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Featural vs. configurational information in faces: A conceptual and empirical analysis

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The perception and memory of faces have been accounted for by the processing of two kinds of facial information: featural and configurational. The starting point of this article is the definition and accepted usage of these two concepts of facial information. I discuss these definitions and their various ramifications from three aspects: methodological, theoretical and empirical. In the section on methodology, I review several of the basic manipulations for changing facial information. In the theoretical section, I consider four fundamental hypotheses associated with these two kinds of facial information: the featural, configurational, holistic and norm hypotheses (the norm-based hypothesis and the 'hierarchy of schemas' hypothesis). In the section on empirical evidence, I survey relevant studies on the topic and consider these hypotheses through a description of various empirical phenomena that carry clear implications for the subject of the study. In conclusion, I propose two alternative directions for future research: first, a 'task-information' approach, which involves specifying what information is used for different tasks; and secondly, taking a different approach to the definition of the visual features for face processing, for example by using principal components analysis (PCA).

In the last 20 years an enormous research effort has been focused on perception and memory of faces. One central question has focused on how faces are analysed and represented in memory—as features or as configurations. The present article concentrates on an analysis of these different kinds of facial information, and their place in the perception of a face and its recognition. Other issues that arise in the face perception area (e.g. the modularity question, neurophysiological studies and computer modelling) are addressed only insofar as they are essential for understanding the topic of the present study (e.g. Ellis & Young, 1989; Nachson, 1995). I focus on conceptual issues and their relation to empirical data gathered from human laboratory experiments.

The starting point is the definition and accepted usage of the following two terms in facial information: I define featural information in reference to isolated facial features

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in everyday use—hair, brow, eyes, nose, mouth, cheeks and chin; and configurational information in reference to the spatial relations between the features, their interaction, and to various proportions, such as nose length to brow length or brow area to face area (Bruce, 1988; Diamond & Carey, 1986; Garner, 1978; Rhodes, Brake, & Atkinson, 1993; Searcy & Bartlett, 1996; Tanaka & Farah, 1993; Tanaka & Sengco, 1997).

In the subsequent sections I discuss these definitions and their various ramifications from three viewpoints: methodological, theoretical and empirical. In the methodological section, I survey several of the basic manipulations for changing facial information. In the theoretical section, I consider four basic hypotheses associated with featural information and configurational information: the featural, configurational, holistic and norm hypotheses (the norm-based hypothesis and the 'hierarchy of schemas' hypothesis). In the section on empirical research, I review the relevant material. As few studies have attempted to compare the different hypotheses (because some of them were developed in the course of the research work), I discuss these hypotheses while describing the empirical findings.

Finally, in the Discussion, I examine the following two basic questions: can one propose which is more important—featural or configurational facial information? My answer is both. And, of all the hypotheses considered, can we determine the one hypothesis that is the most efficient (i.e. that explains all or most of the findings)? My answer is no. These conclusions are supported by the following analysis. First, I discuss the relationship between the four hypotheses and the findings, and then I propose four difficulties in concluding which hypothesis is the most efficient. Secondly, based on the above, I propose for future research an outline of the task-information approach, for dealing with the complex interactions between facial information and memory tasks. Thirdly, I discuss another approach for future research, that of the 'principal component analysis' (PCA). It presents a new way for handling facial information including featural and configurational information.

Methodology: Some basic manipulations

In this section, I examine some of the main experimental manipulations associated with featural information and configurational information. (Other manipulations, such as pixelization and darkening, are discussed in the empirical evidence section.) These are depicted in Fig. 1.

Figure 1 shows seven examples of facial transformations concerning the distinction between featural information and configurational information. With *spacing*, we alter the distance between the facial dimensions or features, for example increasing the distance between the eyes, and increasing the distance between the nose and the mouth.

