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The Reverse-Caricature Effect Revisited: Familiarization With Frontal Facial Caricatures Improves Veridical Face Recognition

JOBANY RODRÍGUEZ[1], HEATHER BORTFELD[1], ISAAC RUDOMÍN[2], BENJAMÍN HERNÁNDEZ[2] and RICARDO GUTIÉRREZ-OSUNA[1]*

[1]*Texas A&M University, USA*
[2]*Instituto Tecnológico de Monterrey, Mexico*

SUMMARY

Prior research suggests that recognition of a person's face can be facilitated by exaggerating the distinctive features of the face during training. We tested if this 'reverse-caricature effect' would be robust to procedural variations that created more difficult learning environments. Specifically, we examined whether the effect would emerge with frontal rather than three-quarter views, after very brief exposure to caricatures during the learning phase and after modest rotations of faces during the recognition phase. Results indicate that, even under these difficult training conditions, people are more accurate at recognizing unaltered faces if they are first familiarized with caricatures of the faces, rather than with the unaltered faces. These findings support the development of new training methods to improve face recognition. Copyright © 2008 John Wiley & Sons, Ltd.

Across a wide range of social judgments and perceptions, individuals' distinct qualities typically are given greater weight than their more common or normative qualities (Blanton & Christie, 2003). This principle applies to face recognition as well. People generally have better recollection for visually distinct faces or for faces with one or more distinct qualities (Going & Read, 1974; Light, Kayra-Stuart, & Hollander, 1979; Valentine, 1991; Valentine & Bruce, 1986; Wells, Memon, & Penrod, 2006). A prominent chin, nose or hairstyle can grab attention during initial exposure and then be used as a memory aid during recognition. This simple fact can be harnessed to create more memorable stimuli. Researchers pursuing this strategy create 'caricatures' of normal faces by exaggerating their distinct qualities, and they find that people are more able to recognize these distorted faces than the veridical faces that were used to create them. This *caricature effect* is well established in the literature on face recognition (Benson & Perrett, 1994; Cheng, Knappmeyer, & Bülthoff, 2000; Lee, Byatt, & Rhodes, 2000; Mauro & Kubovy, 1992; Rhodes, Brennan, & Carey, 1987).

A handful of studies subsequently have demonstrated a *reverse-caricature effect* in which familiarization with caricatures improves recognition of an image of the veridical face (e.g. Deffenbacher, Johanson, Vetter, & O'Toole, 2000; Mauro & Kubovy, 1992;

*Correspondence to: Ricardo Gutiérrez-Osuna, Department of Computer Science, Texas A&M University, TAMU 3112, College Station, TX, USA. E-mail: rgutier@cs.tamu.edu

Stevenage, 1995). A conceptual parallel to the reverse-caricature effect can be found in speech recognition, where exaggeration of auditory features can aid in learning unexaggerated nonnative phonetic contrasts (McCandliss, Fiez, Protopapas, Conway, & McClelland, 2002). Consider as an example the difficulty that native speakers of Japanese have trying to discern the difference between the English phonemes [r] and [l] (this occurs because this particular contrast in sounds is not present in Japanese.) Research indicates that training with spectrally exaggerated versions of these two sounds can help Japanese speakers recognize the unexaggerated versions of these same sounds (McCandliss et al., 2002). Similarly, the reverse-caricature effect demonstrates the potential of using caricatures for training in applied face recognition settings.

A variety of issues regarding the implementation of the reverse-caricature effect need to be examined before the technique will be ready for use in an applied setting. For example, due to technological limitations, the earliest studies of the caricature effect (both direct and reverse) involved some combination of caricaturized photographs or line drawings (Benson & Perrett, 1991a; Lee et al., 2000; Mauro & Kubovy, 1992; Powell, Letson, Davidoff, Valentine, & Greenwood, 2008; Rhodes et al., 1987; Stevenage, 1995). In more recent work (e.g. Deffenbacher et al., 2000; O'Toole, Vetter, Volz, & Salter, 1997) researchers have used three-dimensional (3D) laser scans. Together with the application of a caricature algorithm (see Benson & Perrett, 1991b; Brennan, 1985; Rhodes et al., 1987), these presentations allow for greater experimental control than can be obtained using photograph manipulations or line drawings. However, the influence of this new technology, as well as the presentation choices one might make in using it, has not been studied in a systematic fashion.

