Detection of emotional facial expressions and anti-expressions

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Abstract

Detection of emotional facial expressions has been shown to be more efficient than detection of neutral expressions. However, it remains unclear whether this effect is attributable to visual or emotional factors. To investigate this issue, we conducted **two** experiments using the visual search paradigm with photographic stimuli. We included a single target facial expression of anger or happiness in presentations of crowds of neutral facial expressions. The anti-expressions of anger and happiness were also presented. Although anti-expressions produced changes in visual features comparable to those of the emotional facial expressions, they expressed relatively neutral emotions. The results consistently showed that reaction times (RTs) for detecting emotional facial expressions (both anger and happiness) were shorter than those for detecting anti-expressions. The RTs for detecting the expressions were negatively related to experienced emotional arousal. These results suggest that efficient detection of emotional facial expressions is not attributable to their visual characteristics but rather to their emotional significance.

Keywords

Anti-expressions; Computer morphing; Emotional facial expressions; Visual search.

The communication of emotion through facial expressions serves adaptive social functions (Keltner & Haidt, 2001). Facial expressions would have conferred an evolutionary advantage by facilitating the immediate sharing of biologically significant information, such as on predators or foods.

Consistent with this notion, a previous study has demonstrated the efficiency of detecting the emotional facial expressions of others (Hansen & Hansen, 1988). They investigated the detection of the photographs of angry, happy, and neutral faces in the visual search paradigm. The photos were lined up, and participants responded regarding the existence of different expression. The results showed that the reaction time (RT) for detecting an angry target face in a crowd of neutral distractor faces was shorter than that for a neutral face in a crowd of angry faces. Although some subsequent studies (Hampton, Purcell, Bersine, Hansen, & Hansen, 1989; Purcell, Stewart, & Skov, 1996) have noted problems with the stimuli used by Hansen and Hansen (1988), other studies have reported similar results using different methods (Gilboa-Schechtman, Foa, & Amir, 1999; Lamy, Amunts, & Bar-Haim, 2008; Williams, Moss, Bradshaw, & Mattingley, 2005). For example, Williams et al. (2005) showed that the RTs for detecting a sad or happy face among a group of neutral faces were shorter than those for detecting a neutral face among a group of emotional faces. These data indicate that detection of emotional facial expressions proceeds with greater efficiency than does the detection of neutral expressions.

Despite these results, it has remained unclear whether more efficient detection of emotional versus neutral facial expressions derives from emotional or visual factors (cf. Cave & Batty, 2006). The differences between emotional and neutral facial expressions involve changes not only in the emotional significance attributed to the stimuli, but also in the positions of the physical features presented in the stimuli themselves (e.g., oblique eyebrows in angry expressions versus horizontal eyebrows in neutral expressions). Some studies have demonstrated that several visual features, such as oblique lines and curves, were more rapidly detected than other features such as horizontal lines (e.g., Sagi & Julesz, 1986; for a review, see Wolfe & Horowitz, 2004). The more rapid detection of emotional than of neutral facial expressions might derive from the processing of the visual input representing the physical features that produce expressions, rather than from the processing of the emotional significance of such stimuli.

Some visual search studies have used line-drawings of faces as stimuli (for a review, see Horstmann, 2007). Among these studies, the research conducted by Öhman, Lundqvist, and Esteves (2001) provided clues regarding this issue. The researchers investigated the detection of a schematic angry expression presented among a group of schematic neutral faces. For comparison, they used expressions containing comparable changes in the eyebrows and mouth, but without angry expressions. The RTs for detecting an angry face were shorter than those for detecting the other expressions. These results suggest that the emotional significance of angry expressions, rather than the visual characteristics, was responsible for the efficiency in detecting angry facial expressions. However, these results should be interpreted with caution because schematic faces lack ecological validity. Some neuroscientific evidence suggests that the processing of line-drawings of faces may be different from or weaker than that of faces presented in photographs (e.g., McCarthy, Puce, Belger, & Allison, 1999). Hence, it is important to confirm these findings using photographs as stimuli.

Our primary purpose in this study was to investigate whether the more efficient detection of emotional than of neutral facial expressions is attributable to visual characteristics or to emotional significance. For this purpose, we prepared novel control stimuli using a computer-morphing technique. Computer-generated images can be manipulated to create a new facial image from two contributing facial images (Rowland & Perrett, 1995). For this method, we used photographs of the same individual exhibiting emotional and neutral facial expressions. After spatial standardization of the facial images, the metric differences between the overall facial features of the emotional and neutral expressions were calculated and regarded as 100%. Additional stimuli were then created by manipulating the facial features until the metric differences equaled –100%; that is, we reversed the direction of the facial features of the emotional expressions but retained the general configuration. For example, if the angry expression had V-shaped eyebrows and the neutral expression had horizontal eyebrows, our computer manipulation generated faces with eyebrows shaped in an upside-down V (Λ) shape. Consistent with the facial image-processing literature, which describes attempts to negate differences between the target and the control stimuli as "anti-caricaturing" (Rhodes, Brennan, & Carey, 1987), we refer to these stimuli as "anti-expressions." Examples of anti-expressions are shown in Figure 1a. The anti-expressions would convey less emotion than do normal emotional expressions because the anti-expressions lack the appropriate combinations of featural changes to express emotions (cf. Ekman & Friesen, 1975; McKelvie, 1973). However, the anti- and normal emotional expressions are equivalently different from the neutral facial expressions in visual properties and can therefore be used as control stimuli in experiments measuring reactions to the visual properties of the emotional facial expressions. This method enabled us to keep the visual features of the stimuli constant and to test the effect of emotional significance alone on the detection of emotional facial expressions.