Although this variable seems to be one of the most important variables for examining configurational information, a rather difficult problem arises here, which I call the 'intrinsic connection' (e.g. Bruce, 1988; Haig, 1984; Rhodes *et al.*, 1993; Sergent, 1984). For example, a change in the distance between the eyes (a configurational change) may well be perceived as a change in the nasal bridge, namely a featural change; and vice versa, broadening of the nose may be perceived as a change in the spatial relations between the features, namely a configurational change.

With *sizing* we change the size of a facial feature, for example enlarging the nose. A change in the size of the nose obviously also changes the spatial relations of the features.

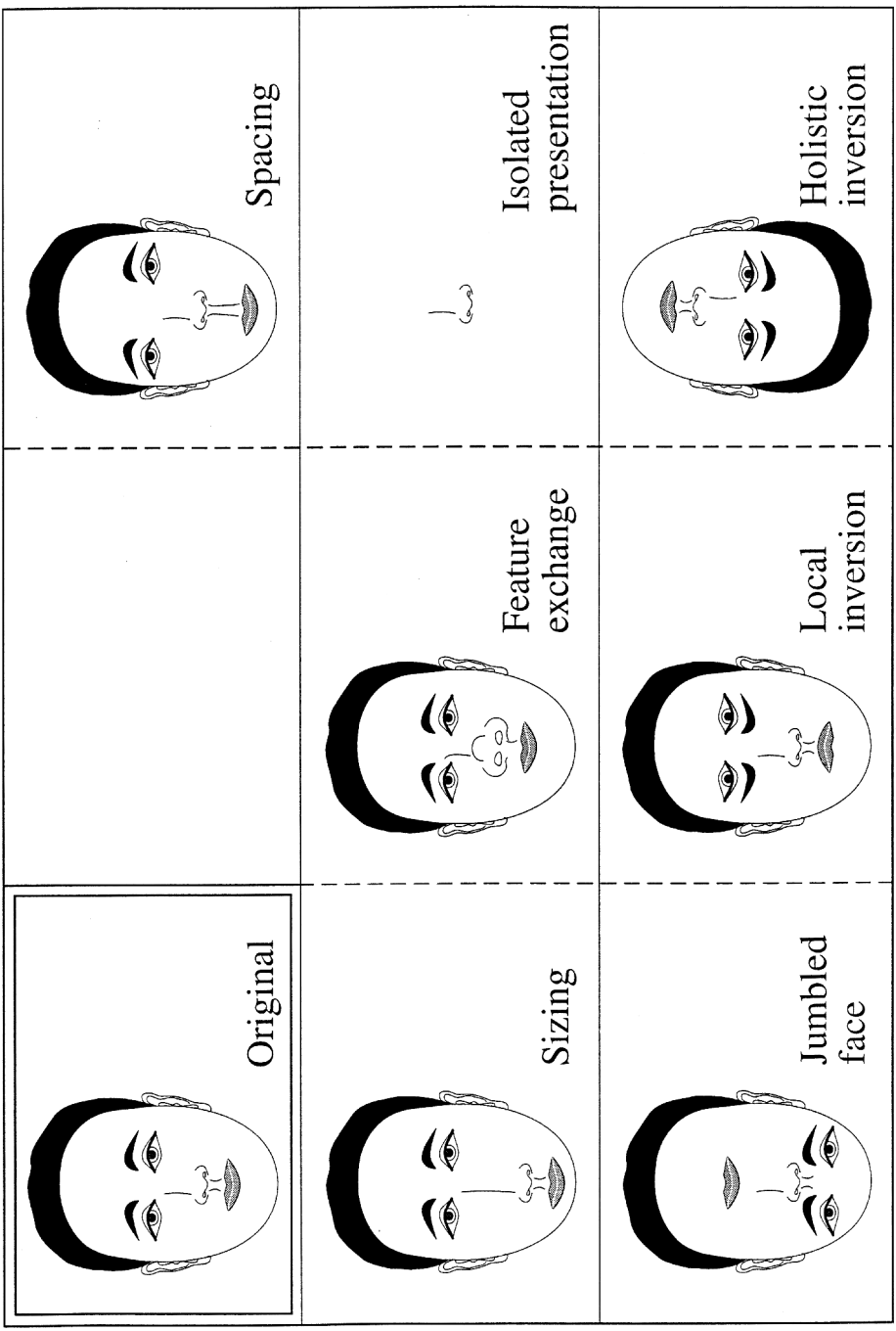

Figure 1. Seven facial transformations.

