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Secrets of the Face

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The face holds secrets of beauty, expression, character and identity. My colleagues and I have focused on the secret of identity, investigating how people decode a face's identity. We have tackled the problem by studying the effects of transformations on face recognition. Here I review our progress on understanding the effects of caricature and inversion transformations. Caricatures can enhance recognition, despite their obvious distortions. We argue that the power of caricatures suggests that distinctive information about a face may be coded as deviations from a norm or average face. In contrast to caricaturing, inversion severely disrupts face recognition. Our studies show that inversion selectively disrupts the encoding of relational information, and we argue that spatial relations between parts of the face play a crucial role in signalling the identity of a face. We conclude that both norm-based coding and relational features contribute to our expertise in decoding the identity of a face. Interestingly, neither skill seems to be restricted to face recognition, challenging the common view that faces are special.

> "no single object presented to our senses ... engrosses so large a share of our thoughts, emotions, and associations as that small portion of flesh and blood a hand may cover, which constitutes the human face"
> *(Eastlake, 1851)*

The face has fascinated scientists and artists since ancient times. But what is it about this small area of flesh and blood, little bigger than a hand, that has exercised the imaginations of so many scholars? Perhaps it is the face's many secrets—the secrets of beauty, expression, character and identity.

First, is the secret of *beauty*: What makes a face beautiful, or conversely, ugly? The ancient Greeks saw the answer in the proportions of the face, an idea that was explored with almost obsessional precision by Renaissance artists like Dürer (1528/1969) who produced numerous drawings in which the facial proportions were systematically varied. More recently, using computer technology, scientists have discovered, somewhat paradoxically, that average faces are attractive (Langlois & Roggman, 1990). The more faces that are averaged into a composite, the more attractive that composite becomes. As Sir Francis Galton (1878) discovered when he tried to average criminal faces photographically to yield the "criminal type", the composite is surprisingly more benign and attractive than the component faces. Although Galton is generally credited with the discovery of this effect it should probably be attributed to A. L. Austin of Invercargill, New Zealand, who observed that blending faces in a stereoscope resulted in "a decided improvement in beauty" (cited by Galton, 1878).

The second secret of the face is *expression*. Our facial expressions reflect our inner emotional states. The ability to decode expressions therefore, is a powerful tool for predicting behaviour. Is that doberman smiling or does that display of teeth mean something else?! The study of facial expressions goes back at least to Charles Darwin who argued for the continuity of expression in humans and other animals as part of his theory of evolution (Darwin, 1872). More secrets of expression are still being discovered—how they are produced by the facial musculature, how posed expressions can induce emotional feelings to match the expression, how the biologically universal expression of emotions is modulated by cultural display rules, and how facial expressions can be used to deceive others (Ekman, 1985, 1992; Ekman & Friesen, 1978; Ekman & O'Sullivan, 1991).

The third secret of the face is its apparent reflection of *character*. The long-standing belief that character is displayed in the face culminated, in Victorian times, in the highly quantitative study of physiognomy. Character traits were predicted using facial measurements and many, including Galton, were fascinated by the idea of facial types. Physiognomy achieved great popularity, with displays of the heads (actually plaster casts!) of hanged murderers attracting the kind of attention that dinosaur displays do today (Cowling, 1989). Today it has little scientific credibility, although the consistency with which certain actors arecast as villains or heroes suggests that physiognomy has yet to be eradicated from our folk psychology.

The fourth secret of the face is *identity*. The face tells us the identity of its owner, which is crucial for predicting that person's behaviour, especially their behaviour towards us (are they friend or foe?), for modulating our own behaviour towards them, and for ensuring that social interactions proceed smoothly. In this sense, then, identity may be the most important secret of the face. Yet it is probably the least studied of the four. Recently, my colleagues and I have begun to explore how we decode facial identity. We do not expect the face to give up its secret easily, but we have made some progress, which is presented here.

Understanding Face Recognition

Why face recognition is hard

Face recognition, the decoding of a person's identity from their face, is a hard problem. Despite the fact that babies are born with a preference to look at faces (for a review see Johnson & Morton, 1991), it takes more than 10 years for children to achieve adult levels of expertise (for a review see Carey, 1992). For example, young children are easily fooled by superficial changes (hats, glasses, moustaches, etc.) to faces (Carey & Diamond, 1977) and even our adult expertise is very finely tuned, being disrupted by unfamiliar kinds of faces (e.g., other-race faces) or faces seen in unusual orientations (e.g., upside-down).

Face recognition is hard because faces are unusually homogeneous—they share a configuration, all having the same basic components of eyes, nose, mouth, hair etc., in the same basic arrangement. Humpty-Dumpty identified the problem in his complaint to Alice on the difficulty of recognising her, "You're so exactly like other people ... the two eyes, so (marking their places in the air with his thumb) nose in the middle, mouth under. It's always the same. Now if you had the two eyes on the same side of the nose, for instance—or the mouth at the top—that would be *some* help." (Carroll, 1946). In our experiments we have tried to determine how we solve this problem that so frustrated Humpty-Dumpty.

Are faces special?

We are also interested in whether we decode the identity of a face in the same way that we decode the identities of other objects from their appearances. That is, do we have a special face recognition "module" or are faces and other objects recognised in the same way? The idea that faces might be special is not implausible. First, there is the innate preference to look at faces over other similar patterns, mentioned above. Second, there are specific areas of the brain for face recognition, which when damaged result in prosopagnosia, an inability to recognise faces, including one's own in the mirror (for reviews see de Renzi, 1986; Farah, 1990). And third, face recognition is certainly important enough to warrant selection pressure for a special recognition module, were one needed. Here we ask whether in fact we have developed such a module.

Current models of object recognition claim that recognition is based on an analysis of an object into its parts and the spatial arrangement of those parts (e.g., Biederman, 1987; Marr, 1982). However, this will not do for faces, which have the same basic parts in the same basic arrangement. A part-based analysis can tell us that we are looking at a face and not a chair, but it can't tell us whose face we are looking at. Clearly, then, faces are special in the sense that a part-based analysis won't do. However, they are not unique in this respect—most discriminations within basic level categories (e.g., chair, dog, house, tree, apple, etc.) cannot be based on part decomposition. The question is really whether faces are handled differently from these other within-category discriminations.

Clues from Caricatures and Corruption

Our approach to understanding the identity secret has been to study how transformations affect face recognition. The first kind of transformation that we have looked at is *caricaturing*, which distorts a face, but paradoxically leaves the identity of the face intact. Caricaturing can even enhance recognition, as we will see below. We have also studied a second and more "corrupting" kind of transformation, one that severely disrupts our ability to recognise faces—

namely *inversion*. By considering the effects of these two quite different kinds of transformation, one good and one bad, we hope to discover the clues people use to decode the identity of faces.

