = 0.28$. Responses were faster for sad (1,221 ms), disgusted (1,183) happy (1,234), and surprised

(1,205) expressions than for neutral expressions (1,335), with all other differences being nonsignificant (fearful: 1,263, angry: 1,303). Faster responses occurred in the parafoveal (1,091 ms) than in the peripheral (1,414) condition.

Trials With One Discrepant Emotional Target

The dependent variables were analyzed by means of 6 (target emotional expression) by 3 (visual field location) by 2 (eccentricity) ANOVAs. For all the experiments, Bonferroni corrections were used for multiple comparisons ($p < .05$).

Visual Search Performance: Response Accuracy and Search Times

See mean scores and multiple contrasts in Table 1. For *response accuracy*, there was an expression effect, $F(5, 260) = 55.62$, $p < .0001$, $\eta_p^2 = 0.52$. The difference between the parafoveal (.892, probability of correct responses) and the peripheral (.846) condition was not significant. Accuracy was highest for happy targets and lowest for sad targets, and it was higher for happy, surprised, disgusted, and fearful targets than for angry and sad targets. For *reaction times*, significant effects of expression, $F(5, 260) = 182.18$, $p < .0001$, $\eta_p^2 = 0.78$, visual field, $F(2, 104) = 12.92$, $p < .0001$, $\eta_p^2 = 0.20$, and eccentricity, $F(1, 52) = 7.39$, $p < .01$, $\eta_p^2 = 0.12$, emerged. Responses were faster for happy, surprised, and disgusted targets than for fearful targets, which were faster than for angry targets, and were slowest for sad targets. In addition, responses were faster for targets appearing to the right (920 ms) or the left (940) of the central face than for targets in the middle locations (976); and they were faster in the parafoveal (882 ms) than in the peripheral (1,009) condition.

Attentional Orienting: First-Fixation Probability, Order of Fixation, and Localization Time

See mean scores and multiple contrasts in Table 2. For *probability of first-fixation*, effects of expression, $F(5, 260) = 60.15$, $p < .0001$, $\eta_p^2 = 0.54$, and eccentricity, $F(1, 52) = 26.14$, $p < .0001$, $\eta_p^2 = 0.34$, were qualified by their interaction, $F(5, 260) = 5.39$, $p < .0001$, $\eta_p^2 = 0.094$. The happy targets were most likely to be fixated first, followed by the surprised and the disgusted targets, then the fearful targets, and finally the angry and the sad targets. Target faces were more likely fixated first in the parafoveal (.433) than in the peripheral (.269) condition. The interaction was due to the effect of eccentricity being stronger for some targets (i.e., happy: $F(1, 52) = 33.03$, $p < .0001$, $\eta_p^2 = 0.39$) than for others (although always significant; i.e., sad: $F(1, 52) = 7.22$, $p < .025$, $\eta_p^2 = 0.12$).

For *rank order of first fixation*, there were effects of expression, $F(5, 260) = 86.24$, $p < .0001$, $\eta_p^2 = 0.62$, visual field, $F(5, 104) = 6.99$, $p < .001$, $\eta_p^2 = 0.12$, and eccentricity, $F(1, 52) = 10.71$, $p < .01$, $\eta_p^2 = 0.17$. Fewer fixations on context faces were made prior to localizing happy, surprised, and disgusted targets than fearful targets, which were fixated earlier than angry and sad targets. The number of fixations prior to localizing the target was lower when the target was to the left (2.52) or the right (2.57) than in the middle (2.66). Fewer fixations were made on context faces in the parafoveal (2.50) than in the peripheral (2.67) condition.

For *localization time*, there were also effects of expression, $F(5, 260) = 67.08$, $p < .0001$, $\eta_p^2 = 0.56$, visual field, $F(5, 104) = 15.94$, $p < .0001$, $\eta_p^2 = 0.24$, and eccentricity, $F(1, 52) = 22.80$, $p < .0001$, $\eta_p^2 = 0.31$. The time to localize the target face was shorter for happy, surprised, and disgusted faces than for fearful faces, which were localized faster than angry and sad faces. In addition, it was shorter for targets appearing to the left (459 ms) or the right (472) than in the middle (530), and shorter for target faces in the parafoveal (433 ms) than in the peripheral (541) condition.