With *feature exchange*, we change or replace facial features. In Fig. 1 the nose has been replaced. Here we should point out once again that the change in the feature changes the spatial relations between the features.

With *isolated presentation*, we show isolated facial features, without the facial setting. In Fig. 1 the nose is shown alone. This presentation of a single facial value omits all the spatial relations, namely the configurational information.

With *jumbled face*, we change the places of the facial features. In Fig. 1 the positions of the eyes and the mouth have been exchanged. Again, it is worth noting that this change entails substantial changes in the spatial relations of the facial features.

With *local inversion*, we invert isolated features while maintaining their position in the face. In Fig. 1 we have inverted the eyes and the mouth, and we get the famous Thatcher illusion (e.g. Thompson, 1980). Here, too, the change involves a change in the spatial relations of the features.

With *holistic inversion*, we invert the entire face. This operation, despite the enormous influence on face recognition, does not change the spatial relations among the facial features.

Theoretical approaches

These experimental manipulations and others (see below) address the following four main hypotheses: (1) the featural hypothesis; (2) the configurational hypothesis; (3) the holistic hypothesis; and (4) the norm hypotheses (the norm-based hypothesis and the 'hierarchy of schemas' hypothesis). I describe them briefly in this section. In the following section on empirical evidence, I expand on the treatment of these hypotheses, and discuss other hypotheses (e.g. parallel processing and spatial frequencies) as well.

The featural hypothesis

This posits that we perceive and remember faces chiefly by means of facial features. For example, we say that this is a picture of the face of Cyrano de Bergerac because only he has such a big nose; or that only one woman in the world has such an enchanting mysterious smile—Mona Lisa. The face as a whole is perceived only as the sum of features, and the face is nothing but the joining of isolated facial features. (Garner, 1978, calls the whole that is no more than the sum of its parts the 'simple whole'.) The methods of face reconstruction, such as the photo-fit and the identikit, are close to this approach. Penry (1971), the inventor of the photo-fit, writes: 'Because each facial part is the sum of its individual details and the whole face is the sum of its sections, the total assessment of it requires a careful visual addition' (p. 101). Still, it is worth emphasizing that Penry did not entirely disregard the fact that the sum of facial features also creates something more, namely a new configuration. While he believes that a given face is a particular combination of individual features, he also suggests that 'in an otherwise similar profile the substitution of only one feature greatly alters the whole facial appearance. Whenever there is even a one-feature difference, the eye is tricked into assuming that the entire facial outline is different' (p. 14). Hence, Penry is a featural theorist who admits that configurational processing plays some role in face perception.

The configurational hypothesis

This holds that we perceive and remember faces by means of two kinds of information,

namely featural and configurational, where the importance of the latter is generally conceived of as greater than of the former (e.g. Bartlett & Searcy, 1993; Diamond & Carey, 1986; Garner, 1978; Rhodes *et al.*, 1993; Searcy & Bartlett, 1996).

