The effect of face inversion on the detection of emotional faces in visual search

Ruth A. Savage & Ottmar V. Lipp

School of Psychology, University of Queensland, Australia

Running Head:

Face inversion and visual search

Addresses for correspondence:

Ruth A. Savage, School of Psychology, University of Queensland, QLD, 4072, Australia. Email: ruth.savage@uqconnect.edu.au

Ottmar V. Lipp, PhD, School of Psychology, University of Queensland, QLD, 4072, Australia. Email: o.lipp@uq.edu.au

Acknowledgments:

This work was supported by Grant DP110100460 from the Australian Research Council and by an Australian Postgraduate Award to RAS.

Abstract

Previous evidence is inconsistent as to whether face inversion attenuates emotion detection advantages in visual search, suggesting either that holistic processing is utilized (Fox & Damjanovic, 2006) or not (Lipp, Price, & Tellegen, 2009). Extending prior research, Experiments 1 and 2 employed search tasks with different posers and varying set size. Consistent with Fox and Damjanovic, both experiments demonstrated attenuation of faster detection of angry faces by inversion, regardless of array size. However, replicating the methods of Lipp et al., Experiment 3 yielded no effect of inversion on emotion detection. These findings seem to suggest that emotional expression detection in visual search is mediated by holistic face processing under some conditions, e.g., when multiple posers are used. However, when task design permits, e.g., when only one poser is used, participants may engage simpler, feature based search strategies to detect an emotional target face.

Key words: emotional expressions, face processing, visual search, face inversion, anger superiority effect, happiness superiority effect

Faces display many important signals including expressions of emotion and intentions, rendering them highly important in interpersonal communication. So important in fact, that claims have been made that the ability to determine the emotional state of others quickly may have survival value in the same way that fast detection of threat in one's immediate environment may be evolutionarily advantageous (Hansen & Hansen, 1988; Öhman, Soares, Juth, Lindström, & Esteves, 2012). Interest in the processes that may mediate such a speeded detection of emotional expressions in our environment has stimulated a plethora of studies using a number of different experimental procedures among which visual search features prominently.

Early investigations using visual search suggested that when presented within crowds of faces, angry faces were detected faster than faces displaying other emotions (Hansen & Hansen, 1988; Lipp, Price, & Tellegen, 2009; Fox & Damjanovic, 2006). Hansen and Hansen (1988) reported that angry faces 'pop-out' of crowds, such that they were found equally quickly regardless of the number of distractor faces presented. This initial finding however, was subsequently attributed to a black patch at the base of the single angry face used, possibly indicating that search performance was driven by this low-level perceptual confound (Purcell, Stewart, & Skov, 1996). Other investigations however, which did not suffer from such a confound, support the notion that angry faces are detected faster, a pattern that has been interpreted as evidence for preferential detection of threat related cues in our environment (Frischen, Eastwood & Smilek, 2008; Öhman et al., 2012).

More recent research has begun to suggest that the effect may instead go in the opposite direction, such that happy faces may be detected faster than angry faces (Juth, Lundqvist, Karlsson, & Öhman, 2005; D. V. Becker, Anderson, Mortensen, Neufeld, & Neel, 2011). Explanations for happy face detection advantages range from attributions to a process similar to the frequency effect seen with familiar words, positive affordances, or to evolutionary selection pressures favouring facial displays of happiness (D. V. Becker et al., 2011). These explanations, however, are difficult to verify using a typical visual search task due to the ease with which other factors, such as low-level perceptual confounds (i.e., Purcell et al., 1996) or expression-related perceptual confounds (i.e., Horstmann et al., 2012), influence search performance. The disparate nature of existing reports seems to suggest that alternative explanations beyond those of survival value or positive affordances may be required. In line with Purcell et al. (1996), suggestions have been made that current mixed findings may be the result of the specific stimulus sets used and low-level perceptual differences between stimuli (D. V. Becker et al., 2011; S. I. Becker, Horstmann, & Remmington, 2011; Savage et al., 2013).

Given that low-level perceptual confounds may significantly influence search performance, D. V. Becker et al. (2011) have put forward a series of recommendations for the improvement of current visual search methodologies used in the study of emotional expressions. Firstly, D. V. Becker et al. advocate the variation of set sizes (number of faces in the array), so that search slopes may be calculated. Search slopes are a measure of search time relative to the number of distractor stimuli (background faces) in the array and are used as an index of the efficiency of search for a particular target. Secondly, D. V. Becker et al. recommend that neutral background faces should be used, as opposed to searching for an angry face among happy faces and vice versa, as this controls for background related confounds (i.e., un-confounds effects of target detection vs. search through distractor faces). D. V. Becker et al. also suggest that participants should only be required to search for one expression at a time, i.e., search for angry faces, as opposed to searching for any discrepant emotion. Finally, D. V. Becker et al. advocate the importance of eliminating low-level confounds as these can have a profound effect on the pattern of results obtained. Demonstrations such as those by Purcell et al. (1996) highlight the susceptibility of visual search to low-level perceptual differences between stimuli and reinforce the importance of attempts to control for these confounds. Although this recommendation is arguably one of the most obvious, it is potentially the most difficult to implement as expression-related confounds, i.e., facial features such as exposed teeth or wide-open eyes, that are inherent to the emotional expression, may also affect visual search (Frischen et al., 2008). D. V. Becker et al. suggest that the effect of low-level perceptual confounds can be reduced through the use of heterogeneous background displays, such that each of the neutral distractor faces are portrayed by a different individual.

The recommendations by D. V. Becker et al. (2011) to improve visual search methodology used to assess the processing of facial expressions of emotion were motivated by the concern that emotion detection may reflect on the processing of particular facial features rather than of the entire expression. However, more detailed consideration of the manner in which faces and facial expressions are processed may suggest that the impact of emotion-related facial features in visual search may be smaller than previously thought. There is strong evidence in the face recognition literature suggesting that faces are processed holistically, that is, they are perceived and represented as a whole, rather than featurally, based on the sum of the individual features that make up the face (Tanaka & Farah, 1993). Holistic processing was initially thought to include only information about the relative spacing of major facial features, but recent research has suggested that it may also include information regarding aspects such as the shape, size, or colour of these features (McKone & Yovel, 2009). As a result of holistic processing, the individual parts of a face (i.e. eyes, nose, mouth) are more difficult to recognise than the face as a whole (Tanaka & Farah, 1993). Evidence for holistic processing can be found in a number of different phenomena, such as the face composite and inversion effects. The face composite effect describes the finding that the upper and lower halves of two different faces are harder to recognise when presented aligned than when presented misaligned (Young, Hellawell, & Hay, 1987). Misaligning the two halves interrupts holistic processing of the face, making it easier to recognise each half. Similarly, face recognition is also impaired when faces are inverted (Yin, 1969). Research suggests that inversion of faces disrupts holistic processing more than it does featural processing because it impairs sensitivity to differences in relative spacing between features more than it changes the features themselves (Farah, Tanaka, & Drain, 1995; McKone & Yovel, 2009). These methods have also been used in order to investigate the processing of emotional expressions, with reports of impaired emotion recognition with aligned composite emotional faces (Calder, Young, Keane, & Dean, 2000), and poorer emotion recognition when faces are inverted (McKelvie, 1995). These findings suggest that emotion recognition is reliant on holistic face processing rather than driven by the detection of critical features.

