Computer-enhanced emotion in facial expressions

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SUMMARY

Benson & Perrett's (1991*b*) computer-based caricature procedure was used to alter the positions of anatomical landmarks in photographs of emotional facial expressions with respect to their locations in a reference norm face (e.g. a neutral expression). Exaggerating the differences between an expression and its norm produces caricatured images, whereas reducing the differences produces 'anti-caricatures'. Experiment 1 showed that caricatured (+50% different from neutral) expressions were recognized significantly faster than the veridical (0%, undistorted) expressions. This held for all six basic emotions from the Ekman & Friesen (1976) series, and the effect generalized across different posers. For experiment 2, caricatured (+50%) and anti-caricatured (−50%) images were prepared using two types of reference norm; a neutral-expression norm, which would be optimal if facial expression recognition involves monitoring changes in the positioning of underlying facial muscles, and a perceptually-based norm involving an average of the expressions of six basic emotions (excluding neutral) in the Ekman & Friesen (1976) series. The results showed that the caricatured images were identified significantly faster, and the anti-caricatured images significantly slower, than the veridical expressions. Furthermore, the neutral-expression and average-expression norm caricatures produced the same pattern of results.

1. INTRODUCTION

Rhodes *et al.* (1987) have demonstrated that caricatured line drawings of familiar faces are recognized faster than veridical (undistorted) line drawings of the same faces. More recently, a similar advantage has been found with photographic-quality caricatures of celebrities' faces (Benson & Perrett 1991*a*; Calder *et al.* 1996).

The particular interest of these studies lies in the fact that the caricatures used were created using objective computer-based procedures. These were developed by Brennan (1985) for line drawings, and then modified by Benson & Perrett (1991*a*, *b*) to produce photographic-quality images. Both versions of computer caricature generator incorporate the same fundamental stages. First, the anatomical features (eyes, nose, etc.) of a target face are marked with a set number of points. Second, the location of each point is compared with the location of an anatomically identical point (e.g. the tip of the nose, the right-most corner of the mouth) in a reference norm; the norm for computerized caricaturing of identity comprises the average locations of these features abstracted from a number of different faces. By increasing the distances between corresponding pairs of points on the to-be-caricatured face and the reference norm, a caricatured representation is produced. Similarly, reducing these distances generates an 'anti-caricatured' representation, an image that is less easily recognized than the original.

Computer-caricatured faces have been used to investigate physical cues underlying the perception of age (Burt & Perrett 1995) and identity (Rhodes *et al.* 1987; Benson & Perrett 1991*a*; Calder *et al.* 1996); these involve aspects of cranio-facial structure that change only slowly, across periods of years. However, the surface features of the face are constantly being manipulated by muscles, one function of which is to signal emotion via facial expressions (Ekman *et al.* 1972). These plastic changes often have short time-courses, and must be continuously monitored in social interaction for cues they convey to an individual's feelings.

We therefore decided to investigate whether the perception of social signals conveyed by mobile facial characteristics can be enhanced by caricaturing. This becomes doubly important when we consider strong evidence that facial expressions are processed independently of facial identity. Reports of double dissociations between groups of brain-injured people (Young *et al.* 1993), cognitive studies of normal subjects (Young *et al.* 1986), single-cell recording in non-human primates (Hasselmo *et al.* 1989) and PET studies of the human brain (Sergent *et al.* 1994) all converge on the view that different neural structures are involved in the recognition of identity and expression from the face.

In experiment 1, then, we examined whether computer-caricaturing procedures can enhance the recognizability of facial expressions of emotion; results showed clearly that this is so. In experiment 2 we replicated this finding and investigated the basis of this caricature effect. We reasoned that a way of addressing this issue would be to examine the effect of changing the reference norm with respect to which the caricatured expressions were created.

It is generally thought that identity caricaturing works by enhancing a face's distinctiveness, and recently Calder *et al.* (1996) and Stevenage (1995) have provided evidence to support this claim. If we apply the same principle to the recognition of caricatured expressions of emotion, we can see that their distinctiveness might be enhanced through caricaturing relative to facial expressions one has seen before (a perceptual norm), or through caricaturing relative to patterns of movements of the facial muscles one has encountered before (a muscle-based norm).

