

In search of the emotional face: Anger vs. happiness superiority in visual search

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Abstract

Previous research has provided inconsistent results regarding visual search for emotional faces, yielding evidence for either anger superiority (i.e., more efficient search for angry faces) or happiness superiority effects (i.e., more efficient search for happy faces), suggesting that these results do not reflect on emotional expression, but on emotion (un-)related low-level perceptual features. The present study investigated possible factors mediating anger/happiness superiority effects, specifically search strategy (fixed vs. variable target search; Experiment 1), stimulus choice (Nimstim database vs. Ekman & Friesen database; Experiments 1 & 2), and emotional intensity (Experiment 3 & 3a). Angry faces were found faster than happy faces regardless of search strategy using faces from the Nimstim database (Experiment 1). By contrast, a happiness superiority effect was evident in Experiment 2 when using faces from the Ekman and Friesen database. Experiment 3 employed angry, happy, and exuberant expressions (Nimstim database) and yielded anger and happiness superiority effects respectively, highlighting the importance of the choice of stimulus materials. Ratings of the stimulus materials collected in Experiment 3a indicate that differences in perceived emotional intensity, pleasantness or arousal do not account for differences in search efficiency. Across three studies, the current investigation indicates that prior reports of anger or happiness superiority effects in visual search are likely to reflect on low-level visual features associated with the stimulus materials used, rather than on emotion.

Key words: Face in the crowd effect; facial expressions of emotion; anger superiority; happiness superiority; visual search.

Expressions of emotion are one of many important signals available on the human face providing information about others' intentions and potentially signaling interpersonal threat. Thus, when Hansen and Hansen (1988) first reported the face-in-the crowd effect, that participants searching through crowds of faces were faster to detect angry than happy expressions, it stimulated a large body of research investigating the detection of emotional expressions within crowds of faces. Findings from these subsequent investigations are mixed, however. Some studies provide evidence for the preferential detection of angry faces, over other emotions, (Hansen & Hansen, 1988; Lipp, Price, & Tellegen, 2009a,b; Horstmann & Bauland, 2006), a pattern of results otherwise known as the anger superiority effect. In other studies happy faces were found most efficiently; a finding known as the happiness superiority effect (Juth, Lundqvist, Karlsson, & Öhman, 2005; D. V. Becker, Anderson, Mortensen, Neufeld, & Neel, 2011). This happiness superiority effect has also been shown in detection tasks that employed dynamic expressions of emotion instead of the still images used in visual search (D. V. Becker et al., 2012). Finally, some studies proffer that there is no evidence for the preferential detection of either expression and claim that previous reports reflect on low-level perceptual confounds rather than the emotion expressed (Purcell, Stewart & Skov, 1996; Purcell & Stewart, 2010).

This division is also reflected in two recent major reviews which examined the support, or lack thereof, for anger and happiness superiority effects. One concluded that there is compelling evidence for the anger superiority effect (Frischen, Eastwood & Smilek, 2008) whereas the second was in support of the happiness superiority effect (D. V. Becker et al., 2011). This divergence in conclusions is the more surprising as both articles proposed similar sets of formal criteria to which research in the area should adhere in order to enable strong conclusions regarding the existence of an anger or happiness superiority effect.

Frischen et al. (2008) proposed three criteria. First, that the number of stimuli ('set size') should be varied to calculate search efficiency, secondly, that the expression of distractor faces should be held constant during a block of trials, and third, that fixed target searches should be used. In a fixed target search the target emotion is constant across trials, i.e., participants are asked to search for happy faces. In a variable target search, the target emotion can vary from trial to trial, i.e., participants are asked to find happy and or angry targets among neutral backgrounds, and are typically instructed to decide whether all expressions in a search array are the same or whether the display contains a different expression. D. V. Becker et al. (2011) extended this list, adding that low-level visual features should be controlled for and that distractor faces should not be completely homogenous. These additional recommendations aimed to minimize the impact of low-level perceptual confounds and to ensure that results generalized across different individuals. The latter issue is of particular relevance for some previous studies that used crowds comprising a single individual face (e.g., Hansen & Hansen, 1988).

Of the criteria proposed, the requirement for fixed target search probably has the most far-reaching consequences. The majority of previous studies used variable target searches, so that accepting the recommendation to focus on fixed target searches would render a large number of studies irrelevant. Yet, it is not clear whether and to what extent the use of fixed versus variable target searches can affect search asymmetries. When considering the utility of variable target searches a distinction needs to be made between those that hold the nature of the distractor stimuli constant, i.e., present angry or happy targets among neutral backgrounds, and those that vary distractor and target stimuli, i.e., present angry targets among happy backgrounds and happy targets among angry backgrounds. In the latter case, what is a target in one trial can be the distractor on another. This procedure confounds the effects of targets and distractors. Therefore, observing an anger superiority effect in such a procedure may reflect on faster detection of angry target faces or on faster search through happy

backgrounds (e.g., de-allocation hypothesis; see S. I. Becker, Horstmann & Remington, 2011; Lipp et al., 2009b; Horstmann et al., 2006). However, this problem does not occur if neutral face distractors are used across all trials and only the emotion of the target face is varied.

Are there reasons to suspect that fixed versus variable target searches can lead to different search asymmetries in the absence of distractor confounds, that is, when the distractor faces are always neutral? For example, using otherwise very similar stimuli and tasks, D.V. Becker et al. (2011) reported a happiness superiority effect in a fixed target search, whereas Lipp et al. (2009a) found an anger superiority effect using a variable target search. Could differences between the search tasks account for these results?

A variable target search leaves more room for search strategies, which could potentially skew the results. For example, in a variable target search, observers can choose to prioritise one target over the other. It is possible that attentional resources are first and foremost focused on angry faces, which renders search for angry faces faster. In a fixed target search, the emotional expression of the target is known in advance, allowing observers to focus all attentional resources on detecting the emotional expression of the target face. Whether or not a fixed target search should be methodologically preferred over a variable target search would depend on whether a general bias for prioritizing angry faces in visual search is theoretically important to explain the anger superiority effect (in which case the variable target search would be needed), or whether the tested hypothesis involves only bottom-up factors (in which case the fixed target search which controls for top down settings would be preferable).