Face inversion has also been used within the visual search paradigm in order to determine whether faster detection of a particular emotional expression reflects on their holistic processing or the detection of distinctive visual features. To date, these investigations have provided inconsistent results. Studies using schematic faces have shown that detection advantages that emerge with upright faces can either disappear when faces were inverted (Fox et al., 2000) or remain unaffected (Öhman, Lundqvist, & Esteves, 2001; Lipp et al., 2009). Using photographic faces, Fox and Damjanovic (2006) report that the detection advantage for angry faces presented among emotional and neutral backgrounds which was evident when faces were presented upright disappeared after face inversion. Given our current understanding of inversion and its ability to impair holistic processing, this finding endorses the view that processing of emotional expressions in visual search is holistic and suggests that faster detection of anger reflects on the emotional expression as a whole rather than on the detection of some low-level perceptual feature. In contrast, Williams, Moss, Bradshaw, and Mattingley (2005) and Lipp et al. (2009) reported detection advantages for emotional targets that survived inversion, a pattern of result consistent with a feature-based account of emotional expression processing in visual search. Clarification of these inconsistent findings is important, as it will enhance our understanding of the manner in which emotional expressions are processed and, by extension, speak to the utility of visual search paradigms in research on the processing of emotional faces. Feature-based accounts will find it difficult to explain a reduction of emotion effects in visual search with inverted faces, regardless of whether they manifest as anger or happiness superiority.

The current study aimed to resolve the inconsistent findings reported by Fox and Damjanovic (2006) and Lipp et al. (2009) using visual search procedures designed in reference to the recommendations made by D. V. Becker et al. (2011). We focussed on these two studies as they provide evidence for either holistic or feature-based processing of emotional expressions in visual search using experimental procedures that were quite similar, differing only in a number of procedural details, which renders them ideal for comparison. Fox and Damjanovic (2006) and Lipp et al. (2009) used tasks that required search for a discrepant expression (variable target search), meaning that participants were to search for both angry and happy faces simultaneously. The recommendations of D. V. Becker et al. (2011) warn against this, however, previous work in our laboratory (Savage et al., 2013) directly investigated the effects of search requirements on performance and found no significant differences between fixed (search for angry/happy expression in different task blocks) and variable (search for a different expression) target searches. Thus, the task requirements as used by Fox and Damjanovic and Lipp et al. were retained in the experiments presented here.

Lipp et al. (2009) and Fox and Damjanovic (2006) both drew their stimuli from the Ekman and Friesen Pictures of Facial Affect database (Ekman & Friesen, 1976) and both used a single model in each trial, such that target and background expressions were posed by the same person. Fox and Damjanovic (2006) varied models across trials whereas Lipp et al. varied models across experiments. This procedure is not consistent with the recommendation of D. V. Becker et al. (2011) that background faces should not be homogenous which was taken into consideration in the design of Experiments 1 and 2, by using nine different models.

The studies by Lipp et al. (2009) and Fox and Damjanovic (2006) differ in a number of ways including the array sizes, presentation times, and trial types used. Fox and Damjanovic used arrays of four faces only, whereas Lipp et al. used arrays of nine. This is again inconsistent with the recommendations of D. V. Becker et al. (2011) as neither study varied array size. Presentation times for these arrays were shorter in Fox and Damjanovic (800ms) than in Lipp et al. (until the participant made a response). Lipp et al. presented four different target expressions (anger, happiness, fear, and sadness) among neutral backgrounds whereas non-target trials consisted only of neutral faces. In contrast, Fox and Damjanovic presented angry and happy target faces among angry, happy and neutral backgrounds, along with non-target trials of four neutral, four angry or four happy faces.

Array size was varied in Experiment 1 of the current study in an attempt to investigate whether the difference in array size may explain the contradictory results reported by Fox and Damjanovic (2006) and Lipp et al. (2009). Participants completed four search tasks. Two tasks utilised arrays of two and four faces, whereas the second two utilised arrays of four and nine faces. Each of these two tasks was presented once with upright faces, and once with inverted faces. Using only four face arrays, Fox and Damjanovic found that faster detection of angry than happy faces disappeared with inversion, and Lipp et al., using arrays of nine faces, found that inversion did not attenuate the differential detection of emotional expressions. Given this inconsistency, it was predicted that when small array sizes were used (two and four faces) faster detection of angry faces would be apparent in the upright, but not inverted tasks, however, when larger array sizes were used (four and nine faces) faster detection of angry faces would be evident among both upright and inverted faces.

Experiment 1

Method

Participants

Forty-three undergraduate psychology students from the University of Queensland participated in this study in return for course credit. Data from 13 participants were excluded from analysis due to excessive errors (more than 25% in any of the four tasks). Of the 30 participants remaining, 20 were female (*M* = 21.35 years, range = 17 to 51 years).

Apparatus and materials

The experimental tasks were displayed on 17-inch CRT monitors, with a resolution of 1024 x 768 pixels and a refresh rate of 85 Hz. 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 faces, obtained from the NimStim database (Tottenham et al., 2009), all of which were male. The set included nine neutral faces and eight each of happy and angry faces (models 20, 22, 24, 25, 30, 32, 34, 37 in poses CA, AN_O, and HA_O and model 21 contributed only CA). The images were edited so that they were grayscale and 187 x 240 pixels in size. The images were presented upright or inverted in the respective task conditions.

Procedure

Participants were tested in a computer lab with six computers and each provided informed consent before the experiment began. Instructions were displayed onscreen before the commencement of each task.

The experiment consisted of four tasks, two search tasks using upright faces and two using inverted faces. For each orientation one task used arrays of two and four pictures and the other used arrays of four and nine. Participants were instructed to determine whether all the faces presented expressed the same emotion or if a different expression was present. The right shift key was used for target responses and was labelled ‘different’; the left shift key was used for non-target trial responses and was labelled ‘same’.

Target trials consisted of one target emotional face (angry or happy) presented among 1, 3 or 8 neutral faces. Non-target trials comprised only neutral faces. The faces were presented on the screen in a 3 x 3 grid, with targets appearing only in one of the 8 positions around the edge of the display. Positions that were not occupied by a target or non-target face remained white.

Each task consisted of 192 trials, broken down into 3 blocks of trials presented consecutively. In each of these blocks, the same 64 trials were presented in a different, pseudo-random sequence. Randomisation was constrained such that no more than three consecutive trials were presented of the same array size or requiring the same target/non-target response. Different pseudo-random trial sequences were created for the tasks with arrays of two and four and the tasks with arrays four and nine, but the same trial sequences for these two tasks were used across the inverted and upright tasks, such that the only difference between the upright and inverted tasks was the orientation of the faces presented.