To investigate the basis of the caricature effect, then, experiment 2 used two different reference norms to generate the computer-caricatured expressions. One norm was derived from a neutral pose, in which facial muscles are relaxed; this muscle-based norm would be optimal if facial expression recognition involves monitoring changes in the positioning of underlying facial muscles. The other norm used an average of the expressions of six basic emotions (excluding neutral) in the Ekman & Friesen (1976) series; this corresponds to a perceptually-based norm, in the sense that it is the average from which other expressions deviate.

For these experiments, caricatured expressions were prepared from greyscale photographs of facial expressions from the Ekman & Friesen (1976) series of pictures of facial affect. This series contains examples of facial expressions associated with basic emotions of happiness, surprise, fear, sadness, disgust and anger, as well as neutral poses. Ekman (1972, 1994) has shown that each of these expressions is associated with a distinct facial musculature, and is recognized in a number of cultures throughout the world.

2. EXPERIMENT 1

(*a*) *Subjects*

Twelve members of the MRC Applied Psychology Unit subject panel with normal or corrected-to-normal vision participated in the experiment. They were between the ages of 20 and 50 years and were paid for participating.

(*b*) *Materials*

Stimuli were created from photographic-quality images (8-bit greyscale) of eight models from the Ekman & Friesen (1976) series (see Appendix 1), each posing one example of the emotional expressions happiness, surprise, fear, sadness, disgust or anger. The models' hair and background details were masked with grey.

The caricature procedure will be described in outline only; for a full description see Benson & Perrett (1991*b*).

Photographs of the facial expressions posed by each model were frame-grabbed at a resolution of 512 × 720 pixels with 256 grey levels. The anatomical features of each facial expression were highlighted with 195 manually positioned points, with each facial feature represented by a set number of points (e.g. 22 points for the mouth). Each facial expression was then stored as a 195-point x/y coordinate database.

Each expression's x/y coordinate database was compared to its reference norm, and the differences in location between equivalent points in the two databases were exaggerated by a factor of 1.5 (i.e. +50%). For each of the six emotional expressions posed by any one model, the reference norm was a picture of the same model posing a neutral expression. This meant that the identity, gender, and age of the target and norm expressions were identical. This was done to minimize the possibility that any effect of caricature could be attributed to the enhancement of characteristics other than the face's expression.

The result of the procedures described thus far was to produce caricatured face shapes of the six expressions. Next, a triangulation was performed on the feature points of the veridical (0%, undistorted) continuous-tone image for each expression to produce a mesh of triangles with the shortest possible sides; details of this triangulation procedure can be found in Benson & Perrett (1991*b*). The feature points in each caricatured (+50%) face shape were also triangulated so that the vertices of each triangle were identical to those in the corresponding veridical image. Finally, the pixel intensity in each of the veridical triangles was mapped on to the corresponding triangle in the caricature by altering the spatial distribution to the new shape.

Figure 1 shows examples of the veridical (0%) and caricatured (+50%) expressions of all six emotions for one of the eight models.

(*c*) *Design and procedure*

Each trial consisted of four consecutive components: a 250 ms presentation of a central fixation cross, a blank interval of 500 ms, the target face for 500 ms and finally a facial mask. The mask was a picture of a man posing a neutral expression, which remained in view until the subject responded. The 96 images (six emotions × eight models × two levels of enhancement) were presented in a random order on a 256 greyscale monitor. The visual angle of presentation was approximately 3.6° (horizontal) × 5.2° (vertical). The subject's task was to identify the face's expression as quickly and accurately as possible by pressing one of six keys on a response box marked with the six emotion labels; the positions of these labels were randomized across subjects. The computer recorded the choice of emotion and the reaction time (from stimulus onset) for each target image. Subjects were presented with three blocks of trials, which ran consecutively without breaks. Each block contained one presentation of the 48 veridical (0%) and 48 caricatured (+50%) images.