In experiments that use emotional expressions from different individuals as target faces, a variable target search may provide a better indicator for the processing of emotional expressions, because emotional expressions from different individuals can differ in homogeneity – for example, it is

possible that happy expressions are more homogeneous across different individuals (e.g., open, up-turned mouth), whereas angry expressions may be more varied (e.g., some individuals tilting their head forward, showing a snarl, others jutting their chin out, pressing their lips together to show anger). If angry and happy expressions differ in their variability, the more homogeneous expression (e.g., happy faces) could potentially benefit more from a fixed target search, because the target can be detected by strategically searching one or a few key features. This supposition is consistent with Calvo and Nummenmaa's (2008) report that emotional faces displaying highly salient features were detected faster and that these salient features facilitated initial orientation to the emotion, speeding detection. If the happiness superiority effect found in the fixed target search of D.V. Becker et al (2011) is due to the fact that the happy faces could be found by limiting search to a few salient features, the results would not reflect on differences in the processing of emotional expressions.

To date, the discussion of potential differential findings emerging from fixed and variable target searches with photorealistic emotional expressions are largely hypothetical, however, as to the best of our knowledge no study has systematically assessed the effect of different search strategies. Hahn and Gronlund (2007) investigated search for angry and happy schematic faces in fixed and variable target searches using the same stimulus configurations across the two search conditions and found an anger superiority effect in both conditions, with no differences between fixed and variable target search. Although the approach chosen by Hahn and Gronlund (2007) is very promising, the conclusions that can be drawn from the study seem limited for two reasons. First, the study used schematic faces rather than photorealistic ones. This has been criticized as preferential detection of angry schematic faces may reflect on low-level perceptual features rather than on the emotional expression conveyed (S. I. Becker, Horstmann, & Remington, 2011; Coelho, Cloete & Wallis, 2010; Horstmann, S. I. Becker, Bergmann, & Burghaus, 2010; Purcell & Stewart, 2010). Moreover, using schematic faces is inconsistent with the

recommendations put forward by Frischen et al. (2010) and D.V. Becker et al. (2011) who advocate the use of photorealistic faces. Second, search among schematic faces does not allow implementing D.V. Becker et al.'s (2011) recommendation to use pictures of different individuals as distractors. Using the same distractors usually renders search quite efficient, as similar distractors can be grouped together (e.g., Duncan & Humphreys, 1989; see also S.I. Becker, Remington & Horstmann, 2011) and the target can – to some degree – pop out from the search display. It is possible that observers did not use different search strategies in variable versus fixed target searches in the study of Hahn and Gronlund (2007) because targets could be readily detected without implementing specific search strategies.

In sum, the currently available evidence does not allow us to determine whether fixed and variable target searches can indeed promote the use of differential search strategies that can skew the results and favor happiness or anger superiority effects. Yet, it is important to examine effects of fixed versus variable target searches; first, to assess whether methodological recommendations for the design of visual search studies can be validated, and secondly, to evaluate whether the use of different search tasks can explain conflicting results from previous studies – such as the happiness superiority effect found in the fixed target search of D.V. Becker et al. (2011), and the anger superiority effect found in the variable search task of Lipp et al. (2009a).

The aim of the present study was to compare fixed and variable target conditions in search for emotional photographic faces (Experiment 1) and to investigate the role of the stimulus sets (Experiment 2, 3) in mediating happiness versus anger superiority effects.

Experiment 1

In Experiment 1, participants completed three search tasks, one variable target search and two fixed target searches for angry and happy expressions in crowds of neutral faces. Following Hahn and Gronlund (2007), the same stimulus configurations were used in all tasks and efforts were made to

implement all the recommendations made by D.V. Becker et al. (2011). In particular, the number of items (set size) was varied between two, four and nine items, to assess search efficiency; the distractors always consisted of neutral faces posed by different individuals. Featural differences were controlled for by presenting happy and angry target faces among the same (heterogeneous) crowd of distractor faces, and by keeping the stimuli identical across fixed and variable target searches.

If the discrepancies of the studies of D.V. Becker et al. (i.e., happiness superiority effect using fixed target search) and those of Lipp et al. (2009a; i.e., anger superiority effect using variable target search) were due to the use of different search tasks, fixed versus variable target search, then we would expect that the variable target search in Experiment 1 would yield evidence for an anger superiority effect and that the fixed target searches would show a happiness superiority effect.

Method

Participants

Forty-five first year psychology students from the University of Queensland participated in this study in return for course credit. Data from 11 participants were excluded from analysis because more than 25% errors were made on at least one of the three tasks. Of the 34 participants left, seven were male and the mean age was 19.24 years (range = 17 to 34 years). Twelve of the participants were Asian and 22 were Caucasian.

Apparatus and materials

Participants were tested in a computer lab with 8 computer booths. 17-inch monitors, with a resolution of 1024 x 768 pixels and a refresh rate of 85 Hz, were used to present the experimental tasks. Participants responded using the left and right shift keys of the computer keyboard. DMDX (Forster & Forster, 2003) was used to present the experimental stimuli and record response times.

The experimental stimuli consisted of 25 photographic images of male faces, obtained from the NimStim database (Tottenham et al., 2009). These included nine neutral faces and eight each of happy and angry faces (models 20, 22, 24, 25, 30, 32, 34, 37 in poses CA_C, AN_O, and HA_O and model 21 contributed only CA_C). The images were edited so that they were grayscale and were 187 x 240 pixels in size. For example images see upper panel of Figure 1.

Three different set size conditions were used in the experiment, with stimulus displays containing 2, 4, or 9 stimuli. On nine picture trials, faces were presented in a 3 x 3 matrix. On four picture trials the faces occupied the four corner positions (1, 3, 7, 9) or the four middle positions (2, 4, 6, 8) and on 2 picture trials the faces occupied the opposing corners or midpoints (1, 9; 2, 8; 3, 7; 4, 6). In each set size and target condition, a target face was presented in each of the 8 outer positions once. The target was never presented in the centre position (5). The positions that were not occupied by a face remained white.