Diamond and Carey (1986) proposed this hypothesis, among other things, as a solution to the facial inversion effect and as an alternative to the hypothesis that facial information is processed through a special cognitive mechanism. They stress that faces are visual forms 'sharing the same configuration'—hair above brow above eyes, and so on. Not all visual forms share the same configuration. Landscapes, for example, are not given this quality as one scene may include water and sky and another houses and trees. Visual forms that do not share the same configuration are distinguishable by 'first order relational properties' (1st-orp), namely according to the spatial relations between similar parts that constitute them (e.g. the relation between a house and a tree). In faces the 1st-orp is constrained by a common configurational pattern, and therefore it is possible to distinguish faces by the spatial relations between the facial elements that define the shared configuration. Diamond and Carey called this 'second-order relational properties' (2nd-orp). (In Fig. 1, jumbling a face alters 1st-orp, while spacing alters to 2nd-orp). This idea of Diamond and Carey offers a solution to the problem known as the 'homogeneity problem': if all faces share a common configuration, how is it possible to distinguish so many faces?

In a similar way, Rhodes (1988) differentiated first-order features characterized as those that may be described independently from other parts of the face (e.g. eyes, nose, mouth) from second-order features, characterized by the spatial relation between them, their position on the face and the shape of the face. (Rhodes also defined higher-level features as a complex group such as age, sex and weight. Garner, 1978, regards the kinds of information created by the spatial relations of parts of the whole as configurational properties, for example symmetry and repetition.)

Despite the similarity between Diamond and Carey's approach and that of Rhodes, the story is not simple. The main reason is the concept of 'shared configuration' suggested by Diamond and Carey. This concept presents a different view of the notion of configuration. According to this view, configuration is understood as a process that compares a face to a facial norm, that comes from learning and acquiring skill in perceiving and remembering faces. Rhodes and Tremewan (1994) differentiated two kinds of configurational information: one referring to the spatial relations between features, and the other to the coding of the information of a given face in relation to the facial norm (see below).

The holistic hypothesis

According to this hypothesis, we perceive and remember faces by using two kinds of information—featural and configurational—where these kinds are perceived as a single entity, the whole face. This perceptual wholeness is difficult to break down into its parts without seriously harming perception and remembering a face and its parts. The holistic hypothesis has two interpretations concerning the relation between feature information and configurational information. According to the accessibility interpretation, the whole face is more accessible in the memory than its parts; according to the configurational coding interpretation, configurational information is more important than featural information—an interpretation not greatly different from the preceding hypothesis (e.g. Farah, 1992; Farah, Tanaka, & Drain, 1995; Farah, Wilson, Drain, & Tanaka, 1998; Tanaka & Farah, 1993; Tanaka & Sengco, 1997). (For a different

interpretation of the holistic hypothesis that views a face as a unit, a facial Gestalt, see Searcy and Bartlett, 1996).

The norm hypotheses

Research in the concepts of norm, prototype and schema has a long and complex history (see discussion in Komatsu, 1992; Rhodes, 1996). For present purposes I distinguish two variant hypotheses on the concept of norm.

Norm-based hypothesis

According to the (prototype) norm hypothesis, all facial information, featural and configurational, is presented in a cognitive system as deviations from the norm, as distances from the abstract prototype face. These deviations emphasize the featural or the configurational qualities of a given face with respect to the norm (e.g. Rhodes, 1996; Rhodes *et al.*, 1993; Rhodes, Brennan, & Carey, 1987; Rhodes, Carey, Byatt, & Proffitt, 1998; Valentine, 1991a, 1991b). The idea of a facial norm and deviations from it can be seen in the way that computerized caricatures are made. Brennan (1985) developed the following technique. First, a true drawing of a specific face is made by marking the outline of the picture of the face at many critical points, which are then connected by lines. Next, a facial norm is created by computation of an average of a large number of such drawings according to age, sex, race and so on. Finally, the drawing of a target face is compared with the norm, the average face. The comparison makes it possible to create caricatures by enlargement of the distances between the target face and the norm, and anti-caricatures by reducing these distances. While caricatures increase configurational qualities of a given face as compared with the facial norm, anti-caricatures decrease these configurational qualities. (For other procedures for creating norms or prototypes, see Benson and Perrett, 1991, 1993).