To acquaint subjects with the experimental task, the experiment began with 72 practice trials. These contained veridical (0%) and caricatured (+50%) representations of the six target expressions posed by a

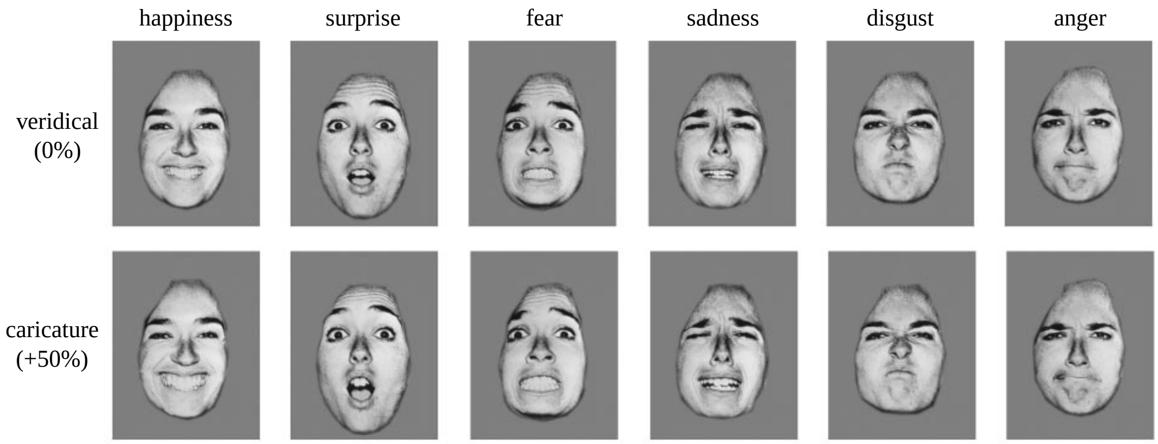

Figure 1. Examples of veridical (0%) and caricatured (+50%) representations of facial expressions used in experiment 1. One model is shown posing expressions associated with the six basic emotions happiness, surprise, fear, sadness, disgust and anger. Caricatured (+50%) representations were prepared relative to a neutral-expression norm.

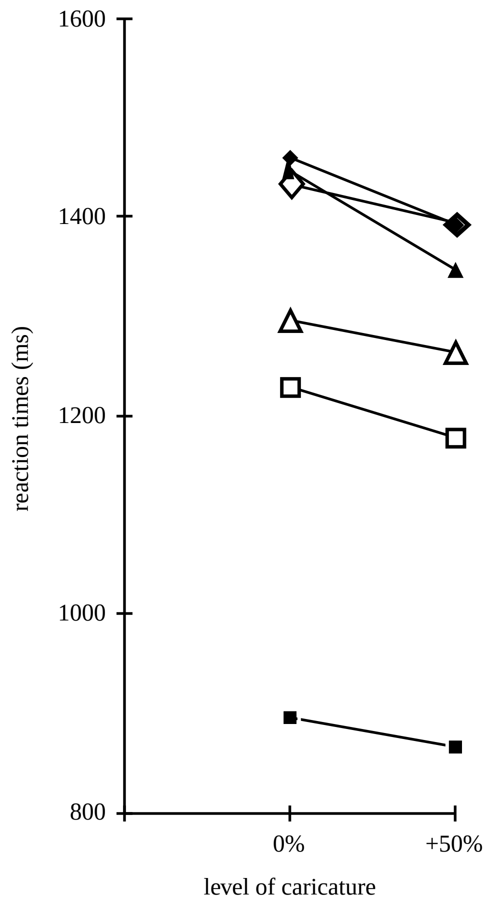

Figure 2. Graph for experiment 1 showing subjects' mean correct reaction times for recognizing facial expressions of happiness, surprise, fear, sadness, disgust and anger in their veridical (0%) and caricatured (+50%) forms. Filled squares, happy; open squares, sad; filled diamonds, anger; open diamonds, fear; filled triangles, disgust; open triangles, surprise.

further two models who were not used in the experimental trials.