Detection Efficiency: Decision Time, First- and Second-Pass Dwell Time, Number of Fixations, and Number of Second-Pass Fixations

See mean scores and multiple contrasts in Table 3. For *decision time*, main effects of expression, $F(5, 260) = 13.50$, $p < .0001$, $\eta_p^2 = 0.21$, and visual field, $F(2, 104) = 4.48$,

Table 1. Mean probability of correct responses and reaction times in the visual search task, as a function of type of emotional expression of the discrepant face and eccentricity, in Experiments 1 (parafoveal condition) and 2 (peripheral condition)

	Type of expression					
	Happy	Surprised	Disgusted	Fearful	Angry	Sad
Accuracy (probability)						
Parafoveal	.971	.948	.940	.921	.827	.744
Peripheral	.897	.892	.887	.843	.799	.756
Mean	.934[a]	.920[ab]	.913[ab]	.882[b]	.813[c]	.750[d]
Response time (ms)						
Parafoveal	768	796	811	922	946	1,048
Peripheral	912	895	920	1,018	1,121	1,187
Mean	840[a]	846[a]	866[a]	970[b]	1,034[c]	1,118[d]

Note. Mean scores with a different superscript (horizontally) are significantly different; means sharing a superscript are equivalent.

Table 2. Mean probability of first fixation on the target face, order of fixation (i.e., mean number of faces fixated prior to the target), and localization time, as a function of type of emotional expression of the target face and eccentricity, in Experiments 1 (parafoveal condition) and 2 (peripheral condition)

	Type of expression					
	Happy	Surprised	Disgusted	Fearful	Angry	Sad
First-fixation probability						
Parafoveal	.602	.517	.522	.392	.307	.259
Peripheral	.336	.327	.361	.216	.201	.173
Mean	.469[a]	.422[b]	.441[ab]	.304[c]	.254[cd]	.216[d]
Order of fixation						
Parafoveal	2.25	2.28	2.37	2.59	2.71	2.81
Peripheral	2.48	2.44	2.47	2.75	2.94	2.95
Mean	2.36[a]	2.36[a]	2.42[a]	2.67[b]	2.82[c]	2.88[c]
Localization time (ms)						
Parafoveal	361	372	384	444	502	535
Peripheral	465	446	473	574	640	648
Mean	413[a]	409[a]	428[a]	509[b]	571[c]	591[c]

Note. Mean scores with a different superscript (horizontally) are significantly different; means sharing a superscript are equivalent.

$p < .01$, $\eta_p^2 = 0.085$, emerged. Decision times were longest for sad targets. In addition, decision times were shorter for targets in the right (448 ms) than in the left (481) visual field, with no differences for targets in the middle (456). Decision time was equivalent in the parafoveal (449 ms) and the peripheral (468) conditions ($F < 1$). It is interesting to note that these differences came mainly from the increased *refixation* time, rather than the time initially spent on the target. This was shown by a significant expression effect on second-pass dwell time, $F(5, 260) = 13.78$, $p < .0001$, $\eta_p^2 = 0.21$; in contrast, the effect on first-pass dwell time did not reach significance, $F(5, 260) = 2.58$, $p = .11$, $\eta_p^2 = 0.047$.