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Figure 1

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We used grayscale photographic stimuli that were carefully prepared to eliminate contrast artifacts (cf. Purcell et al., 1996) and tested the effect of emotional expressions of anger and happiness. Crowds of neutral face distractors, with or without a single target expression, were presented to participants. Participants were asked to determine whether all the stimuli were the same or not and to press a button to indicate their answer. On the basis of studies using line-drawings (e.g., Öhman, Lundqvist et al., 2001), we hypothesized that the detection of normal emotional facial expressions would be faster than that of anti-expressions.

Our secondary purpose involved comparing the time required for detection of angry versus happy target expressions. Some studies using photographic stimuli have reported more efficient detection of angry faces presented among neutral faces than of happy faces presented among neutral faces (Fox & Damjanovic, 2006; Gilboa-Schechtman et al., 1999; Lamy et al., 2008), although others have reported negative findings (Byrne & Eysenck, 1995; Juth, Lundqvist, Karlsson, & Öhman, 2005; Williams et al., 2005). Several studies using schematic stimuli have found superior detection of angry expressions compared to happy expressions (e.g., Öhman, Lundqvist et al., 2001; for a review, see Horstmann, 2007). It is widely assumed that superior detection of angry faces rests on their greater emotional significance as compared to happy expressions (e.g., Öhman, Lundqvist et al., 2001). On the basis of these data, we expected that the detection of normal angry expressions would be faster than that of normal happy expressions. We also expected that differences in the detection of anti-angry and anti-happy expressions would not be evident because these would have little emotional impact.

Experiment 1

We conducted experiments to test the detection of normal and anti-expressions of anger or happiness presented within crowds of neutral expressions. To ensure the robustness of the results, we presented the stimuli in a circular (Experiment 1a) and in a matrix (Experiment 1b) arrangement. We predicted that that the RTs for detecting normal emotional facial expressions would be shorter than those for detecting anti-expressions. We also predicted the RTs for detecting angry expressions would be shorter than those for detecting happy expressions for normal, but not anti-, expressions.

Method

Participants. Seventeen volunteers participated in Experiment 1a (5 females and 12 males, mean age 20.3 years) and 17 others in Experiment 1b (10 females and 7 males, mean age 21.5 years). All participants were right-handed, and had normal or corrected-to-normal visual acuity.

Experimental design. The experiment was constructed as a within-participants three-factor design with stimulus type (normal or anti-expression), emotion (anger or happiness), and set size (2, 4, or 8 for Experiment 1a; 4, 9, or 16 for Experiment 1b) as factors.

Stimuli. The raw materials were grayscale photographs depicting angry, happy, and neutral expressions of a male (jj) and a female (c) model chosen from a standard set (Ekman & Friesen, 1976). In the neutral expressions, the models' eyebrows were largely horizontal. Neither model was familiar to any of the participants.

Anti-expressions were produced by applying computer-morphing techniques (using a Linux computer) to these photographs (Mukaida et al., 2000). The coordinates of 79 facial feature points were identified manually and realigned based on the coordinates of the bilateral irises. Next, the differences between the feature points of the emotional (angry and happy) and neutral facial expressions were calculated. The positions of the feature points for the anti-expressions were then determined by moving each point by the same distance in the direction opposite from that in the emotional face. Minor color adjustments by a few pixels were performed using Photoshop 5.0 software (Adobe). Anti-expressions for anger and happiness were prepared for each model.

Using PhotoShop 5.0 software (Adobe), two types of adjustments were made for the stimuli.

First, the photographs were cropped into a circle, slightly inside the frame of the face, to eliminate the contours and hairstyles not relevant to the expression. Second, the photographs were prepared so that significant differences in contrast were eliminated, thereby removing possible identifying information. The size of the stimuli was 3.5 degrees vertically and 2.8 degrees horizontally. Figure 1 presents examples of the stimuli.

To ensure that the anti-expressions of anger and happiness were recognized as emotionally neutral, the normal expressions and anti-expressions were shown to 13 participants, none of whom took part in the subsequent experiment. These participants were asked to provide the best emotional description for each stimulus face. The most frequently selected category for the anti-expressions was "neutral" (19.9% and 19.2% for anti-angry and anti-happy expressions, respectively). The participants also evaluated the stimulus faces for the recognized emotion using valence and arousal (cf. Greenwald, Cook, & Lang, 1989) on a nine-point scale from –4 (negative; low arousal) to +4 (positive; high arousal). The results showed that the anti-expressions of anger and happiness were rated as emotionally neutral with regard to both valence (mean ± *SD* = 0.7 ± 0.3 and –1.1 ± 0.7 for anti-angry and anti-happy expressions, respectively) and arousal (mean ± *SD* = 0.0 ± 0.5 and 0.4 ± 1.1 for anti-angry and anti-happy expressions, respectively). The analyses for the arousal ratings, reflecting the intensity of either positive or negative emotions (Lang, Bradley, & Cuthbert, 1998), showed that the anti-expressions for both anger and happiness were rated as less emotionally arousing than the normal expressions (paired *t*-tests, $ps < .05$). There were no significant differences in the arousal ratings of the anti-expressions and those of the neutral expressions (paired *t*-tests, $ps > .1$).

The normal and anti-expressions of angry and happy faces were used as target stimuli. The neutral facial expressions were used as distractor stimuli.

In Experiment 1a, the stimuli were arranged on a panel, equidistant from the center, on top of the circumference of a circle (Figure 1). Stimuli were presented in sets of two, four, and eight. When the target stimuli were not presented, only the neutral faces appeared in the sets. When the target stimuli were presented, one photograph from the set was replaced with a photograph depicting the target stimulus; the rest of the photographs were of neutral faces only. The presented stimulus display measured 17.7 degrees vertically and 17.7 degrees horizontally at maximum size.