Design and Procedure

Each participant provided informed consent and was asked to complete three visual search tasks, with a practice task before each. Instructions were displayed onscreen before the commencement of each task. After the participants had completed all the tasks, they were debriefed and thanked for their participation.

The experiment consisted of one variable target search and two fixed target search tasks. In each task the same stimulus displays were used, thus participants viewed the same search matrices in each task comprising either all neutral faces or one happy face among neutral faces or one angry face among neutral faces. The tasks differed in the instructions given to participants and in the labels attached to the response keys. In the variable target search participants were asked to decide whether all faces had the same expression (response 'same') or whether there was a different expression present

(response 'different'). Thus, across trials angry and happy faces were targets. In the fixed target search, participants were instructed to search for one expression, e.g., angry faces. Thus angry faces were targets (response 'angry') and trials without angry faces (all neutral or a happy face among neutral faces) were non-target trials (response 'absent'). When asked to search for happy faces, displays comprising only neutral faces or an angry face among neutral faces were non-target trials. Performance on trials with emotional faces that were not targets (emotional non-target trials) will be reported separately. The right shift key was used for target responses and was labeled 'different' during the variable target search and either 'happy' or 'angry' for each fixed target search. The left shift key was used for no target responses and was labeled 'same' during the variable target search or 'absent' during the fixed target search.

The stimulus displays and trial sequence were identical across the three tasks. Each of the three tasks consisted of 192 trials, divided into two blocks of 96 trials, such that each trial was presented twice. Three types of trials were presented during each block, including 48 non-target trials (all neutral faces), 24 angry trials (angry face presented among neutral faces), and 24 happy trials (happy face presented among neutral faces). Three set sizes were used such that on a third of the 96 trials in each block, two, four, or nine faces were presented, respectively.

Each trial commenced with a black fixation cross presented in the middle of the screen for 500ms. The face stimuli were then presented for 3000 ms or until the participant made a response and the next trial started after an intertrial interval of 1000ms. Trials were presented in a pseudo-random trial sequence. Randomisation was constrained such that no more than three consecutive trials had a target or were of the same set size. The same trial sequence was used for each of the three tasks and the order of the tasks was counterbalanced. Each task was preceded by a practice task consisted of 10 trials each.

Scoring, response definition and statistical analysis

Prior to analysis, errors were defined as incorrect responses or failures to respond within 3000 ms of the onset of the stimulus. Outliers, defined as ± 3 *SDs* from the mean or any response time less than 100 ms, were also classified as errors. Search slopes were calculated for each individual within Excel by fitting a linear function to the three response time means for each set size. Repeated measures ANOVAs were conducted using the multivariate method and Pillai's trace is reported. Results are reported separately for the variable and the two fixed target searches as the percentage of target trials differed between tasks (50% in the variable target search and 25% in each of the fixed target searches) which will affect overall response times. However, given that different patterns in search efficiency are expected between tasks, search for angry faces more efficient than search for happy in variable search, but the inverse in fixed target search, a comparison across tasks remains possible. Follow-up analyses of significant main effects of factors with more than two levels and significant interactions were performed with two-tailed t-tests calculated using Greenhouse-Geisser corrected error values. Inflation of α -error was controlled for by using Sidak's corrections (Rohlf & Sokal, 1981) and an α level of .05 was used for all statistical analyses.

Results

Variable target search

Target trials. As can be seen in Figure 2 (upper left panel), angry target faces were found more efficiently than happy target faces; search slopes: angry: $M = 25.4$ ms/item, $SD = 17.70$; happy: $M = 37.0$ ms/item, $SD = 22.0$; $t(33) = 3.33$, $p = .002$. Analysis of the detection times confirmed this pattern yielding main effects of emotion, $F(1,33) = 39.40$, $p < .001$, $h_p^2 = .54$, and set size, $F(2,32) = 54.71$, $p < .001$, $h_p^2 = .77$, and an emotion x set size interaction, $F(2,32) = 6.81$, $p = .003$, $h_p^2 = .30$. Follow-up tests revealed that angry faces were found faster than happy faces on trials with set sizes of two, $t(32) =$

5.01, $p < .01$, four, $t(32) = 3.95$, $p < .01$, and nine, $t(32) = 9.33$, $p < .01$. The difference at set size nine was significantly larger than the difference at set sizes two, $t(32) = 14.43$, $p < .01$, and four, $t(32) = 5.38$, $p < .01$.

Participants made more errors on trials with happy than with angry targets as confirmed by the analysis, which revealed main effects of emotion, $F(1,33) = 47.41$, $p < .001$, $h_p^2 = .59$, and set size, $F(2,32) = 5.48$, $p = .009$, $h_p^2 = .26$, and an interaction between emotion and set size, $F(2,32) = 3.81$, $p = .033$, $h_p^2 = .19$. The interaction reflects that more errors were made at set size nine than set size four with happy targets, $M = 18.93\%$, $SD = 15.88$ vs. $M = 12.87\%$, $SD = 10.31$, $t(33) = 4.25$, $p < .01$, but not with angry targets, $M = 8.82\%$, $SD = 9.87$ vs. $M = 6.99\%$, $SD = 7.34$, $t(33) < 2.0$, *ns*. Analyses of errors committed provided no evidence of a speed accuracy tradeoff.

Non-target trials. As can be seen in Figure 2 (lower left panel) search on non-target trials was very inefficient, $M = 168.58$ ms/item, $SD = 92.00$. The one-way ANOVA revealed a main effect of set size, $F(2,32) = 87.78$, $p < .001$, $h_p^2 = .85$. Participants were faster to respond on trials with a set size of two than of four, $t(32) = 5.53$, $p < .01$, or nine, $t(32) = 13.38$, $p < .01$, and faster to respond on trials with a set size of four than nine, $t(32) = 7.85$, $p < .01$.

Error percentages differed across set sizes, main effect of set size, $F(2,32) = 14.31$, $p < .001$, $h_p^2 = .47$. More errors were made on trials with a set size of nine than on those with set sizes of four, $t(32) = 4.60$, $p < .01$, and two, $t(32) = 5.15$, $p < .01$. However, no significant difference was found between trials with set sizes of four and two, $t(32) = .55$, *ns*. The results did not indicate the presence of a speed accuracy tradeoff.