Caricatures

Renaissance artists discovered the power of caricatures, and these exaggerated images have been exploited ever since in the popular press (for a history of the development of caricatures see Rhodes, 1994). Surprisingly, early psychological studies of the effectiveness of caricatures were disappointing, suggesting that caricatures were much harder to recognise than had been supposed. For example, Tversky and Baratz (1985) found that undistorted images were recognised much better than caricatures of famous faces. However, the undistorted images were photographs, which contain a lot more information than hand-drawn caricatures, so perhaps the comparison was an unfair one. In our studies we decided to compare caricatures and undistorted images of the same type.

We produced our images using a computerised caricature generator, created by Susan Brennan (1982, 1985). Her program makes a caricature in three steps. First, a photograph of the "victim" is digitised and fixed landmark points are located on the face. These points are marked using a mouse and then the program "joins the dots" to produce a simple line drawing image of the face (see Figure 1). In the second step, this line drawing is compared with that of a norm or average face, and the program identifies corresponding points on the images. Different norms can be used for structurally distinct classes of face, such as males and females or young and old faces. In the third and final step, the program exaggerates all the differences between the corresponding pairs of points to produce a caricature.

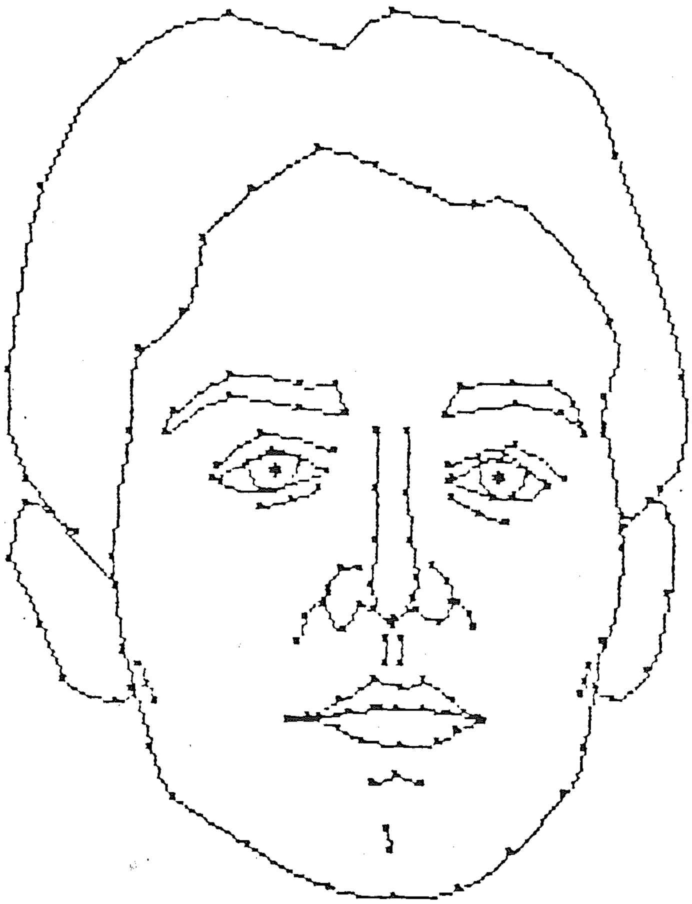

Figure 1. The points and lines used to depict a face.

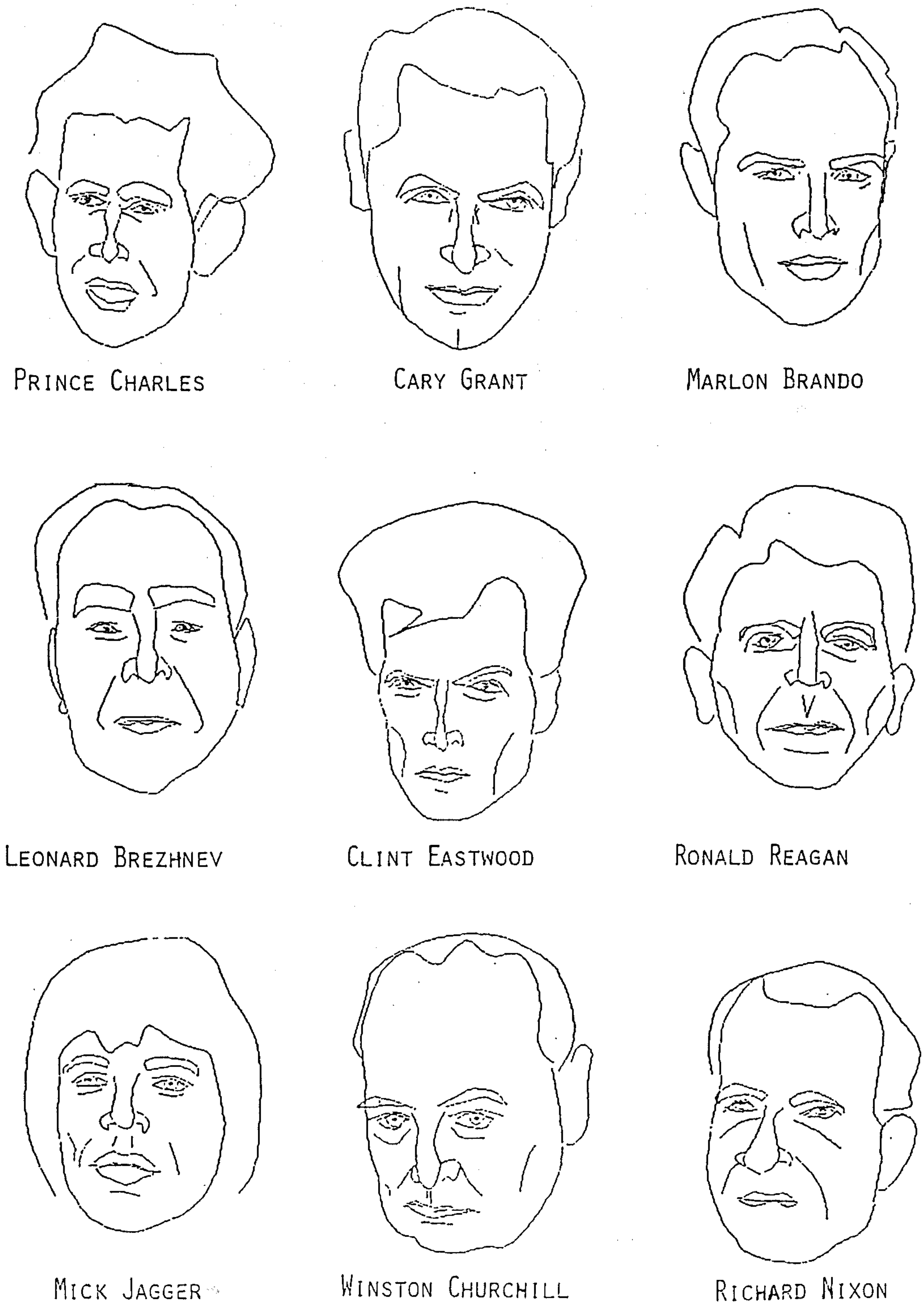

Figure 2. Examples of 50% caricatures of famous faces.