Hierarchy of schemas

Following Goldstein and Chance (1980), Rakover (1999), Rakover and Teucher (1997), Vernon (1955), Wiseman and Neisser (1974) and Yuille (1991), I suggest the hierarchy of schemas hypothesis. The hypothesis suggests that many complex multidimensional stimuli are processed according to existing schemas in the cognitive system. Face recognition depends on a schema of the whole face that contains schemas of features. One of the important components of the whole face schema is the spatial order of the internal facial features: eyes above nose above mouth. (This is why, for example, we see faces in clouds or in ambiguous pictures (e.g. Wiseman & Neisser, 1974).) Similar arrangements also exist in schemas of facial features. For example, the schema of the eyes is based on the order eyebrows above eye in which there is a pupil. The facial information is processed and meaningfully arranged according to these schemas when the perception of the whole face determines the perception of the individual features. (Several researchers suggest that general or global perceptual processing precedes processing of the parts of the whole, for example Bruce, 1988, Navon, 1977, Peressotti, Rumiati, Nicoletti, and Job, 1991).

These two hypotheses assume abstract facial concepts—norm and schema—whereby the cognitive system deals with faces. The main difference between them is that while the norm-based hypothesis suggests that the face is coded in respect of the

norm, as deviations from the norm, the hierarchy of schemas hypothesis suggests that perception and memory of the facial stimulus are accomplished according to schemas (see also on the schema as a search-directing process in Gyoba, Arimura, & Maruyama, 1980; Neisser, 1976; Palmer, 1975, 1977).

In sum, while all these hypotheses refer to both featural and configurational information, the differences among them are a matter of emphasis. The featural hypothesis emphasizes greatly the importance of featural information in the perception and memory of faces; the configurational hypothesis emphasizes configurational information; the holistic hypothesis unifies both types of information in a face template; the norm-based hypotheses conceives both types of information in terms of deviations from the norm-face; and the hierarchy of schemas conceives these types of information as organized in schemas of a face and its features.

Empirical evidence

The various hypotheses described in the previous section on representation and processing of facial information have been tested in a number of empirical studies. However, many of these do not attempt to distinguish these hypotheses empirically. A major aim is to substantiate the influence of configurational information in a controlled experiment. Sergent (1984) argues that although most researchers believe that the face is processed wholly, as one unit, there is little experimental evidence in support of the configurational hypothesis. Much empirical material connected with the question of facial feature salience may in fact be interpreted as supporting the featural hypothesis (e.g. Rakover & Cahlon, 1989, 1999; Rakover & Teucher, 1997; Shepherd, Davies, & Ellis, 1981). Indirect empirical evidence in support of the configurational hypothesis is found in experiments showing that recall of faces judged holistically (e.g. participants judge the face according to its degree of likability and honesty) is better than faces judged according to the physical qualities of their features (e.g. Bower & Karlin, 1974; Patterson & Baddeley, 1977); in experiments on the perception of facial expression (Ekman, 1972); or in experiments showing that face recognition is maintained even when the contours of the features are blurred (Harmon, 1973). As stated, then, the purpose of many of the experiments described below is to exemplify the importance of configurational information, and to refute the featural hypothesis. The empirical phenomena reported here are organized more or less in terms of their historical origins and the complexity of the experimental manipulation supporting the featural, configurational, holistic or norm hypotheses.

Feature exchange

In this series of experiments the participant is shown a pair of faces (simultaneously or successively). The participant's task is to decide if the two faces are the same, similar or different, where some of the pairs were the same and some were different in one or more features. The results were analysed according to various models (e.g. if the participant scans the face serially, feature by feature, or if he or she examines the face in parallel), and the overall conclusion is not unequivocal: some of the experiments support the featural hypotheses, some the configurational, and some both (e.g. Bradshaw & Wallace, 1971; Matthews, 1978; Smith & Nielsen, 1970; see review and discussion in Bruce, 1988; Sergent, 1984).