Fixed target search

Target trials. As can be seen in the upper right panel of Figure 2, there was no difference in the efficiency of finding angry and happy target faces; search slopes: angry: $M = 33.72$ ms/item, $SD =$

17.53; happy: $M = 38.33$ ms/item, $SD = 17.15$; $t(33) = 1.23$, *ns*. Detection times were slower for happy than angry faces at the largest set size as indicated by a main effect of set size, $F(2,32) = 124.31$, $p < .001$, $h_p^2 = .89$, and an emotion x set size interaction, $F(2,32) = 3.99$, $p = .028$, $h_p^2 = .20$. No main effect of emotion was found, $F(1,33) = 1.61$, $p = .213$, $h_p^2 = .05$. Follow-up test indicated that angry faces were found faster than happy faces at set size nine, $t(32) = 3.16$, $p < .05$. All other $ts < 2.31$. More errors were made at set size nine than four, main effect of set size, $F(2,32) = 7.59$, $p = .002$, $h_p^2 = .32$, $t(32) = 2.60$, $p < .05$. All other $ts < 1.47$. No evidence of a speed accuracy tradeoff was found.

Non-target trials. As suggested in the lower right panel of Figure 2, search slopes on non-target trials did not differ between the two tasks: angry: $M = 71.93$ ms/item, $SD = 32.84$; happy: $M = 81.46$ ms/item, $SD = 34.28$; $t(33) = 1.88$, *ns*. Search was slower in the happy than in the angry target task, main effect of task, $F(1,33) = 9.66$, $p = .004$, $h_p^2 = .23$, and slowed with increasing set size, main effect of set size, $F(2,32) = 139.97$, $p < .001$, $h_p^2 = .90$. No significant interaction was found, $F(2,32) = 1.87$, $p = .170$, $h_p^2 = .11$. Participants were faster to respond during trials with a set size of two than four, $t(32) = 6.51$, $p < .01$, or nine, $t(32) = 15.41$, $p < .01$, and faster to respond during trials with a set size of four than nine, $t(32) = 8.91$, $p < .01$.

More errors were made in the happy than in the angry target task, main effect of task, $F(1,33) = 15.01$, $p < .001$, $h_p^2 = .31$, and errors increased with increasing set size, main effect of set size, $F(2,32) = 19.83$, $p < .001$, $h_p^2 = .55$. More errors were made at set size nine than four, $t(32) = 6.19$, $p < .01$, and two, $t(32) = 5.86$, $p < .01$. No difference was found between set sizes two and four, $t(32) = .33$. No significant interaction was found, $F(2,32) = 2.16$, $p = .132$, $h_p^2 = .12$. These results provided no evidence of a speed accuracy tradeoff.

Emotional non-target trials. On trials where a non-target emotional face was present, i.e., a happy face in the fixed target search for angry faces or an angry face in the fixed target search for happy faces, search slopes did not differ, angry target task: $M = 59.21$ ms/item, $SD = 35.40$; happy target task: $M = 64.17$ ms/item, $SD = 30.65$; $t(33) = 1.02$, *ns*. The search times during emotional non-target trials seemed to slow for larger set sizes, main effect of set size $F(2,32) = 89.847$, $p < .001$, $h_p^2 = .85$, such that participants were faster to respond on trials with a set size of two than in those with set sizes of four, $t(32) = 6.18$, $p < .01$, or nine, $t(32) = 15.07$, $p > .01$, and faster to respond on trials with a set size of four than those with a set size of nine, $t(32) = 6.89$, $p < .01$. The effect of task approached significance, with faster performance in the search for angry (happy non-target trials) than in the search for happy faces (angry non-target trials), $F(33) = 3.85$, $p = .058$, $h_p^2 = .10$. No interaction was found $F(32) = .89$ $p = .421$.

Participants made more errors on the happy target task than on the angry target task, however, this difference was limited to the two larger set sizes. The analysis revealed main effects of task, $F(1,33) = 10.31$, $p = .003$, $h_p^2 = .24$ and set size, $F(2,32) = 8.26$, $p = .001$, $h_p^2 = .34$, as well as a task x set size interaction, $F(2,32) = 9.71$, $p = .001$, $h_p^2 = .38$. No significant difference between tasks was evident for trials with a set size of two, $t(32) = 6.73$, *ns*, however, participants made more errors when searching for happy faces than when they were searching for angry faces on trials with set sizes of four, $t(32) = 4.80$, $p < .01$, and nine, $t(32) = 6.79$, $p < .01$. Errors analyses provided no evidence of a speed accuracy tradeoff.

Discussion

The results revealed faster, more efficient and more accurate detection of angry than happy faces during the variable target search. Faster detection of angry faces was apparent in the fixed target search, however, no significant difference was found in search efficiencies between angry and happy

faces although search cost was numerically larger for in the search for happy faces. The faster, more accurate and more efficient detection of angry faces during the variable target search is consistent with previous reports of an anger superiority effect (Frischen et al., 2008). However, the lack of evidence for a happiness superiority effect during the fixed target search, to the extent of revealing faster detection of angry faces, suggests that the distinction between variable and fixed target searches is not sufficient to explain discrepancies reported in previous literature. It should be noted that these findings are consistent with those reported by Hahn and Gronlund (2007) for schematic faces.

The results of Experiment 1 are in contrast to those reported by D.V. Becker et al. (2011), which support a happiness superiority effect. One difference between studies is in the stimulus materials that were used. Our Experiment 1 used faces drawn from the NimStim database (Tottenham et al., 2009), in particular the open mouthed emotional expressions. Across experiments, D.V. Becker et al (2011) used emotional faces derived from a number of different sources. D.V. Becker et al.'s Experiment 1A, which was, in design, very similar to the variable search task used in Experiment 1 and revealed a clear happiness superiority effect, drew on stimulus materials from the Ekman and Friesen Pictures of Facial Affect database (Ekman & Friesen, 1976). Experiment 2 was conducted in order to determine whether the happiness superiority effect found by D.V. Becker et al. (2011) Experiment 1A would replicate under the conditions in which Experiment 1 had been conducted.