The degree of exaggeration is controlled by the user. For example, one may request a 50% caricature in which all the points on the victim's face are moved 50% further from the corresponding points on the norm than they already are. Distinctive aspects are changed more than typical aspects of the face with this procedure, because 50% of a 20-pixel difference is larger than 50% of a 2-pixel difference. Figure 2 shows some 50% caricatures of famous faces. Anticaricatures can be created by moving the points on the victim's face closer to the corresponding points on the norm. Distinctive aspects of a face are exaggerated in the caricatures and reduced in the anticaricatures, and corresponding levels of caricature and anticaricature (e.g., 50% and -50%) are equally distorted (metrically) from the original drawing. A set of caricatures and anticaricatures is shown in Figure 3.

In our first study we investigated the effectiveness of caricatures by asking members of the Stanford University Psychology Department to identify pictures of their colleagues and classmates (Rhodes, Brennan & Carey, 1987). Subjects saw either a 50% caricature, an undistorted 0% drawing or a -50% anticaricature of each face. The caricatures were recognised twice as quickly as the undistorted drawings and four times more quickly than the anticaricatures (see Figure 4). Accuracy was quite poor (M = 33%) and did not differ for the three kinds of drawings, but the reaction time results showed a clear caricature advantage. In more recent studies (Rhodes & Tremewan, 1994) we have used enhanced drawings (see Figure 5) that are easier to recognise, and again found a caricature advantage, this time for *accuracy* of recognition of high school students by their classmates (see Figure 6).

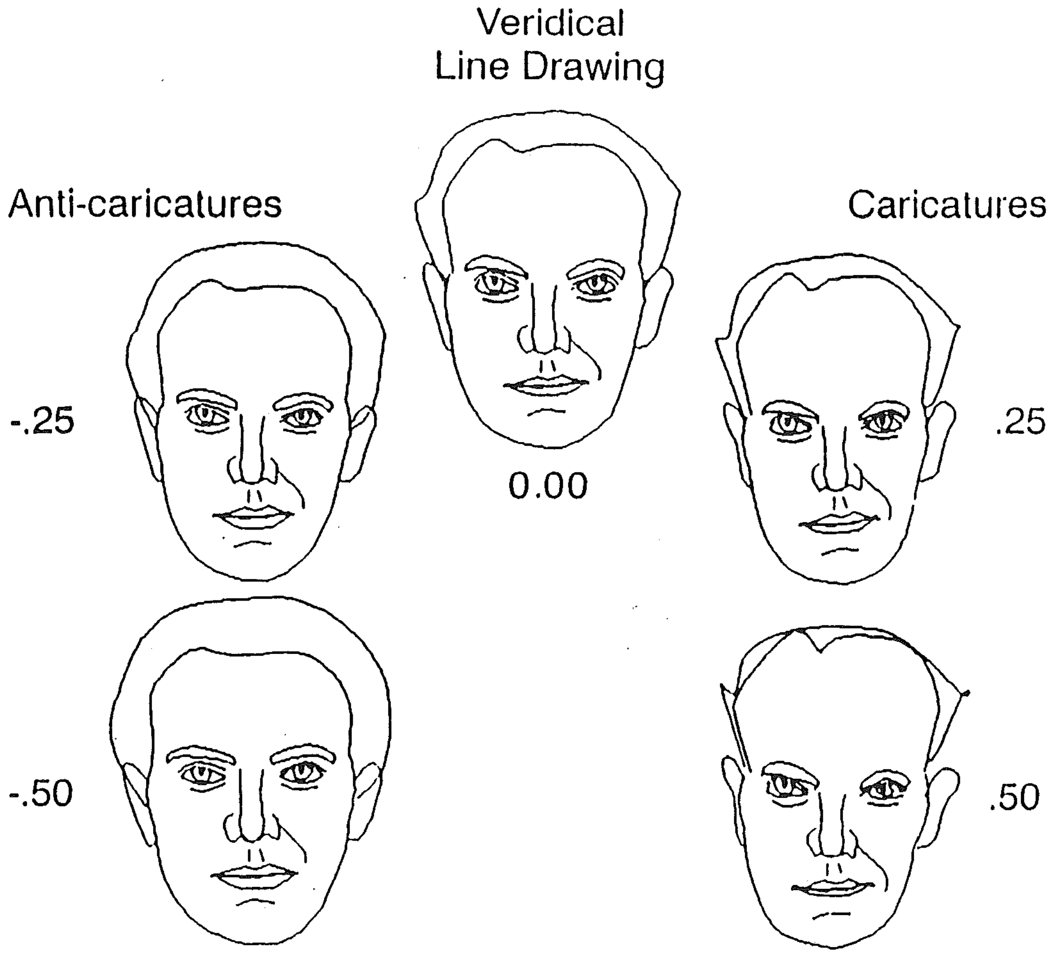

Figure 3. A set of caricatures and anticaricatures. Distortion levels are shown as proportions.

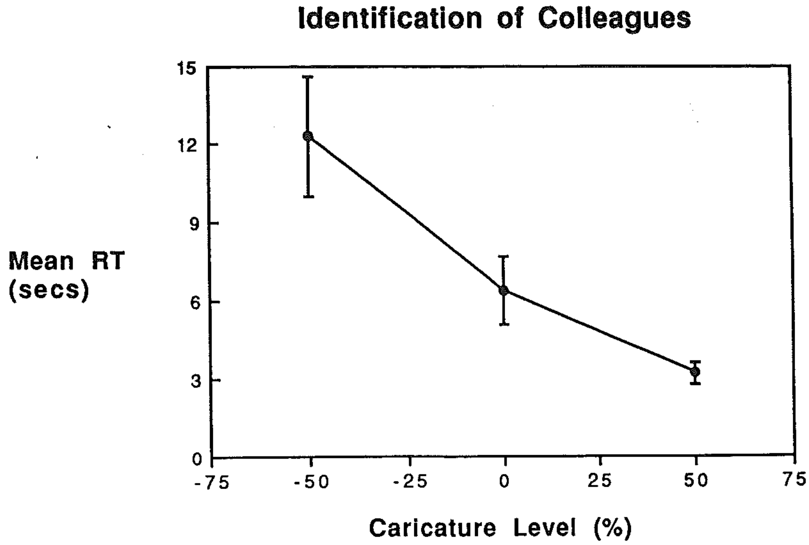

Figure 4. Mean reaction times (msecs) to name drawings of colleagues as a function of caricature level. SE bars are shown.