In one demonstration of the reverse-caricature effect, Deffenbacher et al. (2000) used presentation of a three-quarter view of the 3D stimuli, at both familiarization and test, and this choice of presentation may have been consequential. Other studies focussing on veridical faces have demonstrated that there is an advantage in recognition memory for faces that employ a three-quarter view representation, when compared to either a frontal or profile representation (e.g. Bruce, Valentine, & Baddeley, 1987; Krouse, 1981; Logie, Baddeley, & Woodhead, 1987). It remains unclear, however, whether the reverse-caricature effect will generalize to 3D scans in which caricatures are presented only frontally during familiarization. Also of note, Deffenbacher et al. (2000) familiarized participants with target faces for a total of 60 seconds each prior to recognition testing. The authors indicated that a reverse-caricature effect does not occur with shorter familiarization periods, a constraint that could undermine the feasibility of reverse caricaturing as a training approach in practical scenarios. Given that relatively little work has been done on the conditions that support a reverse-caricature effect, the goal of the present study was to establish tighter boundary conditions under which this effect can occur.

OVERVIEW

In an initial calibration study, we used a modified old/new face recognition procedure (Duchaine, Nieminen-von Wendt, New, & Kulomaki, 2003; Goldstein & Chance, 1980) to determine the minimal degree of exaggeration between veridical and caricature faces that would lead to a direct caricature effect (i.e. whereby caricatures would be recognized more accurately than veridical faces) (Benson & Perrett, 1994; Rhodes et al., 1987). This

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exaggeration level was then used as the basis for each of the subsequent recognition experiments. Then, in order to better mimic the canonical viewpoint for faces and in contrast to the procedure used by Deffenbacher et al. (2000), we used the above old/new face recognition procedure to establish whether the reverse-caricature effect would manifest when only a frontal representation of unfamiliar faces was given during both training and testing (Experiment 1). In the subsequent two experiments (Experiments 2 and 3), we shortened familiarization times, and introduced random facial rotations at test. We predicted that, even under these more difficult conditions, familiarization with caricatures would produce greater recognition performance with unexaggerated faces than would familiarization with veridical versions of those faces.

Participants

Participants were recruited from an Introductory Psychology pool. All participants were undergraduate students (ages 18–25). Ninety-nine students ($n = 60$ female, $n = 39$ male) participated in the calibration study; 88 ($n = 59$ female, $n = 29$ male), 102 ($n = 74$ female, $n = 28$ male) and 102 ($n = 76$ female, $n = 26$ male) students participated in the reverse-caricature studies Experiment 1–3, respectively. A similar gender distribution for participants was maintained across experimental conditions in all studies.

CALIBRATION STUDY

Procedure

Stimuli consisted of forty 3D face models of both genders randomly selected from a larger database of faces maintained at the University of Freiburg (Blanz & Vetter, 1999). All face models were transformed into a geometry image representation, where vertices are mapped into colour pixels, with their XYZ coordinates coded as RGB colours. This representation allowed us to treat 3D facial models as colour images, which facilitated data processing. As shown in Figure 1, faces were rendered frontally without facial texture to focus attention on anthropometric features. From the original set of 40 faces, a corresponding set of caricatures was created by linearly exaggerating the difference between each face (Figure 1, centre) and the average for the database (Figure 1, left). Given that statistically distinct faces need to be caricaturized less than statistically average faces, all facial stimuli

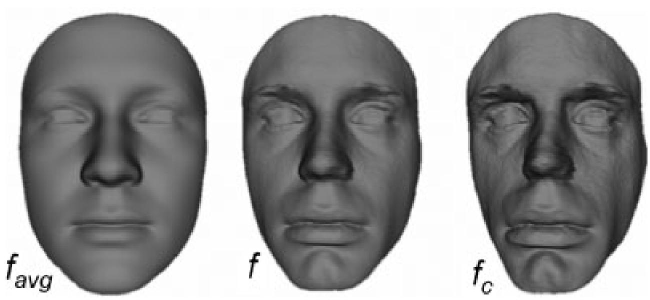

Figure 1. Sample stimuli. The average face (f_{AVG}), a veridical face (f), and its corresponding caricature (f_C) with an exaggeration level $\alpha = +0.64$