Experiment 2

Experiment 2 replicated the procedure of D.V. Becker et al.'s (2011) Experiment 1A, which yielded a happiness superiority effect using the stimuli from the Ekman and Friesen Database. Whereas Experiment 1 used faces from the Nimstim database (Tottenham et al., 2009), the faces for this experiment were drawn from the Ekman and Friesen Pictures of Facial Affect database (Ekman & Friesen, 1976). Participants searched through arrays of two, four, or six faces for emotional targets

among neutral distractors. It was hypothesised that the experiment would replicate the results of D.V. Becker et al. (Experiment 1A), resulting in a happiness superiority effect¹.

Method

Participants

Forty-eight first year psychology students from the University of Queensland participated in this study in return for course credit. Data of four participants were removed due to more than 25% errors. Of the 44 participants remaining, 12 were male and the mean age was 19.55 years (range = 17 to 34 years). Twenty-seven were Caucasian, 14 were Asian, and one each was African, African American or Indigenous Australian.

Apparatus and materials

Experiment 2 was completed in the same laboratory as Experiment 1. The face stimuli for this experiment were obtained from the Ekman and Friesen Pictures of Facial Affect database (Ekman & Friesen, 1976) and consisted of six male individuals (EM, GS, JB, WF, PE, and JJ; see lower panel of Figure 1) each providing an angry, a happy, and a neutral expression. The stimuli were edited to grayscale and a size of 167 x 250 pixels.

Design and Procedure

The general procedure was similar to that of Experiment 1, but the task parameters followed D.V. Becker et al. (2011). Instructions were displayed onscreen before the commencement of each task. The instructions and response key labels were the same as for the variable target search of Experiment 1. The task was a variable target search consisting of 216 trials in total. Three blocks were

¹ In addition to the critical task, participants in Experiment 2 completed three other tasks: One task replicated the variable target search in Experiment 1 using posed expressions with closed mouths (models HA_C and AN_C from the NimStim face set), whereas the others replicated the fixed target searches used in Experiment 1 removing the emotional non-target trials from the trial sequence. The results replicated the results of Experiment 1, showing that search was more efficient for angry than for happy targets in both search procedures (variable target: angry $M = 114.29$ ms/item, $SD = 82.10$; happy $M = 156.81$ ms/item, $SD = 82.19$; $t(43) = 2.50$; $p = .016$; fixed target: angry $M = 34.31$ ms/item, $SD = 14.51$; happy $M = 41.90$ ms/item, $SD = 22.30$; $t(39) = 2.47$, $p = .018$. As these results were not critical for the study, they were omitted from the main text. A detailed summary of the results is available from the first author upon request.

presented without interruption, each including 36 target trials, half of which contained an angry face and half a happy face, and 36 non-target trials, containing only neutral faces. The 72 trials per block comprised 6 angry and 6 happy target trials for each of the three set sizes, two, four, and six. Two similar trial sequences were used which counterbalanced the serial position of happy and angry target trials. The two trial sequences were counterbalanced across participants.

At the beginning of each trial a white fixation cross was presented in the middle of a black screen. The stimuli were then presented for 3000 ms or until the participant made a response. The faces were presented in a 3 x 4 jittered grid and each face was randomly assigned to one of the 12 possible positions. Positions that were not occupied by a face remained black. Scoring, response definition and statistical analysis were the same as in Experiment 1.

Results

Target trials

As can be seen in the upper panel of Figure 3, search for happy targets was more efficient than search for angry targets; search slopes: angry: $M = 69.97$ ms/item, $SD = 58.32$; happy: $M = 40.51$ ms/item, $SD = 41.58$; $t(43) = 3.39$, $p = .002$. Happy targets were found faster than angry targets at all set sizes and search slowed with increasing set size. The ANOVA yielded main effects of emotion, $F(1,43) = 161.52$, $p < .001$, $h_p^2 = .79$, and set size, $F(2,42) = 77.19$, $p < .001$, $h_p^2 = .79$, and an emotion x set size interaction, $F(2,42) = 7.44$, $p = .002$, $h_p^2 = .26$. The interaction reflects that the search advantage for happy faces was smaller at set size two than at set sizes four, $t(42) = 3.58$, $p < .05$, and six, $t(42) = 4.99$, $p < .01$.

Participants made fewer errors when finding happy targets, $F(1,43) = 86.89$, $p < .001$, $h_p^2 = .67$, and fewer errors on the smallest set size, main effect of set size, $F(2,42) = 11.35$, $p < .001$, $h_p^2 = .35$. No interaction was found, $F(2,42) = 2.77$, $p = .074$, $h_p^2 = .12$. Follow-up tests confirmed that fewer errors

were made on trials with a set size of two than those with set sizes of four, $t(42) = 2.65$, $p < .05$, and six, $t(42) = 5.10$, $p < .01$. No significant difference was found between set sizes four and six, $t(42) = 2.43$, *ns*. Error analyses provided no evidence for a speed accuracy tradeoff.

Non-Target trials

The search slope on non-target trials was $M = 126.78$ ms/item, $SD = 57.13$. As shown in the lower panel of Figure 3, non-target search times slowed for larger set sizes, main effect of set size, $F(2,42) = 141.94$, $p < .001$, $h_p^2 = .87$. Follow-up tests found significant differences between all three set sizes, smallest $t(42) = 5.84$, $p < .01$. Participants made more errors on trials with a set size of six, main effect of set size, $F(2,42) = 8.60$, $p = .001$, $h_p^2 = .29$ than on trials with a set size of two, $t(42) = 3.86$, $p < .01$, or four, $t(42) = 2.62$, $p < .05$. No significant difference was found between set sizes two and four, $t(42) = 1.24$, *ns*. No evidence of a speed accuracy tradeoff was apparent.

Discussion

Happy faces were found faster, more efficiently and with fewer errors than angry faces, clearly showing a happiness superiority effect. These findings replicate those of D.V. Becker et al. (2011), but are inconsistent with the results of Experiment 1. They are also consistent with those of Horstmann, Lipp, and S. I. Becker (2012), who reported more efficient detection of happy than of angry faces in a study that assessed the effect of teeth displays on visual search for emotional faces. As in our Experiment 1, Horstmann et al. used stimuli taken from the NimStim database (Tottenham et al., 2009), however, that study employed the exuberant happy expression rather than the open mouthed happy expressions employed in Experiment 1. The exuberant happy expressions, which do not have an angry equivalent, are characterized by a wide open mouth and elevated eyebrows in comparison to the open mouth happy expressions.