For total *number of fixations*, only main effects of expression appeared, $F(5, 260) = 11.89$, $p < .0001$, $\eta_p^2 = 0.19$. There were more fixations on sad and angry targets than on happy, surprised, and disgusted targets, and fewer fixations on fearful targets than on happy and disgusted targets. Number of fixations was equivalent in the parafoveal (1.42) and the peripheral (1.47) conditions, and equivalent for the left (1.43), middle (1.43), and right (1.49) visual field. However, as was the case for decision time, the effect

Table 3. Mean decision time after first fixation on the target face, second-pass time, mean number of fixations, and second-pass fixations, as a function of type of emotional expression of the target face and eccentricity, in Experiments 1 (parafoveal condition) and 2 (peripheral condition)

	Type of expression					
	Happy	Surprised	Disgusted	Fearful	Angry	Sad
Decision time (ms)						
Parafoveal	407	425	427	478	445	513
Peripheral	447	450	447	444	481	538
Mean	427[a]	437[a]	437[a]	461[a]	463[a]	526[b]
Second-pass time (ms)						
Parafoveal	15	20	19	33	50	64
Peripheral	29	26	19	42	48	82
Mean	22[a]	23[a]	19[a]	37[b]	49[b]	73[c]
Total no. of fixations						
Parafoveal	1.32	1.38	1.34	1.47	1.52	1.53
Peripheral	1.36	1.41	1.34	1.50	1.55	1.67
Mean	1.34[a]	1.39[ab]	1.34[a]	1.49[bc]	1.54[c]	1.60[c]
Second-pass fixations						
Parafoveal	.09	.13	.09	.21	.31	.31
Peripheral	.13	.18	.10	.25	.35	.48
Mean	.11[a]	.16[ab]	.10[a]	.23[bc]	.33[cd]	.40[d]

Note. Mean scores with a different superscript (horizontally) are significantly different; means sharing a superscript are equivalent.

of facial expression was mainly due to additional *refixations*, as revealed by effects on second-pass fixations, $F(5, 260) = 21.60$, $p < .0001$, $\eta_p^2 = 0.29$. In contrast, the effect on first-pass fixations was not significant ($F = 1.65$, $p = .15$).

Discussion

The major results revealed, first, a consistent pattern of effects of emotional expression: Happy, surprised, and disgusted target faces were (a) responded to more quickly and accurately, (b) localized and fixated earlier, and (c) detected as different faster than fearful, angry, and sad faces. The search advantage thus involved both earlier attentional orienting and more efficient discrimination from the neutral distractors. Second, the effect of expression was not modulated by eccentricity, as the advantage remained equivalent in the parafoveal and the peripheral presentation conditions. Nevertheless, eccentricity affected attentional orienting – with parafoveal targets being localized earlier than peripheral targets – but not decision efficiency. It is reasonable that larger eccentricities make orienting to target stimuli slower, but that, once these are fixated, discrimination is no longer affected by eccentricity. And, third, visual field influenced response times (reaction, localization, and decision) rather than fixations (probability or frequency) and did not interact with emotional expression. Often, targets appearing on the left or the right visual field took less time than those appearing above or below the central fixation point. This reveals an absence of lateralization.

Experiment 3

In Experiment 3, we presented arrays of upside-down faces to address the issue of whether the search advantage of some faces relies on configural or featural information. Facial expression recognition is highly dependent on configural processing (Calder et al., 2000). Relative to upright faces, recognition of spatially inverted faces is surprisingly poor (see Maurer, Le Grand, & Mondloch, 2002). It is assumed that inversion disrupts the holistic configuration of faces but preserves the local facial features. Accordingly, if the search advantage of happy, surprised, and disgusted faces relies on configural information, such an advantage will disappear when faces are presented upside-down; in contrast, if the advantage remains, some local features – rather than the emotional expression per se – might be producing the effect.

Method

Participants

Twenty-seven psychology undergraduates (19 women; 23 right-handed) participated for course credit. They ranged from 19 to 21 years.

Stimuli, Design, Procedure, and Measures

The same faces as in Experiments 1 and 2 were presented, and the same procedure and measures were used, with one important difference: In Experiment 3, the arrays of faces were displayed upside-down (inverted 180°), in a parafoveal condition.