These results suggest that the identity of a face can (at least sometimes) be decoded more easily from a caricature than from an undistorted image. This could come about in several ways. First, we might have caricatured memory representations of faces, which are more readily activated by caricatures than undistorted images. Perhaps as we become familiar with a person's face and learn which of their features are distinctive, we might exaggerate these features in long-term memory. This would push the face representations apart in our mental "face space" and could reduce confusions between faces.

Alternatively, the memory representations might be undistorted but caricatures could enhance recognition simply because of their greater distinctiveness. A caricature will activate fewer distractors in memory than the undistorted image and this reduction in distractor activation might more than offset the reduction in target activation of the mismatching caricature compared with the matching undistorted image.

How might we distinguish these two possibilities? According to the caricatured-trace account, a caricature advantage would be restricted to highly familiar faces. However, there is no reason to think that the activation processes underlying the selectivity account would be affected by familiarity. In a following study we found that the faces that produced a cariacture advantage in our previous experiment also produced a caricature advantage for a new group of subjects who were unfamiliar with these faces prior to the experiment (Rhodes & Tremewan, 1994) (see Figure 7). Mauro and Kubovy (1992) have reported similar results for recognition of unfamiliar Identi-kit faces. Familiarity does not therefore appear to be needed for a caricature advantage, a result that seems to us to be more compatible with the selective-access account than the caricatured-trace account of caricature effects.

The effectiveness of caricatures also suggests that we mentally represent faces in terms of their distinctive features coded relative to a norm (Carey, Rhodes, Diamond & Hamilton, 1994; Rhodes, et al., 1987; Rhodes & Tremewan, 1994). To see why, consider the nature of the caricature transformation. Under this transformation, all the points that describe a face move systematically with respect to the norm, so that one can think of the norm as a frame-of-reference in which caricature transformations are systematic and simple. In any other co-ordinate system (e.g., the 2-D picture plane or 3-D space) points on the face move haphazardly. If, as seems reasonable, caricatures are effective because they exaggerate the very features we use to recognise faces, then it seems that we are coding each face's distinctive features as deviations from a norm. This means not only that a facial norm or norms play an important role in coding faces, but that each face

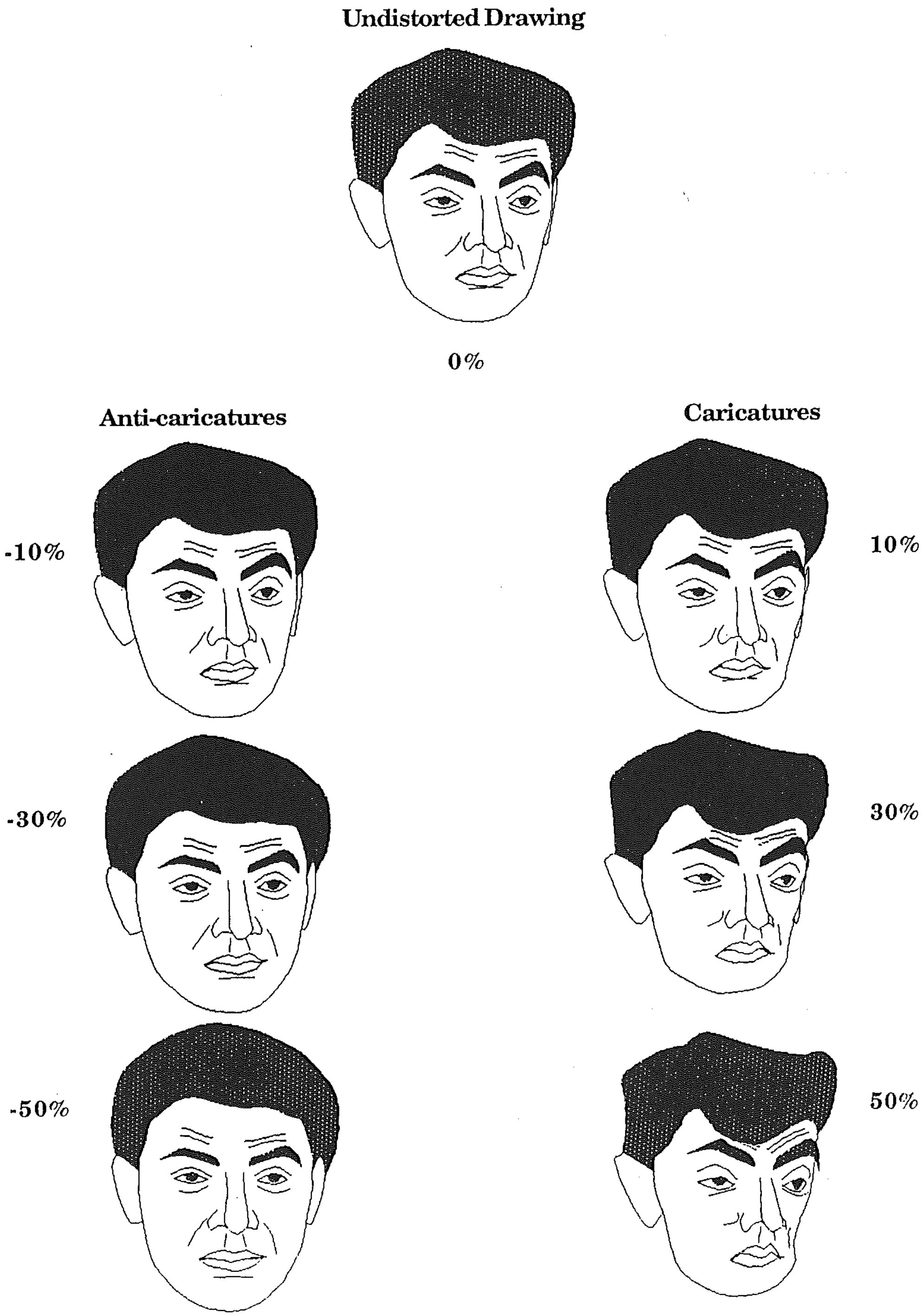

Figure 5. A set of enhanced caricatures and anticaricatures of Rowan Atkinson. Distortion levels are shown as percentages.