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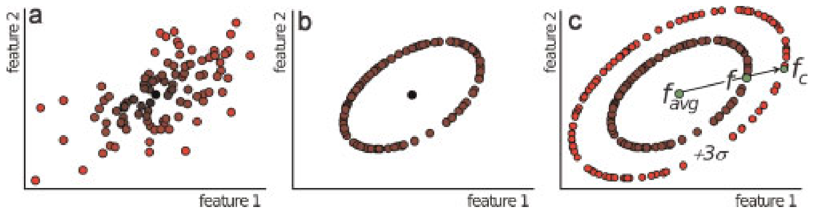

Figure 2. (a) Distribution of faces in a hypothetical two-dimensional space, (b) following normalization by their distance to the average face and (c) following caricaturization

were first normalized to ensure that the same caricature factor could be applied to each face to achieve equivalent levels of distinctiveness (O'Toole et al., 1997). For this purpose, each face f was first normalized by its Mahalanobis distance[1] ($\|\cdot\|_M$) to the average face f_{AVG} $[f = f/\|f - f_{AVG}\|_M]$. Following Brennan (1985), faces were then linearly exaggerated with respect to f_{AVG} $[f_C = f_{AVG} + (1+\alpha)(f - f_{AVG})]$. The overall process is illustrated in Figure 2. Using this method, seven groups of stimuli (40 faces each) were created for testing: six levels of caricature plus the non-exaggerated baseline.[2]

Stimuli were displayed on a 17-inch monitor, configured to a 1280 by 1024 resolution at 60 Hz. Seven groups of participants ($n = 13$, 14, 14, 15, 15, 15, 13) were first familiarized with 10 randomly chosen target faces. Following the experimental procedure in Duchaine et al. (2003), each target face was presented twice for 3 seconds at a time. Afterwards, participants were tested on 50 faces, of which 30 were new (non-target) faces and 10 were the learned targets. The latter were presented twice to increase the amount of data collected during calibration (i.e. each presentation was treated as a different observation). Caricature level was held constant between familiarization and test for each group. Target and non-target faces within a group had the same caricaturization level. Participants were not aware of which exaggeration level they were viewing. Order of presentation was randomized across participants for both familiarization and test. Following Duchaine et al. (2003) and Goldstein and Chance (1980), no time limits were imposed, but participants were asked to make their decision (i.e. old *vs*. new face) as rapidly as possible without sacrificing accuracy.

Results

Recognition accuracy was measured in this and later experiments using the signal detection's sensitivity index, or *d*' (Macmillan & Creelman, 2005). A one-way analysis of variance (ANOVA) on this measure revealed a main effect of condition, $F(6, 92) = 10.45$, $p < 0.001$. Face recognition performance as a function of caricaturization levels are shown in Figure 3(a). Starting from a near-chance level for extreme anti-caricatures ($\alpha = -0.64$) recognition performance increased with the level of caricaturization. Values of $\alpha = -0.21$ (for veridical faces) and $\alpha = +\ 0.21$ (for caricatures) were found to be the minimally

[1]The Mahalanobis distance $\|x\|_M$ is closely related to the Hotelling's *T*-square statistic commonly used in multivariate hypothesis testing $t^2 = n(x-\mu)^T \Sigma^{-1}(x-\mu)$, where μ and Σ are the mean and covariance matrix of the population, n is the number of samples and x is the sample being tested ($\|x\|_M = \sqrt{t^2/n}$).
[2]The seven exaggeration levels $\alpha = \{-0.64, -0.43, -0.21, 0, +0.21, +0.43, +0.64\}$ were selected to be separated from each other by one standard deviation, as measured on the distribution of faces in the database. Note that, for $\alpha = -1$, the anti-caricature becomes the average face.