The 64 trials in each block comprised 32 target trials, including 8 trials for each target emotion (happy and angry) at each array size (i.e., two and four or four and nine). These were matched with 16 non-target trials for each array size. This resulted in each individual being presented once as the target for each emotion during each block. The order of presentation of the tasks was counterbalanced.

At the beginning of each trial a black fixation cross was presented in the middle of the screen for 500 ms. The stimuli were then presented for 3,000 ms or until the participant made a response. An intertrial interval of 500 ms was used.

Scoring, response definition and statistical analysis

Prior to analysis, errors were defined as incorrect responses or failure to respond within 3,000 ms of the onset of the stimulus. Outliers, defined as ±3 *SD*s from an individual's mean, or any response time less than 100 ms were also classified as errors. Follow-up analyses of significant interactions were performed with two-tailed t-tests using Greenhouse-Geisser mean square error values. A Bonferroni adjustment was used to maintain an α level of .05 for post-hoc comparisons.

Results

Target Trials

As can be seen in Figure 1, angry faces were found faster than happy faces both when faces were upright and when inverted, although the effect was larger for upright faces. Angry faces were also found faster than happy faces in both the task with arrays of two and four, and four and nine. A 2 (orientation: inverted vs. upright) x 2 (task: array sizes 2 & 4 vs. 4 & 9) x 2 (emotion: angry vs. happy) x 2 (array size: small vs. large) within-subjects ANOVA was conducted. The hypothesis predicted an orientation x task x emotion interaction; this interaction however was non-significant, $F(1,29) = 2.90$, $p = .099$, = .09. Instead, an orientation x emotion interaction emerged, $F(1,29) = 6.02$, $p = .02$, = .17, such that angry targets were found faster than happy targets, both among upright, $t(29) = 7.64$, $p < .001$, and inverted faces, $t(29) = 4.63$, $p < .001$. This effect was, however, larger among upright than inverted faces $t(29) = 3.00$, $p = .005$. Additionally, there were main effects of orientation, $F(1,29) = 9.10$, $p = .005$, = .24, task, $F(1,29) = 60.34$, p =< .001, = .68, emotion, $F(1,29) = 41.08$, $p < .001$, = .59, and size $F(1,29) = 188.46$, $p < .001$, = .87. Orientation x size, $F(1,29) = 6.49$, $p = .016$, = .18, task x emotion, $F(1,29) = 6.60$, $p = .016$, = .19 and emotion x size, $F(1,29) = 11.41$, $p = .002$, = .28, interactions were also apparent, along with an orientation x task x size interaction, $F(1,29) = 5.08$, $p = .032$, = .15. Response times were faster for smaller arrays in both the task with arrays of two and four, upright $t(29) = 8.83$, $p < .001$, inverted $t(29) = 14.55$, $p < .001$ and four and nine, upright $t(29) = 12.11$, $p < .001$, inverted, $t(29) = 13.32$, $p < .001$. However, the difference between small and large arrays in each task was only significant for the upright orientation, $t(29) = 3.29$, $p = .003$, not the inverted orientation, $t(29) = 1.23$, $p = .229$. On trials with arrays of four faces, detection times were faster in the small array size task than the large array size task for upright faces, $t(29) = 4.10$, $p < .001$, but after controlling for multiple comparisons, there was no difference for inverted faces, $t(22) = 2.68$, $p = .012$. The task x emotion x size interaction also reached significance, $F(1,29) = 7.27$, $p = .012$, = .20. Angry faces were found faster than happy faces for arrays of two faces, $t(29) = 5.42$, $p < .001$, and four faces, $t(29) = 5.81$, $p < .001$, in the small array size task, and for arrays of four, $t(29) = 5.49$, $p < .001$, and nine faces, $t(29) = 11.27$, $p < .001$, in the large array size task. Although, the difference between array sizes was only significant for the large array size task, $t(29) = 5.77$, $p < .001$, not the small array size task, $t(29) = 0.39$, $p = .699$.. All other Fs < 1.71, ps > .201.

Insert Figure 1 about here

Happy targets were missed more often than angry targets and more errors were made in the task with arrays of four and nine than the task with arrays of two and four. Happy targets were more likely to be missed in the task with arrays of four and nine than the task with arrays of two and four, but there was no difference for the angry targets. Errors were subjected to the same analysis as response times, revealing main effects of size, $F(1,29) = 14.99$, $p = .001$, = .34, task, $F(1,29) =$

8.17, p = .008, = .22, and emotion, F(1,29) = 49.01, p < .001, = .63. The effect of orientation just missed significance, F(1,29) = 4.16, p = .051, = .13. An interaction between emotion x size emerged, F(1,29) = 5.46, p = .027, = .16, with more errors to happy than angry targets for small, t(29) = 8.29, p < .001, and large arrays, t(29) = 10.96, p < .001, and more errors on large arrays than small arrays for trials with happy target faces, t(29) = 4.78, p < .001, but after controlling for multiple comparisons, no difference between array sizes emerged for angry target faces, t(29) = 2.12, p = .043. The task x emotion interaction approached significance, F(1,29) = 3.58, p = .068, = .11, as did the orientation x task x emotion x size interaction, F(1,29) = 3.49, p = .072, = .11. No other interactions involving emotion or orientation approached significance. All other Fs < 2.27, ps > .143.

Non-target trials

Non-target trial response times appeared to be longer when searching inverted faces than upright faces, longer in the task with arrays four and nine than the task with arrays two and four, and longer for trials with larger arrays than those with smaller arrays (see Figure 2). This was supported by a 2 (orientation: upright vs. inverted) x 2 (task: array sizes 2 & 4 vs. 4 & 9) x 2 (size: small vs. large) within-subjects ANOVA, revealing main effects for orientation, F(1,29) = 7.61, p = .010, = .21, task, F(1,29) = 101.22, p < .001, = .78, size, F(1,29) = 181.81, p < .001, = .86, and a task x size interaction, F(1,29) =14.30, p = .001, = .33. Response times were faster for the trials with arrays of two faces than four faces in the small array size task, t(29) =11.69, p < .001. Response times were also faster for trials with arrays of four than nine faces in the large array size task, t(29) =12.57, p < .001. The difference between the small and large arrays was greater for the task with arrays of four and nine than the task with arrays of two and four, t(29) = 5.35, p < .001. It is also worth noting that response times were slower for trials with set size four in the task with arrays four and nine, than the task with two and four, t(29) = 3.32, p = .002. The next largest interaction was the inversion x task x size interaction, F(1,29) = 3.81, p = .061, = .12. All other Fs < .22, ps > .645

Insert Figure 2 about here

Fewer errors were made when searching small arrays than large arrays, main effect of size, $F(1,29) = 24.22$, $p < .001$, = .50. The next largest interaction was the task x size interaction, $F(1,29) = 3.71$, $p = .064$, = .11. All other Fs < 3.10, ps < .089.