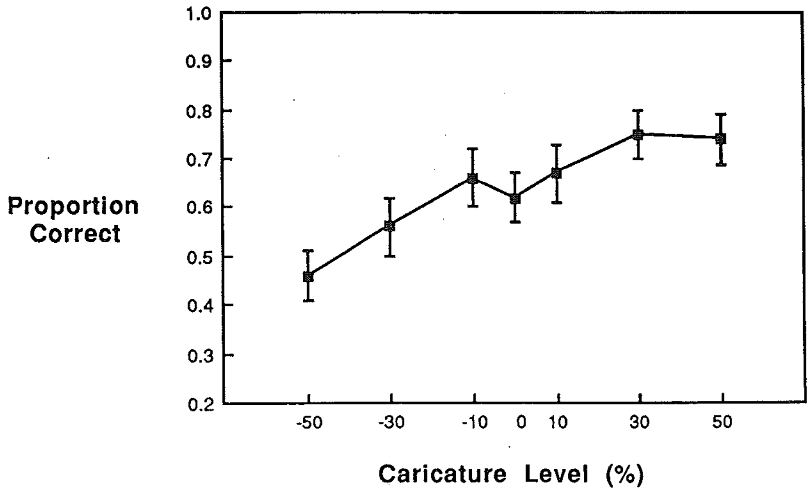

Figure 6. Accuracy to name enhanced drawings of classmates as a function of caricature level.

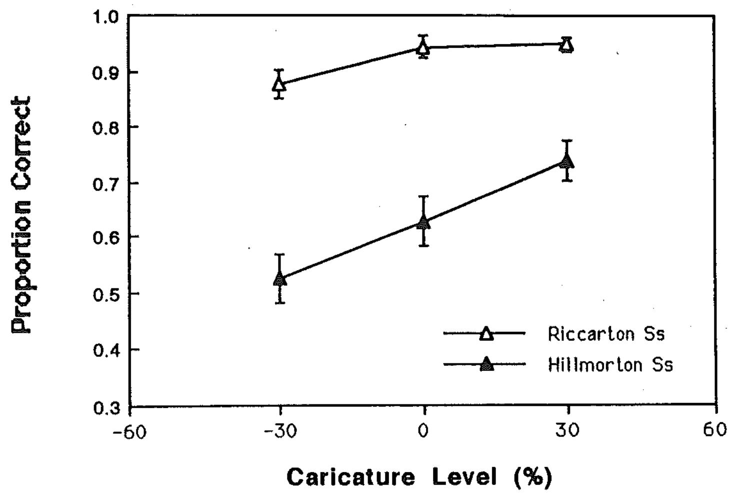

Figure 7. Accuracy of naming enhanced drawings of classmates as a function of caricature level and familiarity. Familiarity is high for Riccarton subjects and low for Hillmorton subjects.

may be represented in terms of a unique set of features.

Recently, we have tried to test this norm-based coding idea by examining the effect of a trans-formation that disrupts norm-deviation features (Carey, et al., 1994). To do so, we created a new type of caricature by moving the points on a face orthogonally to the norm-deviation direction (instead of away from or towards the norm to produce caricatures and anticaricatures, respectively) (Figure 8). If we code distinctive features as deviations from a norm, then these "lateral" caricatures (see Figure 9) should be very hard to recognise, as indeed they are. Figure 10 shows the results of an experiment where we compared performance on 50% caricatures, undistorted images, -50% anticaricatures and 50% laterals. The laterals were very difficult to identify, being recognised even more poorly than anticaricatures. These results support our claim that distinctive features of faces are coded as deviations from a face norm. They also show that caricature effects cannot be *solely* distinctiveness effects because the laterals were harder to recognise than the less distinctive (but equally distorted) anticaricatures.

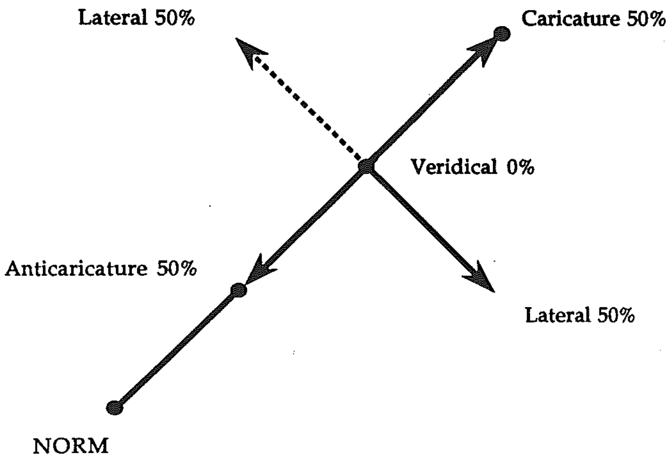

Figure 8. Movement of a point on a face (veridical 0%) in a caricature (away from the norm), anticaricature (towards the norm) and lateral caricature (orthogonal to the norm-deviation direction). All movements shown are for a 50% transformation. The choice of direction for the lateral moves was constrained to reflect the bilateral symmetry of the face. All the points on the left side of the face moved the same way (either left or right with respect to the norm-deviation direction) as did all the points on the right side of the face. This resulted in four laterals for each face. The most face-like one was used in the recognition test.