In Experiment 1b, the stimuli were presented on a panel in 2 × 2, 3 × 3, and 4 × 4 sets. In the 2 × 2 set, the target stimulus appeared in any of the four positions. In the 3 × 3 set, it appeared in any of eight positions excluding the center point. In the 4 × 4 set, it appeared in one of eight randomly chosen positions (16 positions total for the two models). The stimulus display size was 7.1 degrees for the vertical and horizontal components in the 2 × 2 set, 10.6 degrees in the 3 × 3 set, and 14.1 degrees in the 4 × 4 set.

Apparatus. The events were controlled by SuperLab Pro 2.0 (Cedrus), implemented on a Windows computer (MA55J, NEC). The stimuli were presented on a 19-inch CRT flat monitor (GDM-F400, Sony) with a refresh rate of 100-Hz and resolution of 1024 × 768 pixels. The participants' responses were recorded using a response box (RB-400, Cedrus).

.*Procedure.* The experiment was conducted in a soundproofed room. The participants sat in chairs, with their foreheads and chins lightly fixed into steady positions. The monitor was placed 57.8 cm from participants' eyes. During the target stimulus condition, photographs with the target face were presented during each of the eight stimulus displays. During the no-target stimulus condition, the display was also shown eight times. The total number of trials was 384 or 8 (repetition display) × 2 (model) × 4 (expression) × 3 (set size) × 2 (yes or no target stimulus). The stimuli were displayed in random order. At the beginning of the experiment, participants received 36 practice trials. A break was inserted after every 48 trials.

Each trial proceeded as follows. First, a black plus sign was displayed in the center of the monitor for 500 ms to signal that the trial was beginning. Then, the display panel was shown until each participant completed all the questions. Participants were asked whether or not the photographs on the display panel were all the same. Answers were provided by pushing the appropriate button on a response box. The position of the response buttons was counterbalanced across participants, and participants were instructed to answer as quickly and correctly as possible.

Data analysis. Separate analysis was conducted for each experiment. The mean RT of correct responses was calculated for each experimental condition, excluding measurements beyond the total mean ± 3 *SD* as artifacts. To satisfy normality assumptions for the subsequent analyses, the data were subjected to a log transformation. The log-transformed RT was analyzed using a 2 (stimulus type) × 2 (emotion) × 3 (set size) repeated-measures analysis of variance (ANOVA). For significant interactions, follow-up analyses for simple main effects or simple-simple main effects were conducted (cf. Kirk, 1995). When higher-order interactions were significant, the main effects and lower-order interactions were not subjected to interpretation because of their problematic properties (cf. Tabachnick & Fidell, 2001). Preliminary analyses showed that both stimulus models (jj and c) showed similar effects in regard to stimulus type and emotion; accordingly, the factor of model was omitted in the following analyses. Preliminary analyses were also conducted for errors. The error rates were small (< 2%) and there was no evidence of a speed-accuracy trade-off phenomenon. Hence, we report only the RT results.

Results

Experiment 1a. Figure 2 (upper) shows the results for RT. The ANOVA for the log-transformed RTs revealed a significant two-way interaction of stimulus type × emotion, $F(1,16)$

= 8.87, $p < .01$. The main effects of stimulus type, emotion, and set size were also significant, Fs(1,16) = 39.26 and 7.75, and $F(2,32) = 163.66$, respectively, ps < .001. Other interactions did not reach significance, Fs(2,32) < 0.62, ps > .1.

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Figure 2

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Follow-up analyses were conducted for the interaction of stimulus type × emotion. The simple main effects of stimulus type, indicating shorter RTs for normal expressions than for anti-expressions, were significant for both anger and happiness, Fs(1,32) > 14.89, ps < .005. The simple main effects of emotion, indicating shorter RTs for angry expressions than for happy expressions, were significant for both normal and anti-conditions, Fs(1,32) > 5.96, ps < .05.

Experiment 1b. Figure 2 (lower) shows the RT results. The ANOVA for the log-transformed RTs revealed that the highest three-way interaction of stimulus type × emotion × set size was significant, $F(2,32) = 6.41$, $p < .005$. The main effects of stimulus type, emotion, and set size were also significant, Fs(1,16) = 751.74 and 354.20, and $F(2,32) = 41.73$, respectively, ps < .001. The interactions of stimulus type × emotion, stimulus type × set size, and emotion × set size were also significant, Fs(1,16) = 32.33 and $F(2,32) = 5.27$ and 18.64, respectively, ps < .05.

Follow-up analyses were conducted for the three-way interaction. The simple-simple main effects of stimulus type, indicating shorter RTs for normal expressions than for anti-expressions, were significant for all conditions, Fs(1,96) > 48.89, ps < .001. The simple-simple main effects of emotion, indicating shorter RTs for anger than for happiness, were also significant for all conditions, Fs(1,96) > 10.27, ps < .005.

Discussion

The results of preliminary ratings showed that the anti-expressions of anger and happiness were categorized as “neutral” and were recognized as emotionally less arousing than the normal expressions. These results are consistent with those of a previous study that investigated the effect of varying the facial parts of schematic faces on emotion recognition (McKelvie, 1973). That study reported that the face with Λ-shaped brows and up-turned mouth, and the face with horizontal brows and down-turned mouth, analogous to the anti-expressions of anger and happiness, respectively, were not consistently classified according to category of expression.