Discussion

Analysis of Experiment 1 revealed faster detection of angry than happy faces regardless of inversion, although this difference was larger for upright than inverted faces. No difference in the overall pattern was found between the task with arrays of two and four faces, and the task with arrays of four and nine faces. This detection advantage for angry faces is consistent with prior reports (Fox & Damjanovic, 2006; Frischen et al., 2008; Lipp et al., 2009; Savage et al. 2013). Given that the anger detection advantage was larger for upright than inverted faces, the current results support the findings of Fox and Damjanovic (2006) who also reported a significant effect of inversion. Fox and Damjanovic, however, report no effect of emotion for inverted faces, whereas an emotion advantage emerged even when faces were inverted in the present study. This could be an indication that processing of emotional expressions relies on a combination of holistic and featural processing, or may be a reflection of the limited ability of inversion to impair holistic processing. However, given that the detection advantage for angry faces is significantly reduced by inversion it can be concluded that the current pattern of results reflects to some extent on the holistic processing of facial expressions. The fact that the two sets of tasks with differing array sizes yielded a similar pattern of results suggests that differences in the number of faces displayed cannot account for the different findings reported by Fox and Damjanovic (2006) and Lipp et al. (2009).

Experiment 2 aimed to further investigate the effect of inversion on emotion detection found in Experiment 1. In Experiment 1 the variation of array sizes between tasks did not change the pattern of emotion detection. Thus, Experiment 2 aimed to replicate the effect of inversion on the detection advantage for angry faces using a more common task set up. The tasks were designed to be consistent with prior recommendations by D. V. Becker et al. (2011). Given that the use of only two array sizes per task, as in Experiment 1, limits the assessment of search efficiencies, Experiment 2 include three different array sizes within a single task. Participants completed two search tasks, one with upright, and one with inverted faces, with both tasks including face arrays with set sizes two, four, and nine.

Experiment 2

Method

Participants

Twenty-seven participants completed the experiment, data from nine were excluded due to high error rates (>25% in either task). Of the 18 remaining, four were male and the mean age was 18.61 years (range = 17 years - 23 years).

Apparatus, materials and procedure

Experiment 2 used the same experimental stimuli and general procedure as did Experiment 1**.** The experiment consisted of two tasks; one using upright faces and the other using inverted faces. Target trials consisted of one target emotional face (angry or happy) presented among 1, 3 or 8 neutral faces. Non-target trials comprised all neutral faces. The faces were presented on the screen in a 3 x 3 grid, with targets appearing only in one of the 8 positions around the edge of the display. Positions that were not occupied by a target or non-target face remained white.

Each task consisted of 192 trials, broken down into 2 blocks of trials presented consecutively. In each of these blocks, the same 96 trials were presented in a different, pseudo-random sequence with the same randomisation constraints as Experiment 1. The same trial sequences were used across the inverted and upright tasks, such that the only difference between the upright and inverted tasks was the orientation of the faces presented. The 96 trials in each block comprised 48 target trials, including 8 trials for each target emotion (happy and angry) at each array size (two, four and nine). These were matched with 16 non-target trials for each array size. The order of presentation of the tasks was counterbalanced.

At the beginning of each trial a black fixation cross was presented in the middle of the screen for 500 ms. The stimuli were then presented for 3,000 ms or until the participant made a response. An intertrial interval of 500 ms was used. Scoring, response definition and analysis were the same as for Experiment 1.

Results

Target trials

Upright angry faces were found faster than upright happy faces, but there was no difference for inverted faces (see figure 3). A 2 (orientation) x 2 (emotion) x 3 (size) ANOVA was conducted, revealing a main effect of size, $F(1,16) = 80.54$, $p < .001$,   = .91, and inversion x emotion, $F(1,17) = 12.43$, $p = .003$,   = .42, and inversion x size, $F(1,16) = 7.07$, $p = .006$,   = .47, interactions. Participants responded faster to angry than happy target trials for upright, $t(17) = 2.89$, $p = .010$, but not inverted faces, $t(17) =1.18$, $p = .254$. Response times were faster during the upright task than the inverted task for arrays of four faces, $t(16) = 4.73$, $p < .001$, but not nine, $t(16) = 1.03$, $p = .318$, or two, $t(16) = .28$, $p = .783$. The main effect of emotion approached significance, $F(1,17) = 3.64$, $p = .074$,   = .17. Other Fs < 1.75, ps > .206.

Insert Figure 3 about here

Similar analysis of the errors revealed main effects of orientation, $F(1,17) = 46.02$, $p < .001$,   = .73, emotion, $F(1,17) = 14.83$, $p = .001$,   = .47, and size, $F(1,16) = 16.95$, $p < .001$,   = .68, along with interactions between orientation and emotion, $F(1,17) = 39.19$, $p < .001$,   = .70, orientation and size, $F(1,16) = 4.60$, $p = .026$,   = .37, and emotion and size, $F(1,16) = 13.70$, $p < .001$,   = .63. No orientation x emotion x size interaction was evident, $F(1,16) = 1.68$, $p = .218$,   = .17. Angry targets were missed more often than happy targets in the inverted task, $t(17) = 4.99$, $p < .001$, but after controlling for multiple comparisons no difference emerged between the emotions in the upright task, $t(17) = 2.24$, $p = .039$. More errors were made in the inverted than in the upright task for arrays of four, $t(16) = 5.42$, $p < .001$, and nine faces, $t(16) = 3.61$, $p = .002$, but not two faces, $t(16) = 2.08$, $p = .054$. Angry targets were missed more often than happy targets when presented in arrays of four faces, *t*(16) = 5.22, *p* < .001, but not two, *t*(16) = .11, *p* = .914, or nine, *t*(16) = .42, *p* = .680.

A 2 (task) x 2 (emotion) ANOVA analysis of the search slopes produced no significant results, *F*s < 3.04, *p*s >.100 (Upright Angry targets: Mean = 23.44 ms/item, SD = 13.43; upright Happy targets: Mean = 29.94 ms/item, SD = 18.02; Inverted Angry targets: Mean = 27.46 ms/item, SD = 14.59; Inverted Happy targets: Mean = 24.09 ms/item, SD = 11.55).

Non-target trials

Mean reaction time from non-target trials can be seen in Figure 4. A 2 (orientation) x 3 (size) within-subjects ANOVA revealed a main effect of size, *F*(1,16) = 109.30, *p* < .001, = 93. Response times were faster to arrays of two than four, *t*(16) = 6.12, *p* < .001, and nine faces, *t*(16) = 13.49, *p* < .001, and faster to arrays of four than nine, *t*(16) = 7.37, *p* < .001. Other *F*s < 2.40, *p* > .124.

Insert Figure 4 about here

A similar pattern emerged in the analysis of the errors, main effect of size, *F*(1,16) = 15.63, *p* < .001, = 66. More errors were made to arrays of nine than two, *t*(16) = 5.63, *p* < .001, and four faces, *t*(16) = 4.59, *p* < .001, but no difference emerged between arrays of two and four, *t*(16) = 1.04, *p* = .314. Other *F*s < 2.37, *p* > .122.

Search slopes for the non-target trials (upright *M* = 69.03 ms/item, *SD* = 26.45; inverted *M* = 64.85 ms/item, *SD* = 21.68) were not significantly different, *t*(17) = .88, *p* = .391.