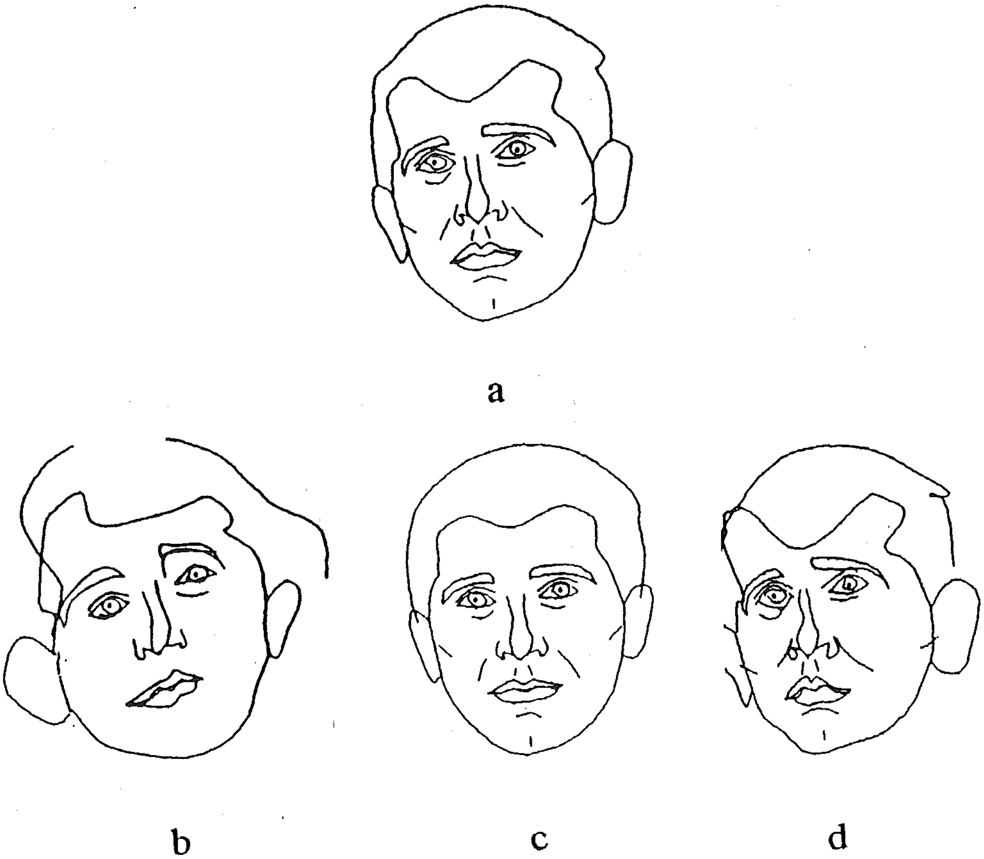

Figure 9. a) Oliver North, b) 50% lateral, c) 50% anticaricature, d) 50% caricature.

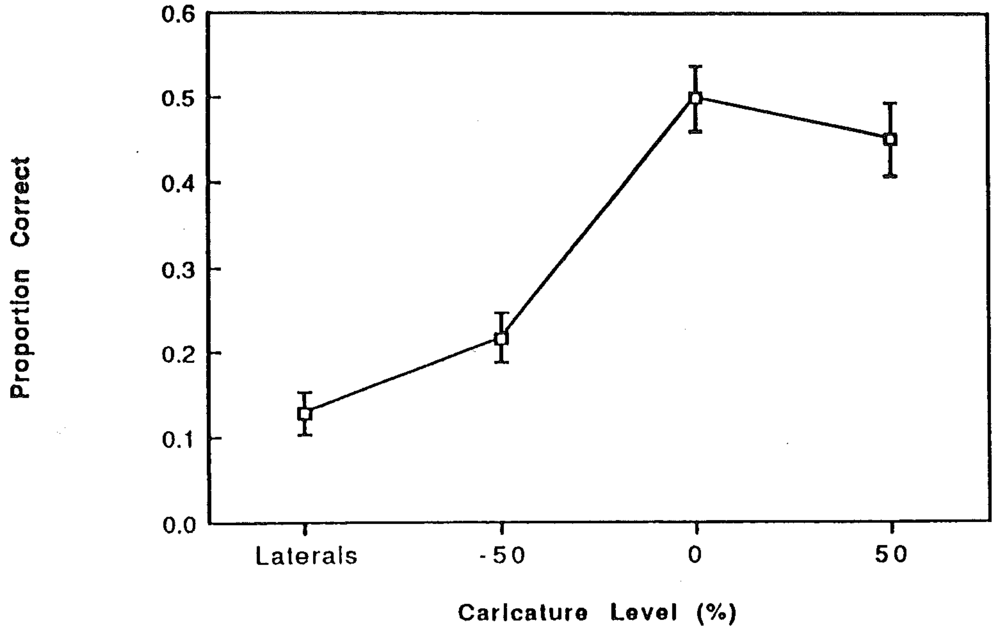

Figure 10. Accuracy of naming famous faces as a function of caricature level.

We have also investigated whether norm-based coding is part of a special system for decoding the identity of faces or whether it is also used for other classes of objects. To explore this question we looked at recognition of birds, which share a configuration in the same way that faces do. Would caricatures enhance recognition of birds just as they enhance recognition of faces? We also examined the performance of experts and non-experts to see whether expertise is important for a caricature advantage (Rhodes & McLean, 1991). Experts showed a caricature advantage, with fastest responses to 50% caricatures of passerine birds. For non-experts, caricatures of a more heterogeneous set of birds were recognised as well as, but not better than, the undistorted images. These results suggest that caricature effects and norm-based coding may not be unique to faces. Other homogeneous classes may also be coded as deviations from an appropriate norm, especially if one has expertise with the class.

To sum up, what have we learned from our caricature studies? First, the effectiveness of caricatures suggests that we code distinctive features of faces as deviations from a norm. Second, we have found that caricatures can enhance recognition accuracy even for relatively unfamiliar faces, which suggests that caricatures might be useful as aids to face recall in forensic settings. This potential seems especially promising given that photographic caricatures can now be produced (Benson & Perrett, 1991). Third, caricature effects are not restricted to faces, suggesting that we can use norm-based coding for other classes that share a configuration. I turn now to the inversion studies, which provide clues about the *kind* of distinctive features that signal facial identity.

Inversion

In contrast to the caricature transformation, inversion severely disrupts face recognition. In fact, faces are more seriously affected by inversion than any other class of mono-oriented object that has been studied (for a review see Diamond & Carey, 1986). Perhaps, then, we can get a clue about the kind of features used to decode the identity of a face by discovering the kind of information that is lost with inversion. Of course, information is not strictly lost when something is inverted, but it may be lost in the sense of no longer being readily available to us.

Diamond and Carey have distinguished two kinds of features in faces—isolated features which can be specified without reference to several parts of the face and relational features which cannot. Examples of isolated features are colour and texture of hair, presence or absence of glasses

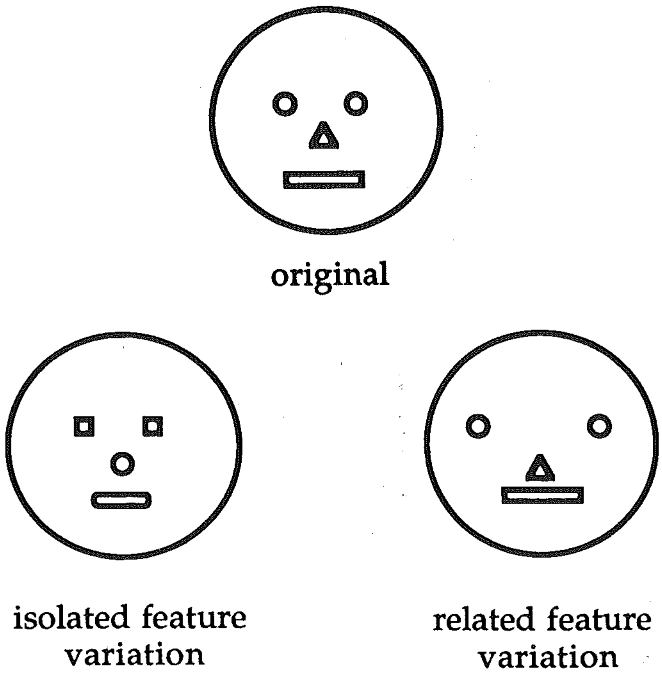

Figure 11. Isolated and relational features. The bottom left face differs from the original face in isolated features (the shapes of its components), the bottom right face differs from the original in relational features (the spatial relations between the components).

or facial hair and the shapes of internal features such as eyes, nose and mouth. Examples of relational features are the spacing of internal features, ratios of distances between parts of the face and global shape. The schematic faces in Figure 11 illustrate the distinction between isolated and relational features. Diamond and Carey's proposal is that the large inversion effect for faces indicates reliance on relational features, which are particularly difficult to encode in inverted stimuli (e.g., Rock, 1974).