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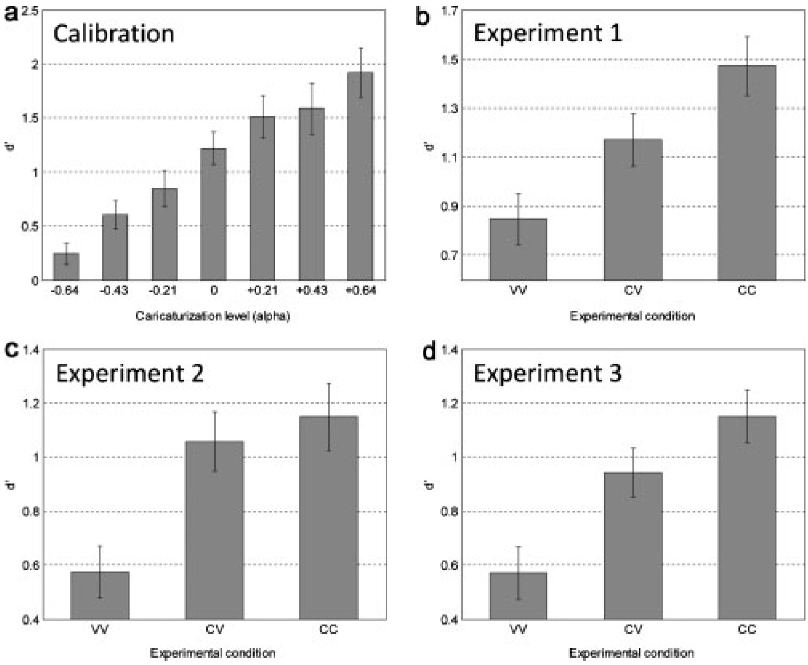

Figure 3. Face recognition accuracy on (a) the Calibration Study, (b) Experiment 1, (c) Experiment 2 and (d) Experiment 3

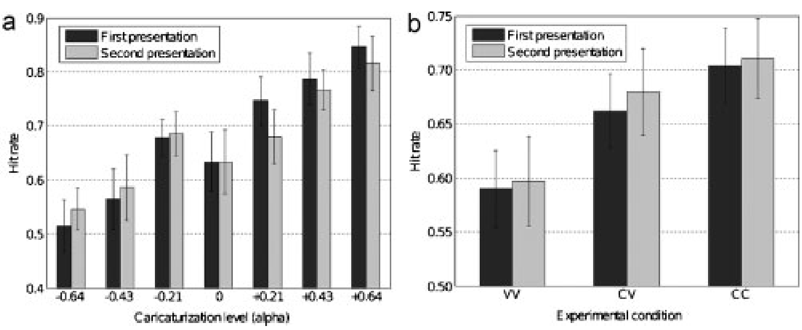

Figure 4. Hit rates on the dual presentations of the targets during (a) the calibration study and (b) Experiment 1

effective levels of exaggeration, $t(27) = 2.55$, $p < 0.05$, and were chosen for the reverse-caricature experiments.

No significant differences were observed in response time across caricaturization levels, $F(6, 92) < 1$ (one-way ANOVA). Additionally, the dual presentation of targets had no main effects on hit rates during test, $F(1, 92) < 1$, and had no interactions with the experimental condition, $F(6, 92) < 1$ (two-way mixed-factor ANOVA); hit rates on the two presentations of the targets are illustrated in Figure 4(a).

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EXPERIMENT 1

The goal of this experiment was to establish the reverse-caricature effect with frontal views rather than with the more favourable three-quarter views. Additionally, participants were trained for shorter periods to test the lower limits of training times.

Procedure

The procedures were the same as in the calibration study, but participants were assigned to one of three experimental conditions: (1) veridical familiarization/veridical test ($n = 30$), (2) caricature familiarization/caricature test ($n = 29$) and (3) caricature familiarization/veridical test ($n = 29$). In all three conditions, the same 10 randomly chosen faces were used (in either caricature or veridical form). The exaggeration levels established in the calibration study were used for all faces ($\alpha = -0.21$ for veridical faces, and $\alpha = +0.21$ for caricatures).