The results pertaining to RTs consistently showed that the normal angry and happy expressions were detected faster than were the respective anti-expressions. These results are congruent with those of previous studies indicating efficient detection of photographs depicting emotional facial expressions (e.g., Gilboa-Schechtman et al., 1999). However, it has been unclear whether such efficient detection of emotional facial expressions was caused by the visual characteristics or the emotional significance of the emotional stimuli. Our results clearly showed that detection of an emotional expression was superior even when the effects of stimulus visual characteristics were controlled. The present results support our hypothesis that the priority of emotional expression detection is not based on visual characteristics but instead involves the processing of emotions.

The RTs for detecting a normal angry face were shorter than for detecting a normal happy face. This is consistent with the results of some previous studies (e.g., Gilboa-Schechtman et al., 1999). Contrary to our prediction, the similar superiority for anger over happiness was also revealed for anti-expressions. This result may suggest differences between the emotional significance of anti-angry and anti-happy expressions. This issue was examined in Experiment 2.

Experiment 2

In Experiment 2, we added a condition in which a neutral expression, presented in a crowd of normal and anti-expressions, was the target in order to provide additional support for the efficient detection of emotional facial expressions. Some previous studies using photographic stimuli have reported that the RTs for detecting an emotional expression among a crowd of neutral faces were shorter than those for detecting a neutral expression among a crowd of emotional expressions (Gilboa-Schechtman et al., 1999; Lamy et al., 2008; Williams et al., 2005). This search asymmetry design represents a typical research strategy for demonstrating efficient detection in visual search (cf. Horstmann et al., 2006). We compared the detection advantages of normal and anti-expressions over neutral expressions. We predicted that the RTs for detecting a normal, but not an anti-, expression among a crowd of neutral faces would be shorter than those for the reverse condition.

In addition, we analyzed the relationship between the RTs and the ratings given to the emotional experiences of the stimuli in order to test the hypothesis that the emotional significance of stimuli affected the detection of facial expressions. After the visual search experiment, the participants rated their emotional experiences in response to the stimuli using dimensional ratings of valence and arousal (cf. Greenwald et al., 1989). The most prevalent interpretation of these dimensions proposes that valence represents the qualitative component whereas arousal reflects the intensity of either positive or negative emotions (Lang et al., 1998); hence, the arousal ratings would correspond to the emotional significance that perceivers attach to the stimuli. We also tested the relationship between the detection performance and the familiarity ratings for the stimuli because a previous study had found that familiarity could affect detection of faces in a visual search (Tong & Nakayama, 1999). We predicted a negative relationship between RT performance and emotional arousal, but not familiarity.

Method

Participants. Seventeen volunteers (11 females and 6 males, mean age 20.9 years) participated in this experiment. All participants were right-handed, and had normal or corrected-to-normal visual acuity.

Experimental design. The experiment was constructed as a within-participants three-factor design with stimulus type (normal or anti-), emotion (anger or happiness), and crowd-target relationship (neutral crowd or neutral target) as factors. We used a single set-size condition to simplify the experimental design.

Stimuli. Individual stimuli were the same as those used in Experiment 1. The stimuli were presented in sets of four.

Apparatus. We used the same apparatus as in Experiment 1.

Procedure. We used the same procedures as those used in Experiment 1 with the exception of two modifications. First, the total number of trials was 256. Second, participants evaluated the stimuli. After the visual search experiment, the individual stimuli were presented to the participants again. They evaluated each stimulus in terms of emotion experienced (i.e., the strength of the emotion that participants felt when perceiving the expression of the model) by rating emotional valence and arousal on a nine-point scale from -4 (negative; low arousal) to +4 (positive; high arousal). They also evaluated familiarity (i.e., frequency of seeing facial expressions in daily life such as those depicted by the stimulus) using a 9-point scale ranging from “not at all” to “very frequently.” We presented the two types of evaluation in blocks, counterbalancing order across participants. The order of stimulus presentation was randomized in each block.

Data analysis. The log-transformed RTs were calculated as in Experiment 1. The log-transformed RTs were analyzed using a 2 (stimulus type) × 2 (emotion) × 2 (crowd-target relationship) repeated-measures ANOVA. Preliminary analyses showed similar effects for stimulus type and emotion in both models, and hence we collapsed the factor of model. Preliminary analyses for errors showed small error rates (< 9%) and no evidence of a speed-accuracy trade-off phenomenon; hence we reported only the RT results.

The ratings of valence, arousal, and familiarity were analyzed using 2 (stimulus type) × 2 (emotion) repeated-measures ANOVAs.

To analyze the relationship between RTs and ratings, we performed a multiple regression analysis using the log-transformed RTs in the neutral crowd condition as the dependent measure. The independent measures were the ratings of valence, arousal, and familiarity, and the nuisance variables for participants (cf. Tabachnick & Fidell, 2001). The assumption of global sphericity was confirmed (Mauchly's test, $p > .1$). We analyzed the coefficients of the ratings using *t*-tests (one-tailed). We calculated the adjusted log-transformed RTs by removing the effects of other independent variables to plot the relationship between the log-transformed RTs and the arousal ratings.

Results

RT. Figure 3 shows the RT results. The three-way ANOVA for log-transformed RTs revealed significant two-way interactions of stimulus type × emotion and of stimulus type × crowd-target relationship, Fs(1,16) = 6.15 and 13.49, respectively, ps < .05. The main effects of stimulus type, emotion, and crowd-target relationship were also significant, Fs(1,16) = 24.26, 44.13 and 4.63, respectively, ps < .001. Other interactions did not reach significance, Fs(1,16) < 0.83, ps > .1.