(*d*) ***Results***

Our principal analyses involved reaction times for correct responses. Reaction times (RTs) greater than 3000 ms (0.01% of the data) were excluded from the analysis. The subjects' mean correct RTs (with outliers removed) are summarized in figure 2.

The RT data were submitted to three-factor ANOVAs by subjects (F_1) and by items (F_2); here the term item refers to the identity of the model posing the expression. The factors analysed in each ANOVA were trial block (block 1, block 2 and block 3; repeated measure), target emotion (happiness, surprise, fear, sadness, disgust and anger; repeated measure) and level of caricature (0% and +50%; repeated measure). Both analyses showed a significant effect of caricature, $F_1\ (1,11) = 10.74, p < 0.01, F_2\ (1,7) = 7.85, p < 0.05$. Hence the caricatured expressions were recognized significantly faster than the original expressions used to create them. There was also a significant effect of emotion, $F_1\ (5,55) = 26.67, p < 0.001, F_2\ (5,35) = 15.80, p < 0.001$; post-hoc *t*-tests ($p < 0.05$) showed that for both analyses happiness was recognized significantly faster than the other five emotions. Note, there were no significant interaction effects between the three factors. Finally, the items, but not the subjects analysis showed a significant effect of block, $F_2\ (2,7) = 11.10, p < 0.005$; post-hoc *t*-tests ($p < 0.05$) showed that subjects' RTs were faster in blocks 2 and 3 than in block 1. There were no other significant effects (all other F_1s and F_2s < 1).

A subsidiary analysis examined error rates to check that enhanced speed of responding to caricatured expressions was not at the cost of accuracy. Error proportions for each expression category were as follows: happiness 0% = 0.01, +50% = 0.02; surprise 0% = 0.13, +50% = 0.20; fear 0% = 0.29, +50% = 0.23; sadness 0% = 0.29, +50% = 0.40; disgust 0% = 0.26, +50% = 0.27; anger 0% = 0.31, +50% = 0.34. Error proportions were arcsin-transformed and submitted to three-factor ANOVAs by subjects (F_1) and by items (F_2). There was no sign of an effect of caricature ($F_1 < 1.5$, $F_2 < 1$); hence subjects' error rates to the veridical and caricatured expressions did not differ. Both analyses showed a significant effect of emotion $F_1\ (5,55) = 15.78, p < 0.001, F_2\ (5,35) = 2.78, p < 0.05$; post-hoc *t*-tests ($p < 0.05$) showed that happiness was recognized more accurately than the other emotions. These effects were exactly in line with those noted for reaction time, showing no trade-off. There was also a significant interaction effect between block and emotion, F_1 (10,110) = 2.74, $p < 0.005$, F_2 (10,70) = 3.02, $p < 0.005$; simple effects analyses showed that from blocks 1 to 3 there were trends towards fewer errors for fear ($0.1 > p_{1\&2} > 0.05$), and slightly more errors for sadness ($p_1 < 0.05$; $0.1 > p_2 > 0.05$).

(*e*) *Discussion*

The results of experiment 1 present a simple message; caricaturing facial expressions of basic emotions facilitates their recognition with no significant cost to accuracy. This pattern was found in both the subjects and items analyses, showing that the effect generalizes across subjects and across the different examples of the facial expressions used.

Neither of the RT analyses showed a significant interaction between the level of enhancement (0 % and +50 %) and target emotion (happiness, surprise, fear, sadness, disgust and anger); this demonstrates that the caricature effect generalizes across the six basic emotions tested. This is of particular importance because recognition of emotions such as happiness is effectively at its ceiling in the Ekman & Friesen (1976) set; yet caricaturing still facilitates speed of recognition. Note also that none of the analyses showed a significant interaction between the level of enhancement and trial block; demonstrating that the size of the caricature effect remained relatively constant across the three blocks of trials. This implies that the caricature advantage does not incorporate any substantial learning component.