We recently tested this proposal by examining whether relational features are indeed more difficult to encode in inverted faces than are isolated features (Rhodes, Brake & Atkinson, 1993). First we showed our subjects several sets of study faces. After each set, we showed them the study faces again, but this time each was paired with a distractor face. Each study and distractor face differed only on a single feature, and subjects had to pick out the study face. For some faces an isolated feature was changed (e.g., glasses or a moustache could be added or removed and the eyes or mouth could be switched with those from another face) and for others a relational feature was changed (e.g., the spacing or orientation of internal features) (See Figure 12).[1] The salience of each type of change was adjusted so as to be equally noticeable when the faces were upright. But what about when the pairs were viewed upside-down? Would the relational feature changes be more difficult to detect than the isolated feature changes, as Diamond and Carey had predicted? Our results showed that they were (see Figure 13).

However, there was one anomalous result. Inversion had its biggest effect when we swapped the eyes or mouth with those from another face, which we had classified as an isolated feature change. Diamond and Carey might argue that changing these component features also changes all the relational features that the components enter into, so that it is really these resulting relational changes that are responsible for the large inversion effect. We tested this idea by presenting the component features, eyes or mouth,

[1] Two other types of changes were also examined, a global change and a change that disrupted the normal facial configuration. However, these are not central to the present debate and so will not be discussed.

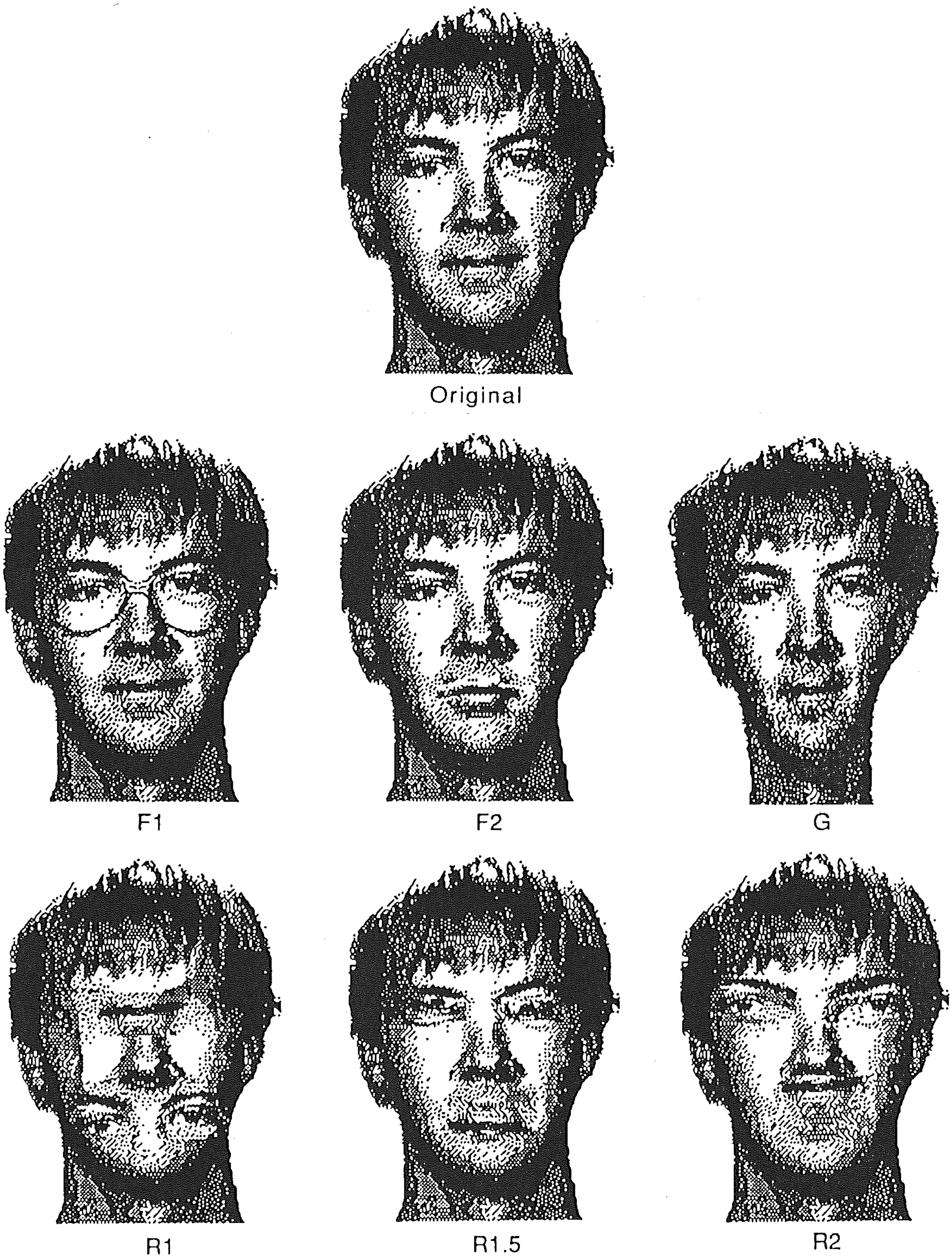

Figure 12. An original face plus six different types of change. F1 (glasses added) and F2 (mouth changed) show isolated feature changes, G is a global change (trapezoid stretch), R1 disrupts the face configuration, and R1.5 (eyes and mouth inverted in face) and R2 (internal feature spacing changed) are relational changes.

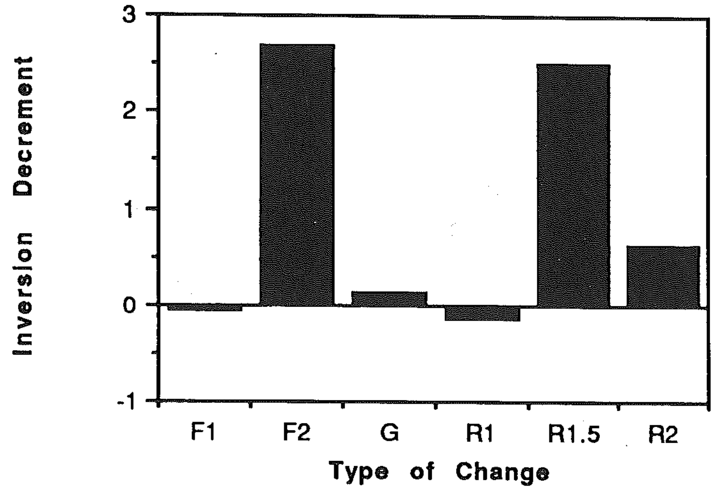

Figure 13. Inversion decrement (percentage reduction in accuracy) as a function of type change.