Discussion

As in Experiment 1, angry faces were again found faster than happy faces, although this effect was only apparent for upright faces. No difference emerged between angry and happy targets for inverted faces. We replicate the inversion effect reported by Fox and Damjanovic (2006) across the first two experiments, which may indicate holistic processing of emotional expressions in visual search. However, the current results are in contrast to those of Lipp et al. (2009) who report no effect in face inversion. Experiment 3 aimed to replicate Lipp et al., Experiment 2.

Experiment 3

Method

Participants

Participants included 52 undergraduate psychology students. Data from two participants were removed due to high error rates (>25% errors in either task). Of the 50 remaining, 14 were male (*M* = 18.57, range = 17 years to 25 years).

Apparatus and materials

Experiment 3 was conducted in the same lab as the previous experiments. Five images of a female model displaying angry, happy, sad, fearful and neutral expression, taken from the Ekman and Friesen Pictures of Facial Affect database (1976) were used in this experiment (Images 48, 49, 51, 53, and 56). These images were edited so that they were 260 x 195 pixels in size.

Procedure

Participants completed two tasks, in which they were instructed to determine whether all the faces displayed the same emotion or if there was a different emotion present. In one task participants searched upright faces, and in the other, inverted faces, with task order counterbalanced. Trials consisted of nine pictures presented in a 3 x 3 grid. Each task consisted of 216 trials, which included three blocks of 72 trials. For each of these blocks, half of the trials were target trials and the other half were non-target trials. Non-target trials comprised only neutral faces and on target trials, one of the nine faces expressed an emotion. The 36 target trials were split evenly between the four emotions, with 9 trials each for angry, happy, sad, and fearful targets. Each target appeared in each position of the grid once. Trial sequence was randomised and each task was preceded by a practice task of 10 trials.

At the beginning of each trial, a fixation cross remained on the screen for 1,000 ms followed by the array of faces. The faces remained on the screen for 6,000 ms, or until the participant made a response. The intertrial interval was 1,000 ms. Scoring, response definition and statistical analysis were the same as for Experiments 1 and 2.

Results

Target trials

Happy faces were found fastest, followed by angry, fearful, and sad faces for both upright and inverted orientations (see figure 5). A 2 (orientation) x 4 (emotion) within-subjects ANOVA was conducted, revealing main effects of orientation, *F*(1,49) = 75.45, *p* < .001,   = 61, and emotion, *F*(3,47) = 64.41, *p* < .001,   = .80, and a orientation x emotion interaction, *F*(3,47) = 7.55, *p* < .001,   = .33. Detection times differed significantly across each of the emotions for both upright and inverted faces, with one exception; after controlling for multiple comparisons, detection time for upright fearful faces was not significantly different from detection time for upright sad faces, *t*(47) =2.76, *p* = .008 (p_{crit} = .004). All other *t*s > 4.00, *p*s < .001.

Insert Figure 5 about here

Analysis of the errors revealed main effects of orientation, *F*(1,49) = 8.75, *p* = .005,   = .15, and emotion, *F*(3,47) = 27.57, *p* < .001,   = .64, but no interaction, *F*(3,47) = .96, *p* = .422,   = .05. More errors were made searching inverted than upright faces. Happy targets were missed less often than angry, *t*(47) = 3.33, *p* = .001, fearful, *t*(47) = 5.76, *p* < .001, and sad targets, *t*(47) = 9.68, *p* < .001. Angry targets were missed less often than sad targets, *t*(47) = 6.35, *p* < .001, and fearful targets were missed less often than sad targets, *t*(47) = 3.91, *p* < .001. The difference between angry and fearful targets only approached significance, *t*(47) = 2.43, *p* = .019.

Non-target trials

Response times were faster for upright (*M* = 1670.45, *SD* = 386.72) than inverted non-target trials (*M* = 2024.05, *SD* = 452.84), *t*(49) = 5.31, *p* = < .001, and fewer errors were made on upright than to inverted non-target trials, *t*(49) = 3.87, *p* = < .001.

Discussion

Experiment 3 revealed a pattern of results consistent with Lipp et al. (2009). Happy faces were found fastest, followed by anger, fear and sadness, a pattern that was evident both with upright and inverted faces. These results replicate the original findings of Lipp et al., Experiment 2, but are inconsistent with the pattern evident in both Experiment 1 and 2 of the current paper. In order to increase the power of Experiment 3, 52 participants were tested to ensure that even a small effect of inversion on emotion detection might be detected . Despite adequate power, inversion did not alter the pattern of emotion detection evident with upright faces. Data of fewer participants were excluded from the analysis due to high error rates, suggesting that the present task was easier than those used in Experiments 1 and 2 as only one array size and one poser were used.

General Discussion

Across the three experiments presented here, two distinct patterns of results emerged. Experiments 1 and 2 revealed an emotion detection advantage such that detection times were faster for angry than happy faces. This pattern was either significantly reduced (Experiment 1) or abolished (Experiment 2) by inversion of the faces. Experiment 3 however, revealed an emotion detection pattern that was unaffected by inversion, replicating the results of the original experiment by Lipp et al. (2009).

The current study attempted to resolve the discrepant findings of Fox and Damjanovic (2006) and Lipp et al. (2009) who reported different effects of inversion on emotion detection in visual search. Experiments 1 and 2 are consistent with the findings of Fox and Damjanovic, suggesting holistic processing of emotionally expressive faces in visual search. As such, these findings contrast with those of Experiment 3 and of Lipp et al., which instead reveal no effect of inversion, providing support for feature-based accounts of emotional expression processing.

The emotion detection patterns that emerged across the three experiments are also inconsistent. Experiments 1 and 2 revealed preferential detection of angry faces, whereas Experiment 3 revealed faster detection of happy faces. Taking into consideration recent evidence, this apparently inconsistent pattern is not all that surprising and fits well with the current mixed findings reported in the area. Savage et al. (2013) demonstrated detection advantages for both angry and happy faces depending on the particular database from which the faces were drawn. When faces from the NimStim database (Tottenham et al., 2009) were used in a search task, preferential detection of angry faces emerged, however, when using faces drawn from the Ekman and Friesen Pictures of Facial Affect database (Ekman & Friesen, 1976), preferential detection of happy faces was evident. This is consistent with the current findings, as we also demonstrated faster detection of angry faces using the NimStim database (Experiments 1 and 2), and faster detection of happy faces using the Pictures of Facial Affect database (Experiment 3). However, the nature of the overall emotion detection pattern, happy face advantage or angry face advantage, observed is of secondary importance for the purposes of the current paper, as the focus is on whether inversion alters this pattern or not.