Inspection of the faces used in Experiment 2 (see lower panel of Figure 1) also suggests a difference in teeth display between the angry and happy expressions. Like the neutral faces, three of the six angry faces have closed mouths whereas all happy faces display teeth to at least some extent. Tooth displays are more prominent in the happy than in the angry expressions of five of the six posers used. Interestingly, the happy and angry expressions of the sixth poser, model JJ, see Figure 1, lower panel bottom right, who does not have a toothy smile, were used as stimulus materials by Horstmann and Bauland (2006) and Lipp et al. (2009b). Both studies found evidence for an anger superiority effect.

Taken together the findings of Experiments 1 and 2 as well as those of Horstmann et al. (2012), it appears that the stimulus materials used may be critical in determining whether a happiness or anger superiority effect is observed (see Juth et al., 2005 for a similar argument). Experiment 3 directly investigated the effect of different stimulus materials on visual search for emotional expressions. The faces used in Experiment 3 were drawn from the NimStim database (Tottenham et al., 2009), which offers three degrees of happiness, closed mouth, open mouth, and exuberant and two degrees of anger, closed mouth and open mouth.

Experiment 3

Experiment 3 investigated the effect of using faces expressing different levels of emotion (angry, happy, exuberant) on search performance. Given the detection advantage for open-mouthed angry faces found in Experiment 1 and the advantage for exuberantly happy faces shown by Horstmann et al. (2012), it was predicted that angry faces would be found faster and more efficiently than happy faces, but that exuberantly happy faces would be found faster and more efficiently than both angry and happy faces.

Method

Participants

Fifty-four undergraduate students volunteered participation and provided informed consent. Data from four participants were excluded due to excessive errors (more than 25%) in any one of the three visual search tasks reported here². Of the 50 participants remaining (mean age of 18.4 years; range 17-34; 10 male), 43 were Caucasian, 6 were Asian and 1 was Indigenous Australian.

Apparatus and materials

The experiment was run in the same laboratory as Experiment 1. Pictures of nine male Caucasian faces (models 20, 21, 22, 24, 25, 30, 32, 34 and 37; Tottenham et al., 2009) with neutral, angry, happy, and exuberantly happy expressions (codes CA_C, AN_O, HA_O, and HA_X; see upper panel of Figure 1) served as background and target stimuli. They were set to gray scale and resized to 187 x 240 pixels. Faces were displayed on 17" CRT monitors (1024 x 768 pixels; 85 Hz) in regular matrices of 2, 4, or 9 pictures on a white background.

Design and Procedure

The general procedure was similar to that of Experiment 1. The instruction and response key labels were the same as for the fixed target search of Experiment 1. In each task, participants were presented with two blocks of 48 trials without interruption. Each block comprised 16 trials at each of the set sizes, 2, 4, and 9. Half of the trials at each set size were target trials, i.e., an emotional face was presented in one of the 8 positions on the perimeter of the 3 x 3 matrix, whereas the remaining were non-target trials. The position of faces on the screen was the same as for Experiment 1. Within blocks, trials were presented in a pseudo-random sequence with no more than three trials of the same set size or

² Participants completed two additional fixed target search tasks using the closed mouth versions of the emotional expressions as targets (models HA_C and AN_C). There was no difference in search efficiency for angry and happy targets (angry Mean = 77.95 ms/item, SD = 25.87; happy Mean = 86.31 ms/item, SD = 31.66; $t(49) = 1.72$, $p = 0.092$). A detailed summary of the results is available from the first author upon request.

requiring the same response. Each trial started with a black fixation cross, presented for 500ms in the center of the screen and followed by the search matrix presented for 3000s or until a response was made. The intertrial interval was 1000ms. Task sequence was counterbalanced across participants and preliminary analyses revealed that it did not affect the results. Hence, analyses are pooled across this factor. Scoring, response definition and statistical analysis were the same as in Experiment 1.

Results

Target trials

Figure 4 (upper panel) displays the detection time for happy, angry, and exuberant target faces. As can be seen, search efficiency differed across targets, main effect of emotion, $F(2,48) = 30.28$, $p < .001$, $h_p^2 = .56$. The slope was shallower for exuberant, $M = 24.04$ ms/item, $SD = 2.18$, than for angry target faces, $M = 34.76$ ms/item, $SD = 2.72$, $t(48) = 3.34$, $p < .01$, and shallower for angry than for happy target faces, $M = 43.53$ ms/item, $SD = 2.85$, $t(48) = 4.08$, $p < .01$. Exuberant faces were found faster than angry or happy faces and angry faces were found faster than happy faces, main effects of emotion, $F(2,48) = 13.45$, $p < .001$, $h_p^2 = .36$, however, this pattern differed across set sizes, main effect of set size, $F(2,48) = 146.73$, $p < .001$, $h_p^2 = .86$, emotion x set size interaction, $F(2,46) = 24.22$, $p < .001$, $h_p^2 = .68$. Exuberant targets were found faster than angry targets at set size four, $t(46) = 3.52$, $p < .01$. At set size nine, angry targets were found faster than happy targets, $t(46) = 5.27$, $p < .01$, and exuberant targets were found faster than happy, $t(46) = 11.22$, $p < .01$, and angry targets, $t(46) = 5.95$, $p < .01$; all other $ts < 2.50$.

Number of errors differed across emotions and set size as suggested by main effects of emotion, $F(2,48) = 6.87$, $p = .002$, $h_p^2 = .22$, and set size, $F(2,48) = 15.89$, $p < .001$, $h_p^2 = .40$. More errors were made on trials with happy targets than exuberant targets, $t(48) = 2.83$, $p < .05$ and more errors were

made on trials with a set size of nine than two, $t(48) = 5.10, p < .01$, or four, $t(48) = 2.93, p < .05$; all other $ts < 2.17$.