Results

Trials With All Faces Identical

A one-way (7: expression) ANOVA yielded no significant effect on response accuracy, $F = 1.18$, $p = .32$, or reaction times, $F = 2.24$, $p = .078$ (all $ps \geq .15$, after Bonferroni corrections). The mean probability of correct responses and reaction times were equivalent for neutral (.947; 1,559 ms), happy (.926; 1,496 ms), surprised (.910; 1,463 ms), disgusted (.972; 1,500 ms), fearful (.954; 1,514 ms), angry (.972; 1,508 ms), and sad (.954; 1,445 ms) faces.

Trials With One Discrepant Emotional Target

The dependent variables were analyzed by means of 6 (target expression) by 3 (visual field) ANOVAs.

Visual Search Performance: Response Accuracy and Search Times

See mean scores and multiple contrasts in Table 4. For *response accuracy*, there were main effects of facial expression, $F(5, 130) = 80.59$, $p < .0001$, $\eta_p^2 = 0.76$, and visual field, $F(2, 52) = 10.44$, $p < .0001$, $\eta_p^2 = 0.29$. Accuracy was higher for happy, surprised, and disgusted targets than for fearful, angry, and sad targets. Accuracy was higher when targets appeared to the left (.882) or the right (.895) of the central face than for targets presented above or below (.846). For *reaction times*, significant effects of expression, $F(5, 130) = 66.95$, $p < .0001$, $\eta_p^2 = 0.72$, indicated that responses were fastest for happy targets, followed by surprised and disgusted targets, which were faster than for fearful and angry targets, and were slowest for sad targets.

Attentional Orienting: First-Fixation Probability, Order of Fixation, and Localization Time

See mean scores and multiple contrasts in Table 4. For *probability of first fixation*, significant effects of expression, $F(5, 130) = 17.14$, $p < .0001$, $\eta_p^2 = 0.40$, revealed that happy, surprised, and disgusted targets were more likely to be fixated first, in comparison with fearful, angry, and sad targets. Effects of expression appeared also for the *rank order of fixation*, $F(5, 130) = 34.26$, $p < .0001$, $\eta_p^2 = 0.57$. Fewer fixations on context faces were made prior to localizing happy, surprised, and disgusted targets than fearful,

Table 4. Mean scores of dependent variables in the visual search task, as a function of type of emotional expression of the target face, in Experiment 3 (parafoveal inverted condition)

	Type of expression					
	Happy	Surprised	Disgusted	Fearful	Angry	Sad
Accuracy (probability)	.989[a]	.971[a]	.974[a]	.898[b]	.765[c]	.650[d]
Response time (ms)	862[a]	919[b]	917[b]	1,091[c]	1,201[c]	1,378[d]
First-fixation probability	.458[a]	.427[a]	.415[a]	.310[b]	.296[b]	.259[b]
Order of fixation	2.60[a]	2.75[a]	2.70[a]	3.01[b]	3.20[bc]	3.39[c]
Localization time (ms)	368[a]	402[b]	403[ab]	510[c]	535[c]	600[d]
Decision time (ms)	494[a]	517[a]	514[a]	581[b]	665[c]	777[d]
Second-pass time (ms)	13[a]	29[ab]	28[ab]	52[b]	109[c]	147[c]
Total no. of fixations	1.34[a]	1.39[ab]	1.34[a]	1.49[bc]	1.54[c]	1.60[c]
Second-pass fixations	.11[a]	.16[ab]	.10[a]	.23[bc]	.33[cd]	.40[d]

Note. Mean scores with a different superscript (horizontally) are significantly different; means sharing a superscript are equivalent.

angry, and sad targets. For *localization time*, there were significant effects of expression, $F(5, 130) = 64.07, p < .0001, \eta_p^2 = 0.71$, and visual field, $F(2, 52) = 4.01, p < .025, \eta_p^2 = 0.13$. The time to localize the target was shorter for happy, surprised, and disgusted faces than for fearful and angry faces, which were localized faster than sad faces. Localization time was shorter for targets appearing to the left (447 ms) than above or below (485), with no differences for those presented to the right (477).