The inconsistent results reported across the three experiments, either in support of or against effects of face inversion on visual search for emotional expressions, could be explained as a consequence of differences in task complexity between the two sets of studies. Experiments 1 and 2 varied set sizes and used a set of nine different posers, with multiple identities presented on each trial. This resulted in the attenuation of the emotion detection pattern when the faces were inverted. Experiment 3 on the other hand found no effect of inversion using only one set size and only one poser. This interpretation is consistent with previous research in that both Lipp et al. (2009) and Williams et al. (2005), using simple task designs, report emotion detection patterns that were not affected by inversion. Both studies used only one poser within a task and although Williams et al. used two array sizes, set size was blocked, such that participants had to search only one set size within each block of trials. This suggests that when search tasks with emotional faces are designed following the requirements of D. V. Becker et al. (2011) that aim to reduce the effects of featural differences, inversion may attenuate emotion detection patterns, potentially providing support for a holistic processing account. However, certain choices regarding stimuli and task design may allow for the emergence of differences in emotion detection with upright and inverted faces. This may indicate that under some conditions emotional expressions are processed holistically in visual search (i.e., when multiple posers are used), but when task design permits, participants may make use of other, simpler feature-based search strategies (i.e., when only one poser is used).

One might argue that the results of Fox and Damjanovic (2006) are inconsistent with the argument advanced above. Using a single array size, only four posers within a task and only one poser for each of the four faces presented on each trial, the task design used by Fox and Damjanovic (2006) could be regarded as simple and hence favouring featural processing. However, Fox and Damjanovic (2006) report inversion effects, a result consistent with holistic processing of emotional expressions. It should be noted, however, that a series of three experiments conducted in an attempt to replicate Fox and Damjanovic (2006), consistently failed to provide evidence for inversion effects. Rather we found a pattern of results similar to that of Lipp et al. (2009) and Experiment 3 of the current paper. These attempted replications not only failed to provide evidence for effects of inversion, but also yielded evidence for preferential detection of happy, not angry, faces (for a similar result see Damjanovic et al., 2010)[1].

The current findings have a number of distinct implications. Finding evidence for effects of inversion on the detection of emotional expressions in Experiments 1 and 2 suggests that concerns about the role of feature driven target detection in visual search for emotional faces may be exaggerated (Purcell et al., 1996; D.V. Becker et al., 2011). However, this only holds for procedures that vary set size and background identity. Visual search procedures that use single identities or employ exaggerated expressions (Horstmann, Lipp & Becker, 2012) may be vulnerable to the effects of low-level featural confounds. In the context of the question as to whether facial expressions of emotion are processed holistically or featurally (Calder et al., 2000) the answer offered by the current research is a resounding ‘that depends’. It suggests that holistic face processing is engaged in the search for emotional expressions presented in tasks that are difficult, for instance because they involve neutral background expressions posed by different individuals or multiple set sizes. However, if the search task is easy and can be solved by searching for simple features that define the target expressions then no recourse to holistic face processing is required. This may suggest that holistic processing is not obligatory when presented with a face. The current

[1] A detailed summary of the three experiments is available from the authors upon request.

results suggest that the style of stimulus processing engaged in is not solely determined by the stimulus materials used, faces, but also by the requirements imposed by the task. They indicate that the processing of faces may be handled with more flexibility than thought previously.

References

Becker, D. V., Anderson, U. S., Mortensen, C. R., Neufeld, S. L., & Neel, R. (2011). The face in the crowd effect unconfounded: Happy faces, not angry faces, are more efficiently detected in single- and multiple-target visual search tasks. *Journal of Experimental Psychology: General, 140*(4), 637-659. doi: 10.1037/a0024060

Becker, S. I., Horstmann, G., & Remington, R. W. (2011). Perceptual grouping, not emotion, accounts for search asymmetries with schematic faces. *Journal of Experimental Psychology: Human Perception and Performance, 37*(6), 1739-1757. doi: 10.1037/a0024665

Calder, A. J., Young, A. W., Keane, J., & Dean, M. (2000). Configural information in facial expression perception. *Journal of Experimental Psychology: Human Perception and Performance, 26*(2), 527-551. doi: 10.1037/0096-1523.26.2.527

Damjanovic, L., Roberson, D., Athanasopoulos, P., Kasai, C., & Dyson, M. (2010). Searching for happiness across cultures. *Journal of Cognition and Culture, 10*(1-2), 85-107. doi: 10.1163/156853710x497185

Ekman, P. & Friesen, W.V. (1976). Pictures of Facial Affect. Consulting Psychologist Press, Palo Alto, CA.

Farah, M. J., Tanaka, J. W., & Drain, H. M. (1995). What causes the face inversion effect? *Journal of Experimental Psychology: Human Perception and Performance, 21*(3), 628-634. doi: 10.1037/0096-1523.21.3.628

Forster, K. I., & Forster, J. C. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments & Computers, 35*, 116-124. doi: 10.3758/BF03195503

Fox, E., & Damjanovic, L. (2006). The eyes are sufficient to produce a threat superiority effect. *Emotion, 6*(3), 534-539. doi: 10.1037/1528-3542.6.3.534

Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., & Dutton, K. (2000). Facial expressions of emotion: Are angry faces detected more efficiently? *Cognition and Emotion, 14*(1), 61-92.

Frischen, A., Eastwood, J. D., & Smilek, D. (2008). Visual search for faces with emotional expressions. *Psychological Bulletin, 134*(5), 662-676. doi: 10.1037/0033-2909.134.5.662

Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology, 54*(6), 917-924. doi: 10.1037/0022-3514.54.6.917

Horstmann, G., Lipp, O. V., & Becker, S. I. (2012). Of toothy grins and angry snarls--open mouth displays contribute to efficiency gains in search for emotional faces. *Journal of Vision, 12*(5), 7. doi: 10.1167/12.5.7

Juth, P., Lundqvist, D., Karlsson, A., & Öhman, A. (2005). Looking for Foes and Friends: Perceptual and Emotional Factors When Finding a Face in the Crowd. *Emotion, 5*(4), 379-395. doi: 10.1037/1528-3542.5.4.379

Lipp, O. V., Price, S. M., & Tellegen, C. L. (2009). No effect of inversion on attentional and affective processing of facial expressions. *Emotion, 9*(2), 248-259. doi: 10.1037/a0014715

McKelvie, S. J. (1995). Encoding Operations and Recognition Memory for Faces. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale, 49*(4), 437-459. doi: 10.1037/1196-1961.49.4.437

McKone, E., & Yovel, G. (2009). Why does picture-plane inversion sometimes dissociate perception of features and spacing in faces, and sometimes not? Toward a new theory of holistic processing. *Psychonomic Bulletin & Review, 16*(5), 778-797. doi: 10.3758/PBR.16.5.778

Farah, M. J., Tanaka, J. W., & Drain, H. M. (1995). What causes the face inversion effect? *Journal of Experimental Psychology: Human Perception and Performance, 21*(3), 628-634. doi: 10.1037/0096-1523.21.3.628

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80*(3), 381-396. doi: 10.1037/0022-3514.80.3.381

Öhman, A., Soares, S. C., Juth, P., Lindström, B., & Esteves, F. (2012). Evolutionary derived modulations of attention to two common fear stimuli: Serpents and hostile humans. *Journal of Cognitive Psychology, 24*(1), 17-32. doi: 10.1080/20445911.2011.629603

Purcell, D. G., Stewart, A. L., & Skov, R. B. (1996). It takes a confounded face to pop out of a crowd. *Perception, 25*(9), 1091-1091-1108. doi: 10.1068/p251091

Savage, R. A., Lipp, O. V., Craig, B. M., Becker, S. I., & Horstmann, G. (2013). In Search of the Emotional Face: Anger Versus Happiness Superiority in Visual Search. *Emotion*. Advance online publication. doi: 10.1037/a0031970

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 46A*(2), 225-245. doi: 10.1080/14640749308401045

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., et al. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research, 168*, 242–249. doi: doi:10.1016/j.psychres.2008.05.006

Williams, M. A., Moss, S. A., Bradshaw, J. L., & Mattingley, J. B. (2005). Look at me, I'm smiling: Visual search for threatening and nonthreatening facial expressions. *Visual Cognition, 12*(1), 29-29-50. doi: 10.1080/13506280444000193

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology, 81*(1), 141-145. doi: 10.1037/h0027474

Young, A. W., Hellawell, D., & Hay, D. C. (1987). Configurational information in face perception. *Perception, 16*(6), 747-759.