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Figure 3

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Follow-up analyses for the interaction of stimulus type × emotion revealed that the simple main effects of stimulus type, indicating shorter RTs for normal expressions than for anti-expressions, were significant for both anger (mean RTs: 1300.7 vs. 1575.3 ms) and happiness (mean RTs: 1530.2

vs. 1659.5 ms), *F*s(1,32) > 5.38, *p*s < .05. The simple main effects of emotion, indicating shorter RTs for angry expressions than for happy expressions, were significant for both normal and anti-expressions, $F(1,32) > 7.12$, *p*s < .05.

Follow-up analyses for the interaction of stimulus type × crowd-target relationship revealed that the simple main effect of crowd-target relationship, indicating shorter RTs for neutral crowd conditions than for neutral target conditions, was significant for normal expressions (mean RTs: 1372.4 vs. 1458.5 ms), $F(1,32) = 15.23$, $p < .001$, but not for anti-expressions (mean RTs: 1620.9 vs. 1613.9 ms), $F(1,32) = 0.18$, $p > .1$.

Rating. The results of ratings are presented in Table 1. For the valence ratings, the results revealed a significant interaction, $F(1,16) = 73.51$, $p < .001$. The main effect of emotion was also significant, $F(1,16) = 12.46$, $p < .001$. The main effect of stimulus type was not significant, $F(1,16) = 0.23$, $p > .1$. Follow-up simple effect analyses for the interaction revealed that the simple main effects of stimulus type were significant for both anger and happiness, indicating more negative and more positive ratings, respectively, for normal angry and happy expressions than for anti-expressions, *F*s(1,32) > 35.35, *p*s < .001. The simple main effect of emotion, indicating more positive ratings for happiness than for anger, was significant only in regard to normal expressions, $F(1,32) = 98.37$, $p < .001$.

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Table 1

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For the arousal ratings, the main effect of stimulus type, indicating higher arousal ratings for normal than for anti-expressions, was significant, $F(1,16) = 10.15$, $p < .01$. The main effect of emotion, indicating higher arousal ratings for anger than for happiness, was also significant, $F(1,16) = 13.52$, $p < .005$. The interaction was not significant, $F(1,16) = 2.43$, $p > .1$.

For the familiarity ratings, an interaction, $F(1,16) = 61.88$, $p < .001$, as well as a main effect for emotion, $F(1,16) = 53.73$, $p < .001$, were significant. The main effect of stimulus type was not significant, $F(1,16) = 2.36$, $p > .1$. Follow-up simple effect analyses for the interaction revealed that the simple main effect of stimulus type was significant for both anger and happiness, indicating less familiar ratings for normal angry expressions and more familiar ratings for normal happy expressions than for anti-expressions, Fs(1,32) > 18.96, ps < .001. The simple main effect of emotion, indicating more familiar ratings for happiness than for anger, was significant only for normal expressions, $F(1,32) = 115.59$, $p < .001$.

Relationship between RTs and ratings. A multiple regression analysis with the log-transformed RTs in the neutral crowd condition as the dependent variable and the ratings as the independent variables showed that the coefficient of arousal was negative and significantly different from zero (standardized coefficient = -0.21; $t(48) = 2.02$, $p < .01$; Figure 4). The coefficients of valence and familiarity were not significantly different from zero (standardized coefficients = 0.07 and 0.07, respectively; ts(48) < 0.65, ps > .1).

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Figure 4

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Discussion

In general, the RT results replicated those of Experiment 1. The normal expressions were detected faster than the anti-expressions. The RTs for detecting a normal and anti-angry face were shorter than those for detecting a normal and anti-happy face. These results suggest the robustness of the phenomena observed in Experiment 1.

The comparisons between neutral target and neutral crowd conditions showed that the detection of normal angry and happy expressions among a crowd of neutral faces was faster than that for the reverse condition. These results are consistent with the previous findings (e.g., Gilboa-Schechtman et al., 1999) and further support the efficient detection of emotional facial expressions. By contrast, the search asymmetry between anti-expressions and neutral expressions was not evident. These results suggest that the visual features of the stimuli do not induce the efficient detection of emotional expressions.

The results of ratings for normal expressions are consistent with those reported in previous studies. The emotional ratings showed that participants experienced highly negative and highly arousing emotions for normal angry expressions, and highly positive and mildly arousing emotions for normal happy expressions. These results are consistent with those of a previous research (Johnsen, Thayer, & Hugdahl, 1995). The familiarity ratings showed that normal happy expressions were more familiar than normal angry expressions. This is consistent with a previous report (Bond & Siddle, 1996).

The ratings for anti-expressions were largely consistent with our expectations. The familiarity ratings showed that participants experienced medium familiarity with anti-expressions, indicating that anti-expressions depicted ordinary facial changes. The emotional ratings revealed that participants experienced less valenced and less arousing emotions in response to anti-expressions than to normal expressions. These results are consistent with the recognition data obtained in Experiment 1 insofar as anti-expressions were labeled as neutral expressions. An unexpected finding was that there were differences between the arousal ratings for anti-angry and anti-happy expressions.

Interestingly, the arousal ratings corresponded to the RT results across experiments. The arousal ratings were higher for normal than for anti-expressions, and for angry than for happy expressions. Similarly, the RTs reflected faster detection of normal than anti-expressions, and of angry than happy expressions.

Furthermore, the regression analysis revealed a negative relationship between RTs and emotional arousal ratings. It has been proposed that the arousal ratings reflect the intensity dimension of emotions (Lang et al., 1998). Therefore, our data revealed that the facial stimuli with the potential to induce intense emotions in the perceivers were associated with efficient detection. The familiarity ratings were not related to the efficient detection of facial expressions. These data support the idea that the emotional facial expressions are detected efficiently because of their emotional significance.