Non-target trials

As illustrated in the lower panel of Figure 4, search efficiency through neutral face backgrounds differed as a function of target emotion $F(2,48) = 17.31, p < .001, \eta_p^2 = .42$. The search slope was steeper during search for happy targets, $M = 100.90$ ms/item, $SD = 43.96$, than during search for angry, $M = 77.88$ ms/item, $SD = 42.44, t(48) = 5.41, p < .01$, or exuberant faces, $M = 80.48$ ms/item, $SD = 43.65, t(48) = 4.80, p < .01$. No difference was found between angry and exuberant task slopes, $t(48) = 0.61, ns$. Search times seemed slower during search for happy than angry or exuberant faces (see Figure 3, lower panel) in particular at larger set sizes. This was confirmed by main effects of task, $F(2,48) = 7.82, p < .001, \eta_p^2 = .25$, and set size, $F(2,48) = 140.81, p < .001, \eta_p^2 = .85$, and a task x set size interaction, $F(2,46) = 8.44, p < .001, \eta_p^2 = .42$. At set sizes four and nine participants were slower to search for happy targets than angry and exuberant targets, all $t(46) > 3.62, p < .01$. All other $ts < 1.19$.

Participants committed more errors on trials with larger set sizes, main effect of set size, $F(2,48) = 37.50, p < .001, \eta_p^2 = .61$. More errors were made on trials with a set size of nine than two, $t(48) = 3.63, p < .01$, and four, $t(48) = 4.10, p < .01$. No difference was found between trials with set sizes of four and two, $t(48) = 0.47, ns$.

Discussion

Experiment 3 replicated the finding of Experiment 1, in that angry faces were found faster than happy faces, suggesting an anger superiority effect. However, consistent with Horstmann et al. (2012) exuberant faces were detected even faster and more efficiently than angry faces. This is consistent with the happiness superiority effect found in Experiment 2 and reported by D.V. Becker et al. (2011). These results suggest that support for either anger and happiness superiority effects can be found

depending on whether open mouthed happy or exuberantly happy faces are selected as stimuli. This raises the question as to whether this pattern of results reflects on different extents of emotionality expressed by the open mouthed and exuberantly happy faces or other features that are related to the expressions, but not linked to emotionality. Inspection of the normative data provided by Tottenham et al. (2009) for the different faces can add an initial insight.

Among other information, Tottenham et al. (2009) report on the extent to which the faces provided in the database are correctly identified as expressing the intended target emotion (% correct) and the reliability of these judgments. For the nine posers employed in the present study, open-mouthed angry faces were labeled as angry on 90% of trials with an average reliability of .90. Open-mouthed happy expressions are labeled as happy on 97% of the trials with an average reliability of 0.96. Exuberantly happy faces were labeled as happy on 85% of the trials with an average reliability of 0.85. This suggests that exuberantly happy faces may not be perceived as happy to the extent that are open mouthed happy faces. However, to confirm whether this pattern of results would emerge in a sample comparable to that used in Experiment 3, Experiment 3a was conducted.

Experiment 3a

Experiment 3a was an internet based ratings study in which participants were presented with the 18 open mouthed happy and angry expressions, the nine exuberant happy expressions and the nine neutral expressions used in Experiment 3. Participants were asked to rate each stimulus for the intensity of the emotion expressed (Likert scale 1-100), as well as on arousal (Likert scale 1-7) and pleasantness (Likert scale 1-7). Moreover, participants also classified each face as expressing neutrality, mania, exuberance, happiness, surprise, anger or rage.

Twenty participants, aged 25 years (range 17-51), 4 males, completed the task. Happy expressions were rated as less intense, $M = 57.64$, $SD = 10.15$, than angry, $M = 75.29$, $SD = 7.76$, or

exuberant expressions, $M = 73.35$, $SD = 6.80$, $F(2,18) = 32.15$, $p < .001$, $h_p^2 = .781$, both $t(18) > 8.0$, $p < .001$, and as less arousing, $F(2,18) = 23.57$, $p < .001$, $h_p^2 = .724$, happy: $M = 4.08$, $SD = 0.55$, angry: $M = 5.06$, $SD = 0.64$, exuberant: $M = 5.07$, $SD = 0.52$, both $t(18) > 5.73$, $p < .01$. Happy, $M = 2.69$, $SD = 0.50$, and exuberant expressions, $M = 3.09$, $SD = 0.62$, were rated as more pleasant than angry ones, $M = 5.84$, $SD = 0.51$, $F(2,18) = 140.63$, $p < .001$, $h_p^2 = .940$, both $t(18) > 15.0$, $p < .001$. Happy faces were most commonly described as expressing happiness (171 out of 180 responses) and angry faces were mostly described as expressing anger or rage (160 out of 180 responses). Exuberant expressions were less reliably categorized, with participants labeling exuberant faces as exuberant, happy, or surprised (68, 42, and 45 out of 180 respectively; 135 out of 180 responses exuberant or happy).

Given that expressions that differed in search efficiency did not consistently differ in emotional intensity, arousal or pleasantness, these results fail to provide support for the notion that differences in perceived emotionality account for differences in search efficiency. The classification data also suggest that perceived emotional expression does not explain differences in search efficiency: Consistent with the norm data published by Tottenham et al. (2009), exuberant expressions, which were found most efficiently, were less reliably categorized as happy than open mouthed happy expressions.

General Discussion

The current study was designed to investigate inconsistencies in previous literature on visual search for emotional faces. Some previous research has suggested that angry faces are found faster in neutral or emotional crowds than are other emotions (Frischen et al., 2008), whereas other research claims that happy faces are found fastest and most efficiently (D.V. Becker et al., 2011). Experiment 1 investigated whether these discrepant patterns of results reflect on differences in search strategies employed in fixed and variable target searches. Participants were asked to search arrays of neutral faces for either angry or happy targets (fixed target searches) or for emotional targets (variable target

searches). Consistent with earlier work (e.g., Lipp et al., 2009a,b; Horstmann & Bauland, 2006), Experiment 1 revealed an anger superiority effect during the variable target search. In the fixed target search, angry faces were found faster, but not more efficiently than happy faces. These results indicating that differences in search strategy cannot resolve the inconsistent pattern of results reported previously.