Experiment 1 used caricatures prepared relative to a neutral-expression norm. As discussed in §1, an average-expression norm might also provide a suitable basis for caricaturing, and an interesting contrast to the neutral-expression norm. Experiment 2 investigated this issue by comparing subjects' performance with facial expressions caricatured relative to both neutral-expression and average-expression norms. Also, in addition to the veridical (0 %) and caricatured (+50 %) representations, an anti-caricature (−50 %) level was included. Recall from §1 that an anti-caricature representation is one in which the position of the target face's features are shifted towards the position of the same anatomical features in the norm face.

In experiment 2 we used one model from the Ekman & Friesen (1976) series. We felt that this was justified given the degree of concordance found across the results from the eight different models used in experiment 1, and to test this issue further we chose a model that was not used in the previous experiment. Finally, experiment 2 used a slightly different procedure to experiment 1. In experiment 1 the target face was presented briefly (500 ms) with a neutral expression mask. In experiment 2 the target face was left in view for 2 s. Using this longer exposure allowed us to assess whether the caricature advantage was dependent on using a short presentation time.

3. EXPERIMENT 2

(*a*) *Subjects*

Twenty-four people between the ages of 20 and 40 years and from the same source as experiment 1 participated in the experiment.

(*b*) *Materials*

Photographic-quality images of model JJ from the Ekman & Friesen (1976) series, posing one example of the six basic emotions used in experiment 1, were prepared at three levels of caricature (−50 %, 0 % and +50 %).

Two sets of images were constructed. One set used the procedure outlined for experiment 1, with JJ's neutral-expression pose as the reference norm. The other set used an average-expression norm created from the mean locations of the reference points across the six different emotions posed by model JJ. The resulting sets of images are shown in figure 3.

(*c*) *Design and procedure*

For each of the neutral-expression and average-expression norm caricatures there were 18 face images per set (six emotions × three levels of caricature). Half (12) of the subjects were presented with the average-expression norm images, and half with the neutral-expression norm images.

The presentation format for the two groups of subjects was identical. Each trial consisted of a 250 ms presentation of a fixation cross, a blank interval of 500 ms and then the target face for 2 s. Subjects categorized the face's expression by pressing one of six keys, as in experiment 1. When the subject had seen the 18 different images, the same procedure was immediately repeated a further eight times, using different random orders for each block of trials, and with no breaks between blocks. The first block was discounted as practice, leaving eight blocks of data for analysis. In all other respects (equipment, visual angle, etc.) the procedure was identical to that of experiment 1.

(*d*) *Results*

As for experiment 1, RTs for correct responses constitute the principal focus of interest; RTs greater than 3000 ms (0.46 % of the data) were again excluded from the analysis. Mean correct reaction times pooled across the six emotions are illustrated in figure 4.

The RT data were pooled across the six emotions and submitted to a two-factor ANOVA examining type of norm (neutral-expression and average-expression; between subjects), and level of caricature (−50 %, 0 % and +50 %; repeated measure). There was a significant effect of level of caricature, $F(2,22) = 26.22$, $p < 0.001$. Post-hoc *t*-tests ($p < 0.05$) showed that the +50 % caricatures were recognized fastest, followed by the veridical (0 %) images and then the −50 % anti-caricatures. The main effect of norm and the interaction between type of norm and level of caricature

Figure 3. The reference norms and sets of caricatured expressions used in experiment 2. Six facial expressions posed by a single male were caricatured at three levels of exaggeration (-50%, 0% and $+50\%$) relative to two different types of norm: an average-expression norm (left; note that an average pigmentation has been superimposed on this image to make the shape easier to interpret visually) and a neutral-expression norm (right). From top to bottom the six emotions shown are happiness (top row), surprise (second row), fear (third row), sadness (fourth row), disgust (fifth row) and anger (bottom row).