Detection Efficiency: Decision Time, First- and Second-Pass Time, Number of Fixations, and Second-Pass Fixations

See mean scores and multiple contrasts in Table 4. For *decision time*, main effect of expression emerged, $F(5, 130) = 30.33, p < .0001, \eta_p^2 = 0.54$. Decision times were shorter for happy, surprised, and disgusted targets than for fearful and angry targets, and were longest for sad targets. Target expression influenced both first-pass, $F(5, 130) = 12.23, p < .0001, \eta_p^2 = 0.32$, and second-pass time, $F(5, 130) = 22.49, p < .0001, \eta_p^2 = 0.46$. For total *number of fixations*, main effects of expression, $F(5, 130) = 28.83, p < .0001, \eta_p^2 = 0.53$, indicated that there were more fixations on sad and angry targets than on fearful, disgusted, surprised, and happy targets. Nevertheless, the effect was mainly due to refixations, $F(5, 130) = 30.48, p < .0001, \eta_p^2 = 0.54$; it did not reach statistical significance for first-pass fixations ($F = 2.12, p = .080$).

Effects of Inversion

Given that the pattern of effects of emotional expression in the inverted condition (Experiment 3) was equivalent to that in the upright conditions (Experiments 1 and 2), it is important to demonstrate that the manipulation of inversion was effective. A 2 (upright vs. inverted parafoveal presentation, i.e., Experiment 1 vs. 3) by 6 (emotional expression) ANOVA was conducted on each dependent variable. In comparison with the upright condition, inversion impaired performance on all variables except response accuracy ($F < 1$; M upright vs. inverted: .892 vs. 874): Reaction times, $F(1, 52) = 10.57, p < .01, \eta_p^2 = 0.17$ (882 vs. 1,061 ms); probability of first fixation on the target face, $F(1, 52) = 4.43, p < .05, \eta_p^2 = 0.080$ (.443 vs. .361); order of fixation, $F(1, 52) = 45.96, p < .0001, \eta_p^2 = 0.47$ (2.50 vs. 2.94); localization time, $F(1, 52) = 4.76, p < .05, \eta_p^2 = 0.84$ (433 vs. 470 ms); decision time, $F(1, 52) = 9.99, p < .01, \eta_p^2 = 0.16$ (449 vs. 591 ms); second-pass time, $F(1, 52) = 5.62, p < .025, \eta_p^2 = 0.10$ (33 vs. 63 ms); number of fixations, $F(1, 52) = 6.95, p < .01, \eta_p^2 = 0.12$ (1.42 vs. 1.63); and second-pass fixations, $F(1, 52) = 9.28, p < .01, \eta_p^2 = 0.15$ (0.19 vs. 0.36).

Probability of Correct Detection Responses Before, During, and After First Fixation on the Target

See mean scores and multiple contrasts in Figure 3. To examine the extent to which overt attention to the target is required for detection, a 6 (target expression) by 3 (phase: Prior to fixation on the target vs. upon fixating the target vs. after having exited the target) by 3 (type of display: Upright parafoveal vs. upright peripheral vs. inverted parafoveal) ANOVA was conducted on the probability of correct responses across the experiments. This approach serves to compare a preattentive (i.e., detection without attention to the target) versus an overt attention (i.e., fixation required) account of the differences in visual search as a function of emotional expression. There were main effects of expression, $F(5, 390) = 73.33, p < .0001, \eta_p^2 = 0.49$, and phase, $F(2, 156) = 129.96, p < .0001, \eta_p^2 = 0.63$, which were qualified by an expression by phase interaction, $F(10, 780) = 30.21, p < .0001, \eta_p^2 = 0.28$. To decompose the interaction, separate analyses were conducted for each phase. Before the target was fixated, there were no significant differences as a function of target expression. During fixation on the target, reliable effects of expression appeared,