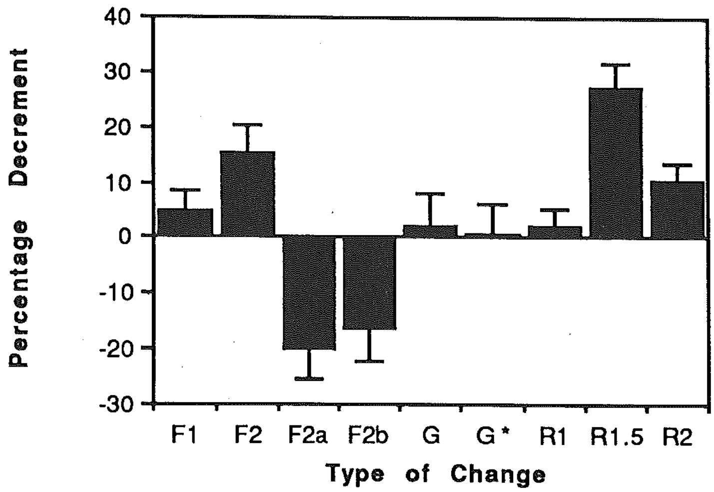

Figure 14. Inversion decrement (percentage reduction in accuracy) as a function of type of change in follow-up experiment. F2a and F2b were eyes or mouths presented alone (out of the face context).

alone (i.e., not in a face). If the large inversion decrement for these changes is really due to relational feature changes, then it should disappear with the features presented alone. As Figure 14 shows, the large inversion decrement did indeed disappear.[2] Therefore, we support Diamond and Carey's claim—i.e., that reliance on relational features accounts for the disruptive effect of inversion on face recognition.

[2] In fact the isolated eyes and mouths were recognized better inverted than upright. However, all of the inverted study sets were smaller than the upright study sets (to avoid floor and ceiling effects), so that the absolute size of the inversion decrements are not directly interpretable.

Yin (1969, 1970) interpreted the unusually large inversion decrement for faces as evidence that faces are special. His best bet was that their expressiveness made them special, and he suggested that faces were unusually vulnerable to inversion because expression was lost. How does this sit with our claim that relational features are difficult to encode in inverted faces? Perhaps it was the resulting changes in expression (see Figure 12), rather than the changes in relational features per se, that were responsible for our results. However, results by Diamond and Carey (1986) suggest that expression is probably not the

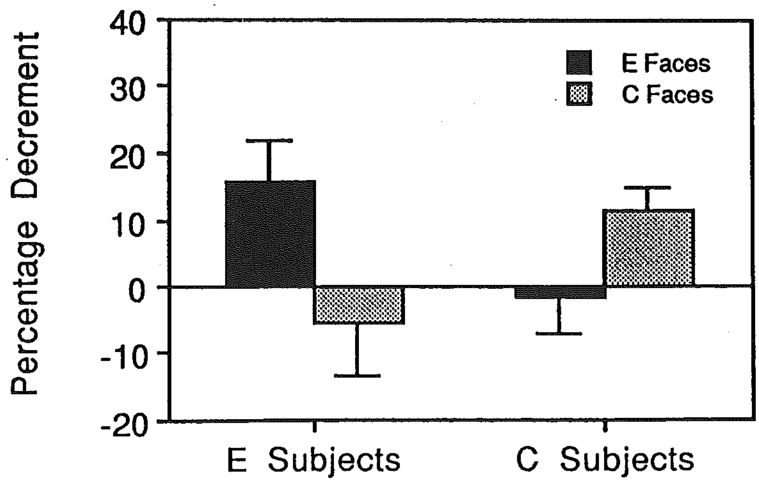

Figure 15. Inversion decrement (percentage reduction in accuracy) as a function of race of face and race of subject. The inversion decrement is larger for own- than other-race recognition.

key to large inversion decrements. They found equally large inversion decrements for dog recognition, based on whole body profiles, by dog experts. Therefore large inversion effects seem to stem from difficulty coding relational features, rather than difficulty coding expression per se (see also Bartlett & Searcy, 1993).

More generally Diamond and Carey's results suggest that faces are not special, because relational features can be used to recognise members of other familiar classes that share a configuration. Nevertheless they are special in that their unusual homogeneity forces us to rely on relational features to a greater extent than for most other objects. Diamond and Carey acknowledged this duality by entitling their article, "Why faces are and are not special"!

Diamond and Carey have also proposed that expertise is needed to use these subtle relational features, as only dog experts and not dog novices, showed the large inversion decrements. This proposal suggests an intriguing explanation for the difficulty people experience with other-race faces (for a recent review see Bothwell, Brigham & Malpass, 1989). Perhaps lack of expertise with these faces means that relational features can't be used effectively and that people must rely largely on isolated feature cues. This speculation leads to the counter intuitive prediction that inversion should be *less* disruptive to recognising other-race faces than own-race faces. When we tested this hypothesis, using Caucasian subjects from New Zealand and Chinese subjects from Singapore, we found that the prediction was supported (Rhodes, Tan, Brake & Taylor, 1989). Inversion had a reliably larger effect on recognition of own- than other-race faces (Figure 15).

Concluding Remarks

So, what progress have we made on the identity secret? What have we learned about how the identity of a face is decoded? Our caricature results suggest that we focus on whatever information is unique or distinctive about a face. When we encounter a face we code whatever makes that face different from others, probably by comparing it to a norm or average face. This representation would then be compared with memory representations of known faces, and if a match was found, the identity would be revealed. Our inversion results suggest that a particular kind of distinctive feature is especially important for faces, namely relational features. Therefore, in contrast to our focus on components, eyes, nose and mouth, when we try to describe a face, our visual systems seem to rely more on the subtle spatial relations between these components. Perhaps this is why we are so poor at describing faces, and must resort to wearing a red carnation buttonhole in order to identify ourselves if we are being met by a stranger at a station or airport.

As part of our effort to understand how we decode the identity of a face, we have also tried to discover whether faces are special. We agree with Diamond and Carey, that they are and are not special. Just as a large inversion decrement extends to other familiar objects that share a configuration, so too does the caricature advantage. Therefore, both relational features and norm-based coding can be used for classes other than faces, meaning that faces are not special. However, because faces are unusually homogeneous, we rely on these strategies to a greater extent for faces than most other objects, so that faces are indeed special in this restricted sense.

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Author Notes

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