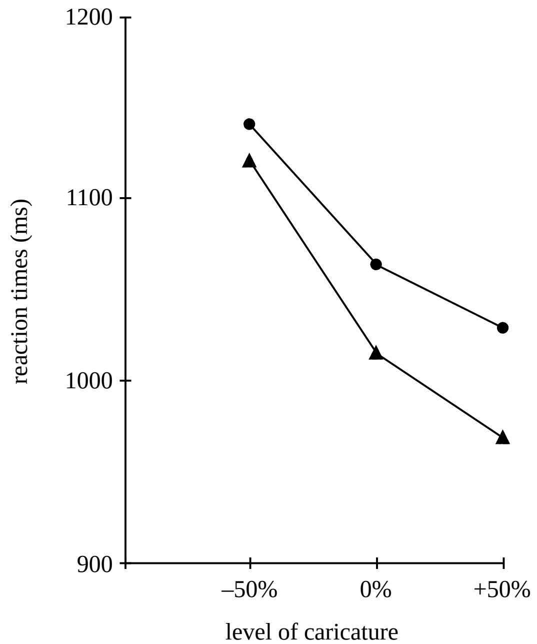

Figure 4. Graph for experiment 2 showing subjects' mean correct reaction times for the three levels of caricature (-50%, 0% and $+50\%$), with images prepared relative to neutral-expression and average-expression norms. Filled circles, average norm; filled triangles, neutral norm.

were not significant (Fs < 1), indicating that the same pattern of caricature effect ($+50\% < 0\% < -50\%$) was observed in both norm conditions.

In a subsidiary analysis, error proportions were arcsin-transformed and submitted to a two-factor ANOVA. Error proportions for the two norm conditions were as follows: average-expression norm $-50\% = 0.04$, $0\% = 0.03$, $+50\% = 0.03$; neutral-expression norm $-50\% = 0.10$, $0\% = 0.06$, $+50\% = 0.04$. There was a significant effect of level of caricature, $F(2,22) = 7.34$, $p < 0.005$. Post-hoc t-tests ($p < 0.05$) showed that the -50% anti-caricatures were recognized less accurately than the veridical (0%) images; the trend towards more accurate recognition of the $+50\%$ caricatures did not reach statistical significance. Thus there was no sign of subjects trading accuracy for speed.

(*e*) *Discussion*

Experiment 2 shows three things. First, the data replicate the main finding of experiment 1; caricatures ($+50\%$) of facial expressions are recognized significantly faster than their veridical (0%) representations. This held even though the experiment used a new model and a different presentation time.

Second, experiment 2 extends this finding by showing that veridical (0%) expressions are recognized faster than their anti-caricatured (-50%) equivalents.

Third, the average-expression and neutral-expression norm caricatures produce the same basic pattern of effects. In fact, inspection of figure 3 shows that caricatures and anti-caricatures produced from the different reference norms were quite similar in appearance. We are thus unable to use this manipulation to arbitrate between muscle-based and perceptually-based models of emotion recognition, and must note instead that these different theories may have very similar empirical consequences.

4. GENERAL DISCUSSION

These experiments demonstrate that caricaturing facial expressions ($+50\%$) facilitates their recognition (experiments 1 and 2), whereas anti-caricaturing (-50%) impairs recognition (experiment 2). The findings were shown to generalize across different basic emotions and across posers' identities in experiment 1, and to be obtainable for caricatures prepared relative to neutral-expression or to average-expression norms in experiment 2. These results are important because previous caricature research has only examined non-dynamic changes in facial structure. In addition, the prototype expressions from the Ekman & Friesen (1976) series are sufficiently salient to be readily and reliably identified in a number of cultures, with recognition rates often close to 100% in Western societies. Therefore, any enhancement of perceived emotion for these expressions is decidedly non-trivial.

Clearly, then, the caricature advantage reflects a general perceptual phenomenon, being found as readily for facial expression recognition as it is for recognition of structural characteristics such as age or identity.