General Discussion

Our primary purpose was to investigate whether the efficient detection of emotional facial expressions is attributable to visual characteristics or to emotional significance. Our results consistently showed that RTs for detecting normal expressions among neutral expression crowds were shorter than those for detecting anti-expressions. Because the normal and anti-expressions were equivalently different from the neutral expressions in visual properties, the efficient detection of normal expressions could not be attributable to their visual characteristics. These results are consistent with those of previous studies reporting efficient detection of photographs of emotional facial expressions (e.g., Gilboa-Schechtman et al., 1999). However, as in our Experiment 2, all previous studies have examined efficient detection of facial expressions depicted in photographs by comparing the detection of an emotional face target presented among distractors of neutral faces with the reverse condition (e.g., Gilboa-Schechtman et al., 1999). This type of comparison cannot dissociate the effects of emotional and visual factors, and might suffer from the confounding effect of distractors (cf. Eastwood, Smilek, & Merikle, 2001). Our results confirmed that the detection of emotional facial expressions among neutral face crowds was more efficient than that of control stimuli in terms of visual properties. Furthermore, the results of Experiment 2 revealed a negative relationship between RTs and emotional arousal ratings. Taken together, these results indicate that the efficient detection of emotional expressions is attributable to the emotional significance of the stimuli, rather than to their visual characteristics.

Our results are consistent with those of previous studies using a visual search paradigm with non-facial stimuli (Blanchette, 2006; Öhman, Flykt, & Esteves, 2001; Tipples, Young, Quinlan, Broks, & Ellis, 2002; Waters, Lipp, & Spence, 2008). These studies have consistently reported that the detection of a target emotional stimulus (e.g., snakes, kittens) among distractors consisting of neutral stimuli (e.g., plants) was more efficient than that occurring in the reverse situation. Our results, together with these data, suggest that the emotional significance of facial and non-facial stimuli induces efficient detection.

The enhanced subjective awareness for emotional versus neutral facial expressions represents a related issue. Some researchers have proposed that attention and awareness are tightly coupled (e.g., Treisman & Kanwisher, 1998). Some previous studies using tachistoscopic presentations of schematic (Hugdahl, Iversen, & Johnsen, 1993; Magnussen, Sunde, & Dyrnes, 1994) and photographic (Sato & Yoshikawa, 2000) facial stimuli have reported that perceptual awareness of emotional facial expressions was enhanced compared with that of neutral facial expressions. Similar results have been reported by some studies under inattentional conditions with schematic (Mack & Rock, 1998) and photographic (Milders, Sahraie, Logan, & Donnellon, 2006) facial stimuli. These data, together with ours, suggest that efficient attentional capturing by emotional faces relative to neutral faces may enhance subsequent subjective awareness.

Our secondary purpose involved comparing the detection of angry and happy target expressions. Our results consistently showed that the RTs for detecting a normal angry face were shorter than those for detecting a normal happy face. These results are in accord with those of previous studies (e.g., Gilboa-Schechtman et al., 1999) and confirm that the photographs of angry expressions are more efficiently detected than those of happy expressions.

The superior detection of anger over happiness was observed for both normal and anti-expressions. These results can be interpreted in terms of the emotional significance of stimuli. The rating results of Experiment 2 showed that participants experienced higher arousal while viewing angry expressions than happy expressions, common to normal and anti-expressions. Furthermore, the regression analysis showed a negative relationship between RTs and emotional arousal ratings. These results suggest that superior detection of angry expressions rests on their greater emotional significance as compared to happy expressions.

Our results may account for previous inconsistent findings about the superior detection of anger versus happiness (e.g., positive and negative data in Gilboa-Schechtman et al., 1999 and Byrne and Eysenck, 1995, respectively). Our results suggest that the superior detection of angry expressions could be attributable to their higher emotional significance compared to happy expressions. Thus, one can expect that the use of different stimuli, including weaker angry expressions or stronger happy expressions, might produce different results. Based on our results, we propose that the emotional arousal, rather than the valence, of emotional facial expressions might be important for their efficient detection.

Some limitations affecting our study must be acknowledged. First, our results cannot completely exclude the effects of visual factors. Although the anti-expressions had featural changes comparable to those of the emotional facial expressions vis a vis the neutral expressions, these were nor comparable to emotional facial expressions in terms of other visual factors, such as holistic information (cf. Tanaka & Farah, 1993). Some researchers have proposed that facial expression recognition may be achieved by holistic template matching (e.g., Rutherford & McIntosh, 2007), which may induce different detection performances for normal and anti-expressions. Future studies are necessary to further investigate the influence of these visual factors on the detection of facial expressions.

Second, because we created artificial anti-expressions using a computer-morphing technique, there are limitations to the generalizability of the results obtained by this study. This method limited the extent to which open mouths could be depicted in material expressions, resulting in the use of only two models in the present stimulus set because other models portrayed widely opened mouths in depictions of angry and happy expressions. Although we found consistent results across models, further replication with different stimulus sets would enhance the robustness of these findings. A related issue concerns the difficulty of testing expressions depicting bared teeth. Some types of angry and happy facial expressions display teeth (Ekman & Friesen, 1975). Therefore, it must be noted that our findings are restricted to angry and happy expressions without bared teeth. Future research is needed to investigate the detection of emotional facial expressions including bared teeth.

In short, our main finding was that the RTs for detecting the normal angry and happy expressions were shorter than those for detecting the respective anti-expressions. This result suggests that efficient detection of emotional facial expressions is attributable to emotional significance rather than to visual characteristics.

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Table 1. Mean (with *SE*) ratings of valence, arousal, and familiarity.