Results

A one-way ANOVA on the d' revealed a main effect of condition on recognition accuracy, $F(2, 85) = 7.96$, $p < 0.001$. Face recognition performance of the three experimental conditions is shown in Figure 3(b). Consistent with other researchers' findings and our own calibration study, participants exposed to caricature targets and caricature probes (CC) showed higher recognition accuracy than participants shown veridical targets and veridical probes (VV), $t(57) = 3.90$, $p < 0.001$. Of greater interest for the current study, participants familiarized with caricature targets and tested on veridical probes (CV) had higher overall recognition accuracy than those shown VV, $t(57) = 2.17$, $p < 0.05$.

No significant differences were observed in response time across the three conditions, $F(2, 85) < 1$ (one-way ANOVA). Additionally, the dual presentation of targets had no main effects on hit rates during test, $F(1, 85) < 1$, and had no interactions with the experimental condition, $F(2, 85) < 1$ (two-way mixed-factor ANOVA); hit rates on the two presentations of the targets are illustrated in Figure 4(b).

EXPERIMENT 2

The goal of this experiment was to establish whether the reverse-caricature effect would manifest given a shorter familiarization time than was used in Experiment 1.

Procedure

Participants were again assigned to one of three experimental conditions: VV ($n = 34$), CC ($n = 34$) and CV ($n = 34$), where they were familiarized with 10 randomly selected faces. However, unlike in the previous experiments, target faces were presented only once for 3 seconds (see Goldstein & Chance, 1980). Participants were then tested with a single presentation of 40 faces, of which 30 were new (non-target) faces and 10 were the learned faces. These procedures were introduced to increase the difficulty of the recognition test. In all three conditions, the same 10 randomly chosen faces were used (in either caricature or

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veridical form). The exaggeration levels established in the calibration study were used for all faces ($\alpha = -0.21$ for veridical faces, and $\alpha = +\ 0.21$ for caricatures).

Results

A one-way ANOVA revealed a main effect for recognition accuracy (d') across the three groups, $F(2, 99) = 7.78$, $p < 0.001$. Face recognition performance on the three experimental conditions is shown in Figure 3(c). Participants exposed to CC showed higher recognition accuracy than participants shown VV, $t(66) = 3.65$, $p < 0.001$. More importantly, participants familiarized with CV had higher overall recognition accuracy than those shown VV, $t(66) = 3.31$, $p < 0.01$. No significant differences were observed in response time across the three conditions, $F(2, 99) < 1$ (one-way ANOVA).

EXPERIMENT 3

The goal of Experiment 3 was to rule out the possibility that the results of the previous two experiments were based on the use of a superficial ‘picture matching’ strategy by participants rather on actual face recognition. To this end, test faces were rotated relative to their frontal orientation during familiarization.

Procedure

Participants were again assigned to one of three experimental conditions: VV ($n = 34$), CC ($n = 34$) and CV ($n = 34$), using identical procedures to the previous studies, with two exceptions. First, participants were familiarized with a single presentation of the target faces for 6 seconds each. Second, all faces were presented with a modest random rotation during test. The random rotations were uniformly distributed in the range of ± 5 degrees in each of the three axes.

Results

A main effect was observed for recognition accuracy (d') across the three groups, $F(2, 99) = 9.46$, $p < 0.001$. Face recognition performance on the three experimental conditions is shown in Figure 3(d). Participants exposed to CC showed higher recognition accuracy than participants shown VV, $t(66) = 4.21$, $p < 0.001$. More importantly, participants familiarized with CV had higher overall recognition accuracy than those shown VV, $t(66) = 2.79$, $p < 0.01$. No significant differences were observed in response time across the three conditions, $F(2, 99) < 1$.

DISCUSSION

Results from the three reverse-caricature studies support the hypothesis that even very brief familiarization with frontally presented caricatures leads to greater recognition of their unexaggerated counterparts than does familiarization with veridical versions of those faces. Taking the results from Experiment 1 as a baseline, Experiment 2 explored the effect of shorter familiarization times (3 seconds *vs.* 6 seconds) on recognition performance,

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whereas Experiment 3 explored the effect of random rotations at test (±5 degrees); both Experiments 2 and 3 also explored the effect of single presentations at test. Our results indicate that the reverse-caricature effect is robust to differences in stimuli presentation schemes, familiarization times and modest rotations of the faces.