Figure Captions

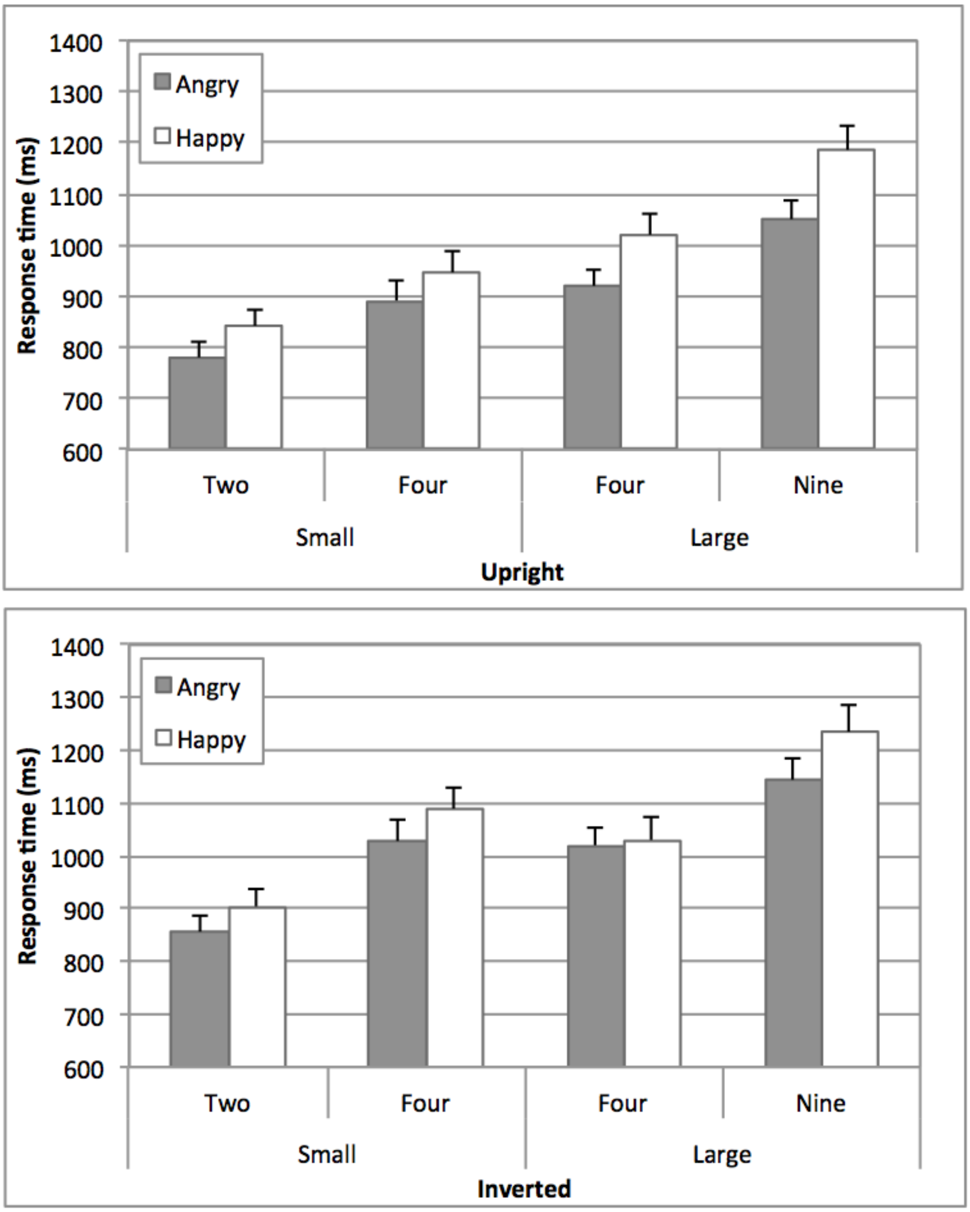
Figure 1. Target detection times for small and large arrays during the tasks with set sizes of two and four, and four and nine. Response times for the upright tasks are displayed in the upper panel, and the inverted task in the lower panel. Error bars represent standard errors.

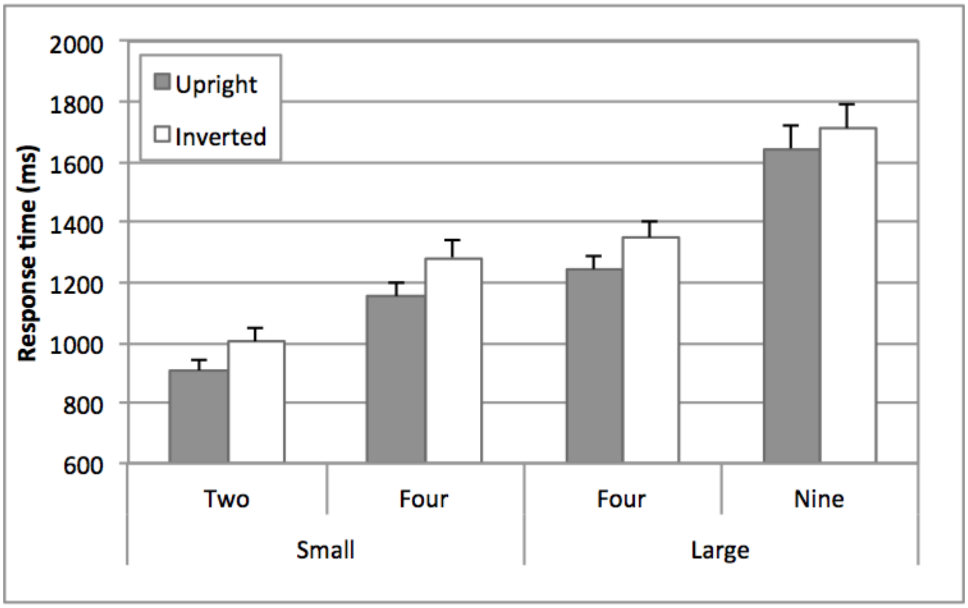
Figure 2. Non-target trial response times for small and large arrays during the tasks with arrays of two and four, and four and nine. Error bars represent standard errors.