The natural interpretation of these results would be that facial expression recognition uses a similar representational framework to the facial identity system; a framework that employs a coding system that caricatures can exploit to their advantage. An influential current account of the representation of facial distinctiveness is Valentine's (1991) multidimensional space model. To the extent that it provides an adequate account of caricature effects on the recognition of identity, then, Valentine's model may also give interesting insights into the recognition of emotion from the face. However, if one were to use the multidimensional space conception for the coding of facial expressions, such a space would likely have a lower dimensionality for expression than identity (because we recognize fewer expressions than identities). In addition, it is possible that the coding of facial expressions involves a relatively small number of feature changes (mouth shape, eye shape, nose shape, eyebrow positioning, etc.), and that caricaturing simply facilitates the coding of what would effectively be a feature checklist.

Up to this point we have noted certain similarities between facial identity and facial expression caricatures and their comparable effects on recognition. However, it is also important to note that there is a fundamental difference between these two types of stimuli. Caricatured identities are non-veridical in that they no longer look exactly like the person; a consequence of this is that once a certain limit is passed, the image looks like a caricature of person X, not an actual photograph of X. Caricatured expressions are also non-veridical in the sense that they are derived from a prototype image. However, they do not have the 'artificial' appearance of identity caricatures; in our figures it is not immediately obvious to the viewer which are the original images and which are the caricatures.

For facial expressions, then, the caricature effect may operate by shifting an expression along a dimension that corresponds to variations in the emotion's intensity; in support of this suggestion we have noticed that the caricature transformation will work smoothly up to limits well beyond those used for the present study. Further work using expression measurement techniques such as facial action coding system scoring (Ekman & Friesen 1984) may help to establish whether this is because our computer-enhanced expressions accurately mimic the effects of movements of the facial muscles, or whether they enhance facial signals of emotion by going beyond the range of naturally occurring movements. In addition, it may be useful to determine whether intensity judgements are monotonically related to the degree of caricature for these computer-enhanced facial expressions.

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APPENDIX 1.

A list of identifiers and recognition rates for the photographs from the Ekman & Friesen (1976) series used in experiments 1 and 2.

(*a*) *Experiment 1*

Experimental faces; identifier in the Ekman & Friesen (1976) series, and percentage recognition as this emotion in their norms:

Happiness (mean = 99%):
7 C-2-18; 14 EM-4-07; 57 MO-1-04; 66 NR-1-06; 74 PE-2-12; 85 PF-1-06; 93 SW-3-09; 101 WF-2-12.

Surprise (mean = 90%):
11 C-1-10; 19 EM-2-11; 63 MO-1-14; 70 NR-1-14; 81 PE-6-02; 90 PF-1-16; 97 SW-1-16; 107 WF-2-16.

Fear (mean = 88%):
9 C-1-23; 16 EM-5-21; 37; 59 MO-1-23; 68 NR-1-19; 79 PE-3-21; 88 PF-2-30; 95 SW-2-30; 104 WF-3-16.

Sadness (mean = 89%):
8 C-1-18; 15 EM-4-24; 36 JJ-5-05; 49 MF-1-30; 58 MO-1-30; 67 NR-2-15; 75 PE-2-31; 86 PF-2-12; 94 SW-2-16; 102 WF-3-28.

Disgust (mean = 94%):
12 C-1-04; 20 EM-4-17; 40 JJ-3-20; 55 MF-2-13; 64 MO-2-18; 71 NR-3-29; 82 PE-4-05; 91 PF-1-24; 98 SW-1-30; 108 WF-3-11.

Anger (mean = 90%):
10 C-2-12; 18 EM-5-14; 38 JJ-3-12; 53 MF-2-07; 61 MO-2-11; 69 NR-2-07; 80 PE-2-21; 89 PF-2-04; 96 SW-4-09; 105 WF-3-y01.

Neutral mask face 41 JJ-3–04.

(*b*) *Experiment 2*

Experimental faces; identifier in the Ekman & Friesen (1976) series, and percentage recognition as this emotion in their norms:

Happiness (100%): 34 JJ-4-07.
Surprise (97%): 39 JJ-4-13.
Fear (96%): 37 JJ-5-13.
Sadness (93%): 36 JJ-5-05.
Disgust (88%): 40 JJ-3-20.
Anger (76%): 38 JJ-3-12.

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