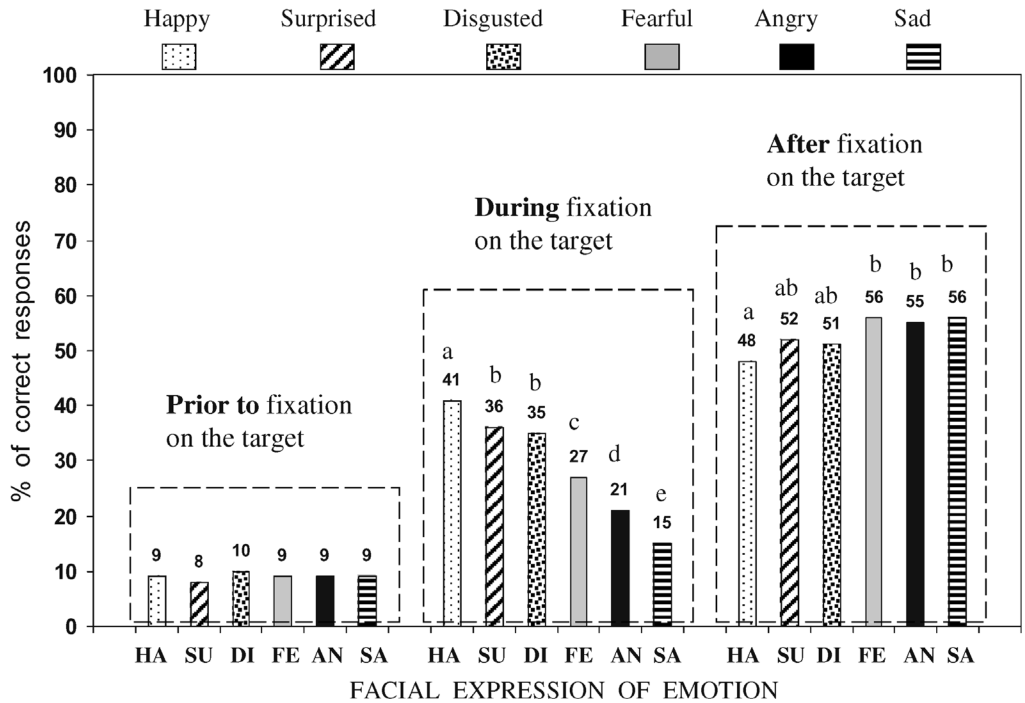

Figure 3. Correct detection responses prior to, during, and after fixation on the target face, collapsed across the parafoveal, peripheral, and inverted presentation conditions. Mean scores with a different superscript are significantly different.

$F(5, 390) = 33.03$, $p < .0001$, $\eta_p^2 = 0.39$ (see means and contrasts in Figure 3). After fixation on the target, smaller, though still significant, effects of expression emerged, $F(5, 390) = 6.77$, $p < .001$, $\eta_p^2 = 0.08$ (see Figure 3). The strong effect of phase revealed a low probability of responses before localization (9.1%), relative to during (29.2%) and after (53.0%) fixation (all ps < .01).

Discussion

The pattern of effects of emotional expression on all the visual search measures was essentially the same in the inverted condition of Experiment 3 as in the upright conditions of Experiments 1 and 2. This supports a featural rather than a configural explanation of the search advantage of some expressions over others. As the advantage remained when configural processing was disrupted by inversion, it follows that the advantage must depend on some featural information. This, however, does not imply that configural information is not important in face visual search. In fact, inversion impaired performance for all faces and practically all measures, which suggests that the configurally intact information (upright presentation) facilitates visual search. Our results thus show that, although configural processing is generally important for all faces, the advantage of some of them over others is dependent on featural processing. Another finding has also emerged consistently across the three experiments: Less than 10% of correct detection responses were made before the target was fixated, similarly for all faces. This implies that search was serial rather than parallel, and that the advantage of some faces was not due to enhanced preattentive processing, but rather to facilitated attentional processing.