Rating	AN	HA	aAN	aHA
Valence	-2.1(0.2)	1.5(0.2)	0.0(0.2)	-0.7(0.2)
Arousal	1.7(0.3)	0.3(0.3)	0.4(0.3)	-0.1(0.1)
Familiarity	2.9(0.2)	7.3(0.3)	4.9(0.4)	4.5(0.3)

AN = anger; HA = happiness; aAN = anti-anger; aHA = anti-happiness.

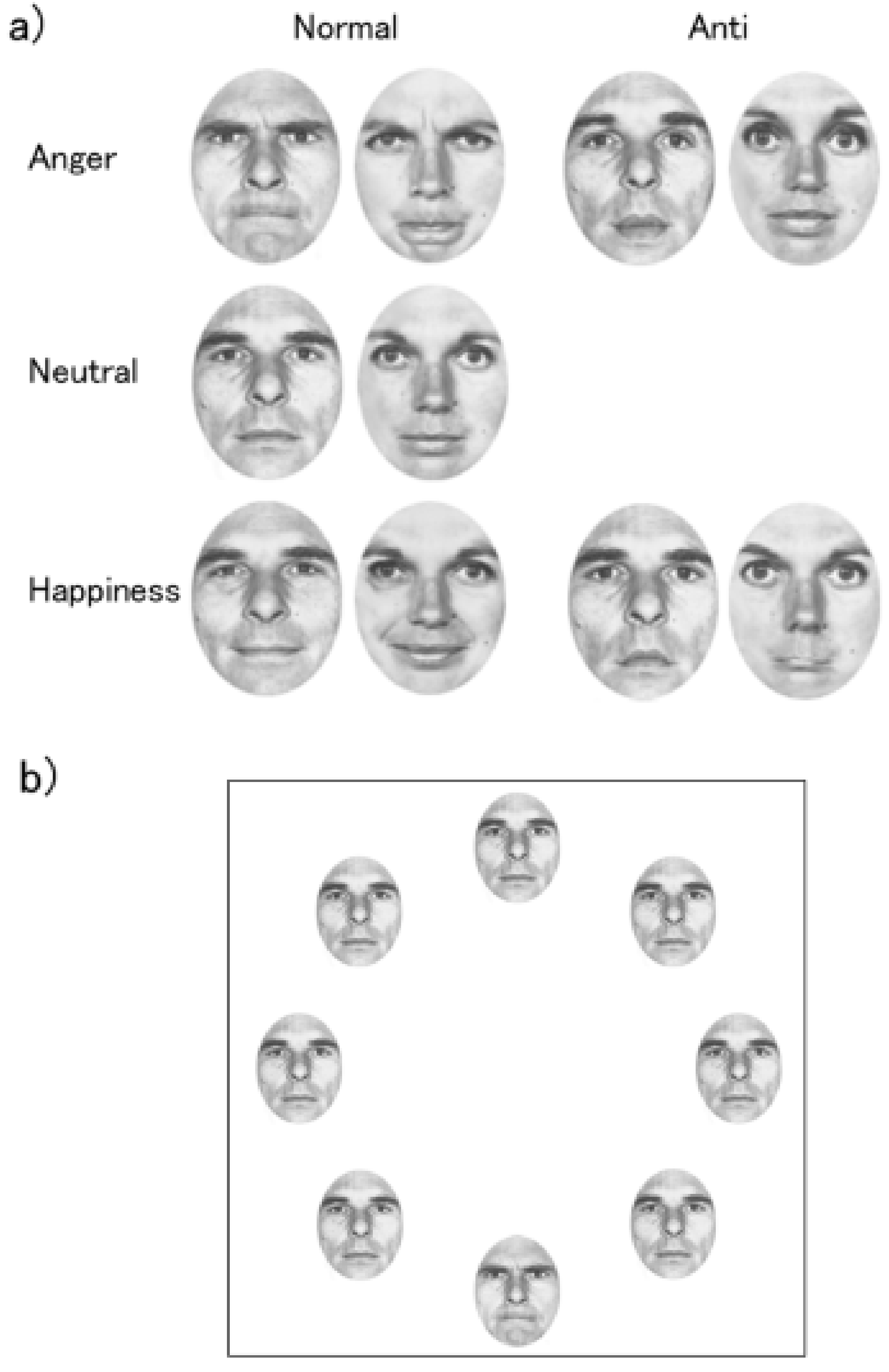

Figure 1. a) Examples of the target stimuli. b) An example of the display panels used in Experiment 1.