By definition, caricatures increase the salience of idiosyncratic or normatively distinct qualities. This form of distortion appears to increase the amount of memorable information available for later recognition. As a result, exposure to facial caricatures can increase later recognition of the veridical faces, those that were used to create the caricatures in the first place. This apparent paradox has important implications for the development of training tools for face recognition.

Implications

Although a caricature advantage has been demonstrated in previous work, many of these investigations focussed on cases in which faces were exaggerated during both familiarization and recognition (e.g. Benson & Perrett, 1994; Rhodes et al., 1987). Effects of this sort are theoretically important, but it is unclear how they might be applied to enhance memory of faces in practice, when most operational scenarios demand that faces be recognized in their veridical form. Demonstrations of a reverse-caricature effect similar to that found here (e.g. caricaturized training; veridical testing) were based on very different stimuli, such as line drawings and veridical photographs (Stevenage, 1995), or three-quarter view representations of faces (Deffenbacher et al., 2000).

We hope that the current findings inspire new procedures that will lead to improvements in face recognition in applied settings. Consider law enforcement as one promising area. Police officers are often required to learn the faces of the at-large suspects that they must try to apprehend. Law enforcement agencies also post the pictures of wanted individuals when they are soliciting the assistance of the public.

How could the results from our study be extended to these applied settings? First, stimuli would have to contain both the 3D shape and the 2D reflectance/texture of faces. Our focus on facial shape in this study served two purposes: it helped participants focus on anthropometric features of the face rather than on non-configural features (e.g. skin colour, skin blemishes, eye colour), and made our results comparable with those of Deffenbacher et al. (2000), who also used shape-only faces. Extensions of the caricature process to both facial shape and facial reflectance are technically straightforward; the challenge lies in determining suitable levels of exaggeration for shape and reflectance when both sources of information are present. To this end, work by O'Toole, Vetter, and Blanz (1999) suggests that the relative contribution of shape and texture may be gender dependent; recognition of male faces depends more on shape than on reflectance, whereas recognition of female faces relies on both channels equally. Second, the caricature process requires a 3D model for each target face. In most practical settings, however, one will not have the luxury of performing a 3D face scan of each target face; 3D scanners are still expensive instruments, and scanning is not possible when the wanted individual is at large. One potential solution to this problem is to use photogrammetric techniques to reconstruct 3D face models from 2D photographs; visually convincing reconstructions have been demonstrated by Blanz and Vetter (1999) using morphable models. Whether these reconstructions are sufficiently accurate to be used for caricaturing is a matter that requires further investigation, as even minute reconstruction errors would be amplified by the exaggeration process. Finally, the effects of race, gender and age on reverse-caricature training would have to be characterized in order to design large facial databases. In the current studies, we presented familiarization and test faces one at a time on a computer and, as a result, participants were able to gain some sense of the norms that defined the full population. This might be necessary for the type of effects we observed, as caricatures can only be defined in relation to the norms of a given population. Perhaps, if we had used other methods in which the stimuli were presented in isolation or embedded within a sample of faces that had different norms (e.g. other-race effects), our caricature effect would have been diminished or disappeared altogether. These ambiguities point to the need for future research that can define the boundary conditions for our effect, so that caricatures can be used successfully to improve face recognition in real world settings.

CONCLUSIONS

Our findings extend previous reports of a reverse-caricature effect, further demonstrating its potential as a training tool for face recognition. In contrast to the work by Deffenbacher et al. (2000), in which an optimal three-quarter view and a 60-second familiarization exposure were used, our study shows that a reverse-caricature effect can also be obtained when only a frontal representation is available during training, with a significantly shorter familiarization time, and that the effect is robust to modest rotations of faces. Although future research will need to explore the cognitive mechanisms underlying this effect and identify the boundary conditions that guide its application, these findings offer clear evidence that facial distortions can improve face encoding and subsequent recognition, if they exaggerate features that make a face most distinctive with regard to a particular population of faces.

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