General Discussion

There was a visual search superiority of happy, surprised, and disgusted faces, over fearful, angry, and sad faces. This was reflected in global search performance measures, that is, shorter response times and better accuracy, and also in earlier overt attentional orienting and greater detection efficiency. This occurred in the absence of differences in preattentive processing, as revealed by the minimal correct responding prior to eye fixations on the target. This pattern did not vary with target eccentricity and remained equivalent when faces were presented upside-down. We will first consider the empirical contribution of this study and then discuss the findings in relation to two theoretical issues, that is, the mechanisms of search and detection of emotional faces, and the perceptual versus emotional account of the search and detection advantage.

Our results show a superiority of three expressions (happy, disgusted, and surprised) over the others (fearful, angry, and sad), as targets in crowds of neutral faces. In no previous study were all six facial expressions compared. Generally, two or three expressions (typically, angry and happy) were included (Byrne & Eysenck, 1995; Fox & Damjanovic, 2006; Hansen & Hansen, 1988; Horstmann &

Bauland, 2006; Juth et al., 2005; Purcell et al., 1996). The current study thus extends the range of relevant comparisons. The fact that performance was better for happy than for angry targets in all measures is in contrast with findings typically obtained with schematic faces (e.g., Calvo et al., 2006; Lundqvist & Öhman, 2005; Schubö et al., 2006) and with some studies using real faces (Fox & Damjanovic, 2006; Hansen & Hansen, 1988; Horstmann & Bauland, 2006), in which an angry-face superiority was found. The reliability of the present findings is strengthened because we used 28 different models posing the facial expressions. In contrast, all the prior studies reporting an angry-face superiority employed two or three different models. This issue regarding the number and variety of exemplars of each expression may be important for deciding about the happy- versus angry-face advantage. When a larger sample of stimuli was used, a happy-face superiority was found (Juth et al., 2005, 60 models; or a happy-face superiority for nonanxious participants: Byrne & Eysenck, 1995, 12 models; or, at least, an angry-happy-face equivalence: Williams et al., 2005; 12 models). This suggests that the so-called angry-face advantage might be restricted to small subsets of real faces or to prototypes of schematic facial stimuli, which might not be representative of the natural variance in expressions of anger.

Processing Stages and Mechanisms

The current data extend the results of prior research by showing how three different cognitive components of visual search are affected by facial expressions. In prior studies, global performance measures, that is, response times and accuracy, were used. By means of eye-movement measures, we have identified three successive stages, that is, preattentive processing, overt attentional orienting, and decision efficiency. Preattentive processing refers to detection of a target prior to selection, that is in the *absence of* attention allocation. Overt attentional orienting involves the selective *initial* gaze direction towards the target. Decision efficiency is related to the amount of resources that are allocated to the target *after* it is under overt attention, before the detection response.

Our data show that emotional faces in a crowd are not detected preattentively, and that preattentive processing is not responsible for the differences in visual search as a function of emotional expression. Only in less than 10% of trials did correct detection occur prior to fixation on the target, and this was practically identical for all six emotional expressions. Accordingly, overt localization of the target generally occurred prior to target detection and discrimination from the context distractors. This reveals that search is serial rather than parallel and is in accordance with studies showing no “pop-out” of faces (see Wolfe, 1998). The pop-out of neutral faces versus objects has been attributed to low-level factors (Van Rullen, 2006). In fact, there is agreement that the pop-out effects found for angry real faces (Hansen & Hansen, 1988) were due to low-level factors (Purcell et al., 1996). Given that our emotional face stimuli were comparable on a number of global low-level image properties (luminance, contrast, color, and texture), it is understandable that no preattentive advantage emerged for any facial expression.