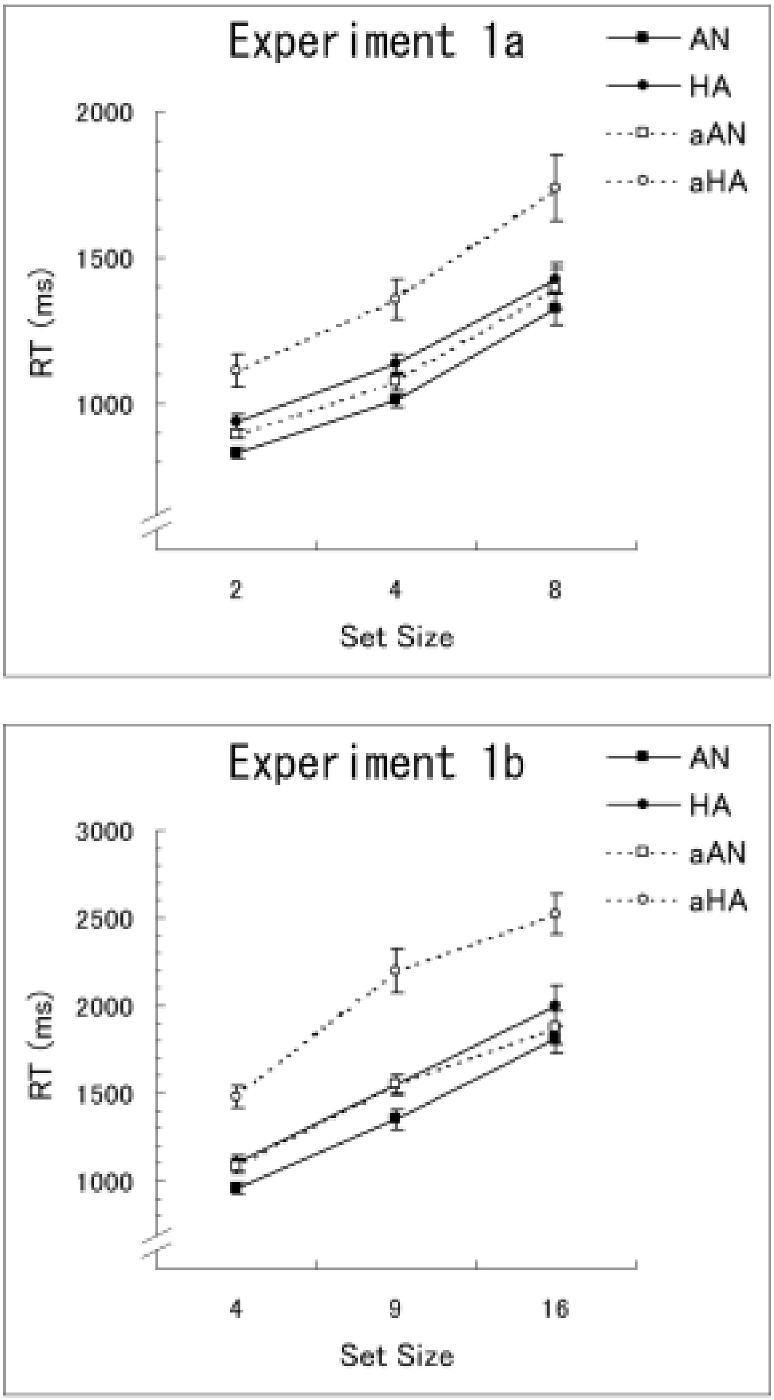

Figure 2. Mean (with *SE*) reaction time (RT) in Experiment 1a (upper) and 1b (lower). AN = anger; HA = happiness; aAN = anti-anger; aHA = anti-happiness.

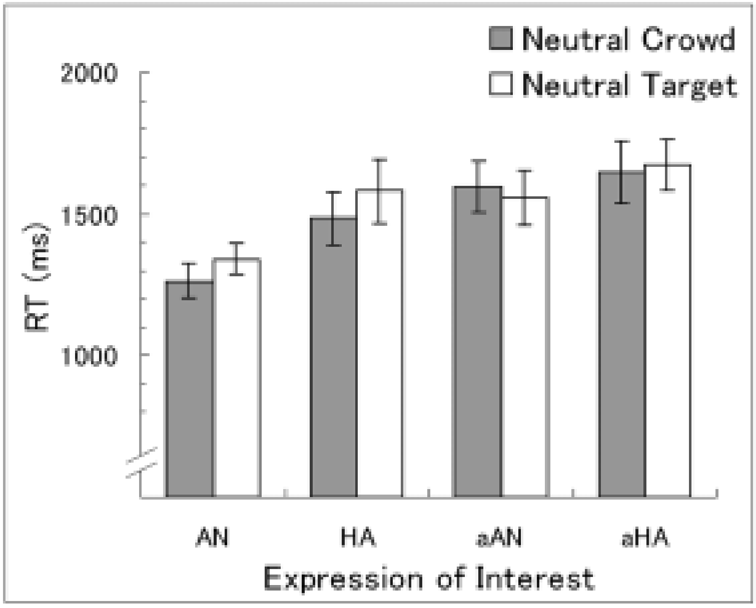

Figure 3. Mean (with *SE*) reaction time (RT) in Experiment 2. AN = anger; HA = happiness; aAN = anti-anger; aHA = anti-happiness.

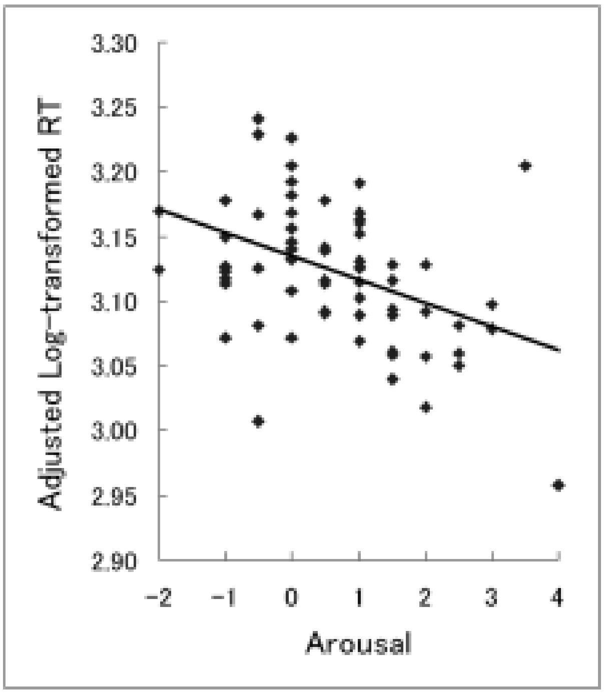

Figure 4. Scatter plot of the relationship between the adjusted log-transformed reaction time (RT) and the ratings of arousal. The regression line is also plotted.