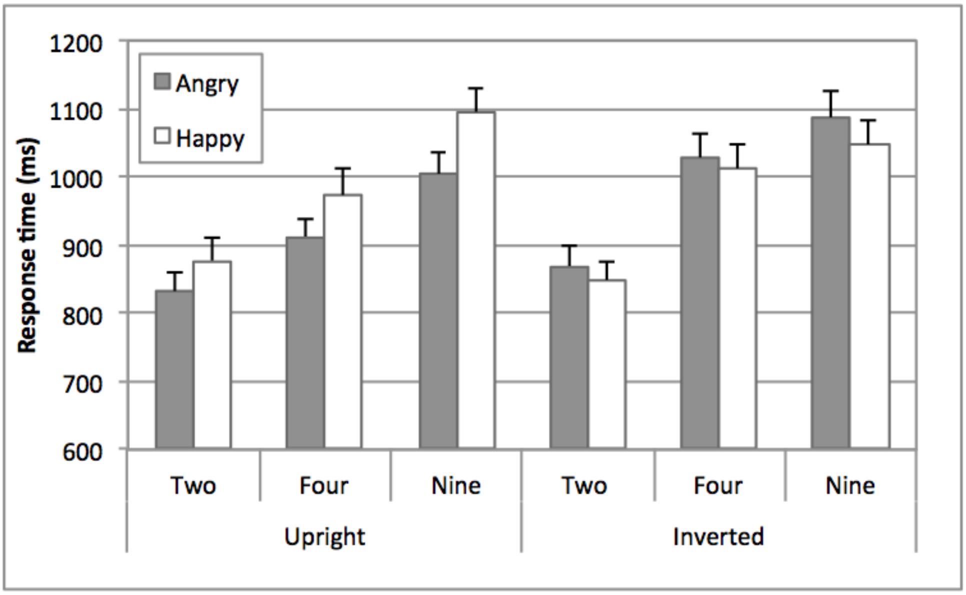
Figure 3. Target detection times for angry and happy targets in arrays of two, four, and nine faces presented upright or inverted. Error bars represent standard errors.

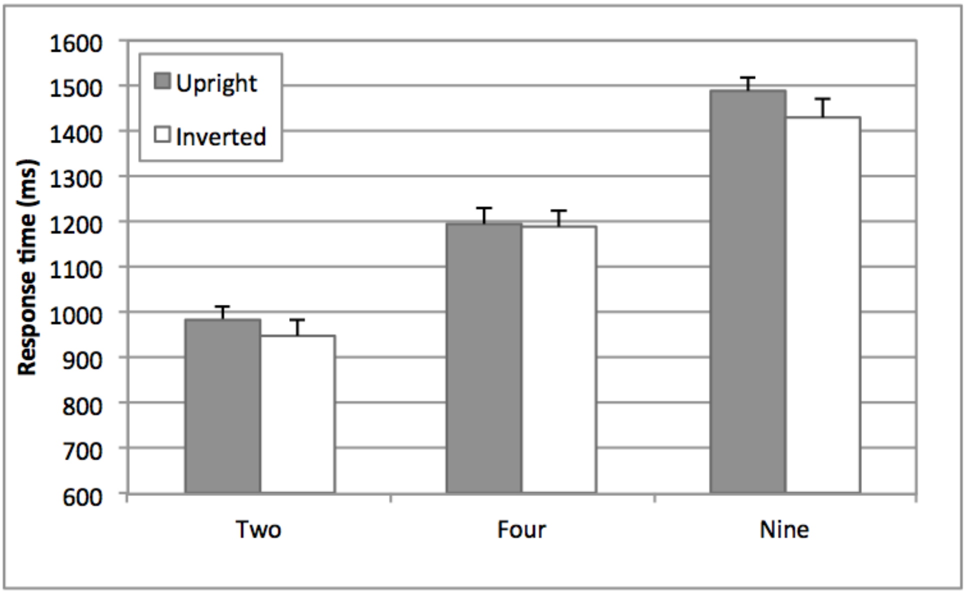
Figure 4. Non-target trial response times for upright and inverted faces for arrays of two, four, and nine faces. Error bars represent standard errors.

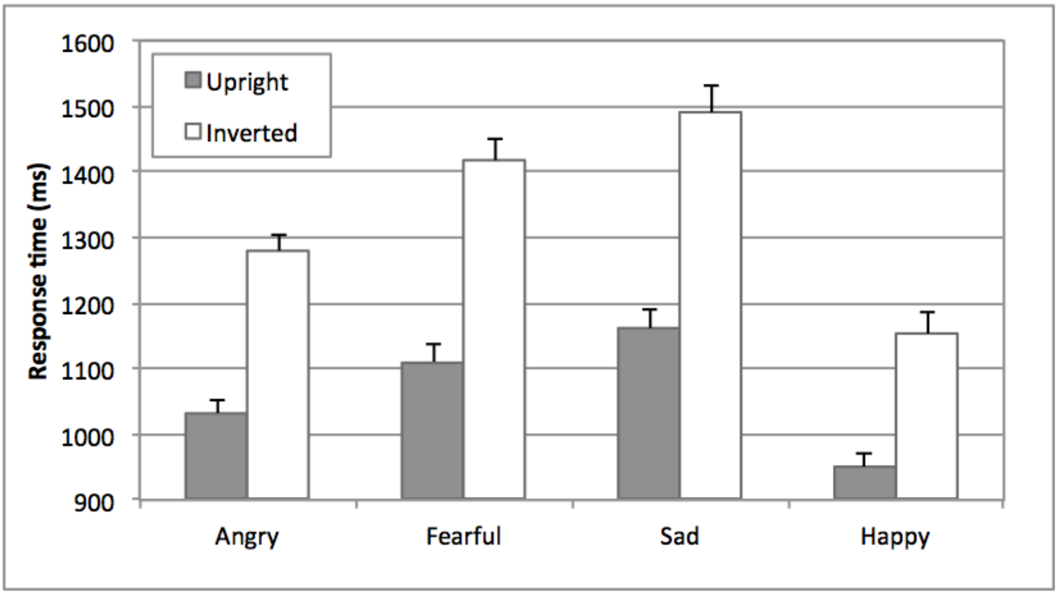
Figure 5. Target detection times for upright and inverted faces. Error bars represent standard errors.


1400
1300
1200
1100
1000
900
800
700
600
Response time (ms)
Angry
Happy
Two
Four
Four
Nine
Small
Large
Upright
1400
1300
1200
1100
1000
900
800
700
600
Response time (ms)
Angry
Happy
Two
Four
Four
Nine
Small
Large
Inverted


2000
1800
1600
1400
1200
1000
800
600
Response time (ms)
Upright
Inverted
Two
Four
Four
Nine
Small
Large


1200
1100
1000
900
800
700
600
Response time (ms)
Angry
Happy
Two
Four
Nine
Two
Four
Nine
Upright
Inverted


1600
1500
1400
1300
1200
1100
1000
900
800
700
600
Response time (ms)
Upright
Inverted
Two
Four
Nine


1600
1500
1400
1300
1200
1100
1000
900
Response time (ms)
Upright
Inverted
Angry
Fearful
Sad
Happy