The extent to which attentional resources are required for face detection, nevertheless, varies for the different expressions. First, there was selective orienting towards happy, surprised, and disgusted targets, as revealed by a more likely first fixation, shorter localization times, and fewer nontarget prefixations, in comparison with the other faces. This suggests that, prior to overtly shifting attention to the target, some facial expressions were more likely to be perceived by *covert attention*, which then would selectively guide the first fixation to them. This further implies that the functional field of view varies as a function of expression, consistently across less (parafoveal) and more (peripheral) eccentric locations. Presumably, visual information conveyed by certain expressions – potentially due to single salient features (see below) – is more readily accessible by the magnocellular visual pathway originating from the peripheral retina (see Vuilleumier & Pourtois, 2007). Second, there were more correct detection responses *during* the first fixation on happy, surprised, and disgusted target faces, in comparison with fearful, angry, and sad faces, which tended to be responded correctly to a greater extent *after* having fixated away from the target. And, third, there was enhanced detection efficiency for happy, surprised, and disgusted faces, as revealed by shortened decision times and fewer on-target fixations, particularly for second-pass time and fixations, thus showing reduced *re-processing* demands. In total, although the search process relies on attention for all facial expressions, some of them, particularly the happy faces, would require a lesser amount of attentional resources.

An Emotional Versus Perceptual Account

Why is there such privileged processing of happy, surprised, and disgusted faces, as shown by the search performance advantage, and the facilitation of attentional orienting and decision efficiency mechanisms? Two factors can be considered: The affective meaning of expressions and the physical discriminability of each emotional target against a background of neutral faces. Regarding affective content, a threat and a negativity hypothesis have been proposed (see Calvo et al., 2006; Öhman et al., 2001; Tipples et al., 2002). In our study, this hypothesis would apply to the disgusted-face superiority, but it would be inconsistent with the angry (and the fearful and sad) face data. Furthermore, of the three faces showing a similar advantage, one of them (i.e., happy) conveys a positive emotion, and another (i.e., surprise) is ambiguous with respect to valence, which also argues against the negativity hypothesis. Accordingly, no firm conclusions can be established regarding the role of affective content.

The current data from the inverted display condition are more favorable to an explanation that relies on the physical distinctiveness of single facial features. Although inversion generally impaired performance, the search, orienting, and detection advantage of some expressions over others remained essentially the same in the upright and the inverted conditions. The inverted-face paradigm has also been used in prior research with happy and angry expressions. The results, however, have been equivocal, with inversion either eliminating (Fox & Damjanovic, 2006) or not (Horstmann & Bauland, 2006) the superiority of angry faces. In our study, with six types of expressions, the fact that face inversion did not change the search patterns suggests that some prominent facial feature must have influenced the process in two ways: First, by facilitating guidance of overt attention within the array – thus affecting orienting; and, second, by making some emotional faces easily discriminable from the neutral faces – thus affecting detection. Accordingly, the happy (and surprised, and disgusted) face advantage may be dependent on the perception of single features. Although we controlled for the *global* low-level visual similarity between targets and distractors, this does not rule out the possibility that *local* variations (e.g., in contrast density for the mouth region) *within* some facial expressions could guide the search process.

What facial features can make such a contribution? Smiles have been proposed as a powerful feature attracting attention and facilitating identification (Leppänen & Hietanen, 2004, 2007), and the local contrast between the smiling, exposed teeth and the surrounding face is indeed strong. While this could explain the advantage of our happy-face stimuli, it would not account for that of the disgusted and the surprised faces. For these expressions, other features might be involved, but, to our knowledge, no study has examined their role in visual search. Nevertheless, even if single facial features make a major contribution to search differences between emotional faces, this may not completely undermine the role of emotional content. It is possible that some features that are consistently associated with particular expressions have acquired the affective properties of expressions, and would then be used as diagnostic cues for orienting and as shortcuts for discrimination.

Conclusion

Happy, surprised, and disgusted faces are detected faster and more effectively than fearful, angry, and sad faces, both because of earlier attraction of overt attention to their location and, once fixated, because of more efficient discrimination from the neutral context faces. This advantage involves attentional rather than preattentional mechanisms, and featural rather than configural processing. An important issue to be investigated is the nature of the critical facial features contributing to search differences between emotional expressions, and the extent to which the featural effects are due to their physical or their affective properties.

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