Given that Experiment 1 revealed an anger superiority effect, Experiment 2 aimed to replicate the happiness superiority effect reported by D.V. Becker et al. (2011, Experiment 1A) and succeeded. Experiment 1 had employed open mouthed emotional and neutral faces drawn from the NimStim database (Tottenham et al., 2009) whereas Experiment 2 used faces from the Pictures of Facial Affect database (Ekman & Friesen, 1976). Taken together with a recent report of a happiness superiority effect obtained with exuberantly happy faces derived from the NimStim database (Horstmann et al., 2012), these results suggest that the stimulus set used, and the low-level stimulus features inherent in them, may determine whether an anger superiority effect or a happiness superiority effect emerges. The effect of different stimulus materials on the search efficiency for emotional faces was further explored in Experiment 3, which employed three sets of target stimuli from the NimStim database, open mouthed angry and happy and exuberantly happy faces, in fixed target searches. These experiments implemented the criteria proposed by D.V. Becker et al. (2011) for the design of visual search studies involving emotional faces. Nevertheless, and replicating Experiment 1, more efficient detection of angry than of happy faces was revealed. However, detection of exuberantly happy faces was even more efficient than was the detection of angry faces. This suggests that the use of different stimulus materials will determine whether an anger or a happiness superiority effect is found.

Given that the pattern of results observed in visual search for emotional faces seems to depend largely on the stimulus materials used, the question emerges as to whether it is indeed the expressed

emotion that drives the results, or some low-level visual differences in the stimuli. The labeling data and ratings of emotional intensity, arousal, and pleasantness from Experiment 3a did not provide a pattern of results that easily mapped on that obtained for differences in search efficiency. Although based on self-report data, this outcome brings the interpretation of previous visual search studies into question and suggests that an emotional account for their results is inadequate.

Search efficiency is increased if target and distractor sets are homogeneous and target-distractor difference is high (Duncan & Humphreys, 1989), thus differences in target-distractor similarity across stimulus sets may provide an explanation for the inconsistent findings. The happy faces, used in Experiment 1 and 3 (NimStim database; Tottenham et al., 2009), appear more similar to the neutral distractors than either the angry faces (Experiments 1 and 3) or exuberant faces (Experiment 3). Conversely, the happy faces used in Experiment 2 (Pictures of Facial Affect database; Ekman & Friesen, 1976) seem to differ to a greater extent from the neutral distractors than do the angry faces. Thus, and under the caveat that these assessments are a-posteriori, the question emerges whether visual search is the most appropriate method to assess attentional biases to facial expression of emotions or whether other paradigms, like categorization, may permit a less biased assessment (Leppänen & Hietanen, 2003, D. V. Becker et al., 2012; but see Craig, Mallan, & Lipp, in press). It is tempting to assume that differences in search efficiencies for emotional faces reflect evolved mechanisms for detection threat (Öhman, Soares, Juth, Lindström, & Esteves, 2012) or for positive affordance (D. V. Becker et al., 2011). However, the current data strongly suggest that past differences in search efficiencies reported in the literature reflect on lower-level stimulus properties that can also lead to differences in search efficiency.

In a visual search task, participants are required to detect targets that are defined according to a particular criterion. However, complex stimulus materials such as faces may offer shortcuts that can

make the search task easier. Rather than searching for differences in expression, participants may search for bright spots or darker areas. In the language of experimental design, these shortcuts are labeled confounds. Two types of confounds have been considered to drive performance in search tasks with emotional faces, emotional expression related and emotional expression unrelated confounds. Emotional expression unrelated confounds tend to be simple low-level visual features such as the black blotch at the base of the angry faces, which was shown by Purcell, Stewart and Skov (1996) to account for Hansen and Hansen's (1989) initial finding that angry faces pop out of crowds. Emotional expression related confounds refer to components of facial expressions that are important in conveying the emotion, but may also influence search performance (Frischen et al., 2008). These include features such as the raised eyebrows, wide-open eyes or mouths with obvious displays of teeth that can influence search performance as low-level perceptual features rather than as part of an emotional expression (Frischen et al., 2008).

Most previous research has failed to control the low-level effects of emotional expression related confounds in visual search and thus, cannot separate their effects from those of the emotional expression. One approach to reduce the susceptibility of visual search to emotional expression related confounds could be to employ stimuli that are equated for their perceptual distinctiveness from the neutral expressions, while still retaining the emotional meaning. This may be achieved through the use of a calibration procedure in which emotional face morphs and neutral images are presented to determine the level of morphing at which discrimination performance is equal for happy and angry expressions (e.g., 80% correct identification at a presentation duration of 1 s; Arnold & Lipp, 2011). These morphs could then be used as targets in visual search.

The present study was designed to clarify previous contradictory reports of anger and happiness superiority effects in visual search for emotional expressions. Together, the data presented here

demonstrate that whether happy or angry target faces are detected faster appears to depend on emotional expression related confounds which differ across stimulus sets selected from different face databases rather than the valence or the intensity of the emotional expression. They suggest that the question of anger versus happiness superiority may not be solved with a research strategy that samples stimulus materials from pre-existing face databases that were not designed to provide stimuli for use in visual search tasks.

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Figure Captions

Figure 1: Example stimuli used. The upper panel shows the neutral, closed mouth happy, closed mouth angry, open mouth happy, open mouth angry, and exuberantly happy expressions for one poser from the NimStim database (Tottenham et al., 2009). Note: this model was not used in the current experiments, but publication of these images is permitted. The lower panel shows the images from the Ekman and Friesen (1976) Pictures of Facial Affect database used in Experiment 2. We would like to thank Paul Ekman for permission to reproduce the images.

Figure 2: Target detection times on target trials (upper panels) and search times on No Target trials (lower panels) in the variable (left panels) and fixed (right panels) target searches of Experiment 1 as a function of set size. Lines represent search slopes and linear functions are displayed.

Figure 3: Target detection times on target trials (upper panel) and search times on No Target trials (lower panel) in Experiment 2 as a function of set size. Lines represent search slopes and linear functions are displayed.

Figure 4: Target detection times on target trials (upper panel) and search times on No Target trials (lower panel) in Experiment 3 as a function of set size. Lines represent search slopes and linear functions are displayed.