As examples, let us examine the experiments of Tversky and Krantz (1969) and of Sergent (1984). Tversky and Krantz showed the participants one or two pairs of schematic faces distinguished by three components: eyes, mouth and face shape. Participants had to (1) grade the degree of dissimilarity between the two faces appearing in one pair, and (2) grade which of the two pairs showed a greater degree of dissimilarity between the faces in a pair. Analysis of the results showed that the total degree of dissimilarity between the faces was nicely explained by simple addition of the degree of dissimilarity of the components of a face. That is, the result strongly supported the featural hypothesis.

Sergent likewise presented pairs of schematic faces differentiated by three dimensions: eyes, chin and spatial relations between the internal features of the face. The participant had to (1) grade the degree of dissimilarity between the two faces in a pair, and (2) decide for each pair if it was the same or different, where the pairs appeared in upright or inverse orientation. Analysis of the dissimilarity data showed, in contrast to Tversky and Kranz, that the general impression of the face could not be explained by simple addition of the parts of the face. Analysis of reaction time (RT) showed that the eyes and the chin were processed independently. But this was not the case for the spatial relations dimension. When the face was shown in upright orientation, an interaction was produced between the spatial relations and the two other dimensions, expressed as reduction of RT. Such an interactive effect was not found when the faces were shown inverted. As configurational information is based on mutual influence, namely interaction between the facial features, these results were interpreted as supporting both hypotheses—the featural (mainly in faces shown in inverse orientation) and the configurational (mainly faces shown upright). (See also Takane and Sergent, 1983).

Spacing and sizing

In this series of experiments the participant is shown faces in which changes are made in the distance between the features and in the size of the features. These transformations are thought to change configurational information (see Fig. 1). Several studies found that these manipulations systematically influenced face perception and recognition, findings that are interpreted as supporting the configurational hypothesis.

Haig (1984) showed participants a series of unknown faces, on which the above transformations were made, in a face recognition task. He found that participants were very sensitive to slight changes in the distances between facial features, for example the reduction of the distance between the eyes greatly affected recognition of the original face. Haig (1984, 1986) also found that changes in facial features and the relations between them produced the perception of a new face (for a similar effect see Penry, 1971, p. 14).

Hosie, Ellis, and Haig (1988) asked participants to grade the degree of similarity between a familiar target face and a face that had undergone transformation. They found that the degree of dissimilarity increased with the degree of distortion of the face, and spacing and sizing of the internal facial features impaired recognition of the target face more than changes in the external features.

Rhodes (1988) obtained ratings of facial features and similarity judgments of faces performed by participants in her experiment, and measures of distances among facial features; she then analysed the data by a multidimensional technique. The results supported the hypothesis that faces are processed by employing both featural

(eyes, nose and mouth) and configurational (spatial relations among facial features) information.

Recently, however, Macho and Leder (1998) found that facial features are processed independently. They varied eye separation, width of nose and size of mouth and discovered that similarity judgments (whether a test face is more similar to one of two target faces) are based on a single feature and are not affected by the interaction between features.

Low spatial frequencies

Any spatial pattern, including the human face, can be viewed as a blend of a number of simple sine waves, characterized by their spatial frequency, direction and amplitude. Harmon (1973) and Harmon and Julesz (1973) suggested that the facial information required to identify a face is located in the range of low spatial frequencies. These frequencies do not show the details of the face but its general configuration. To test the hypothesis, they eliminated high frequencies by a technique called blocking, quantization or pixelization. The face is divided into a network of pixels (a pixel is a small area possessing a uniform degree of greyness). As the number of pixels increased, so did the degree of distinctiveness of the facial details and high spatial frequencies; as the number of pixels decreased, the blurring of the face and low spatial frequencies increased. Harmon and Julesz reduced the number of pixels by dividing the face into a network of squares, each containing a number of pixels. The degree of greyness of each square was calculated as the average of degrees of greyness of the pixels that composed it. Despite this, Harmon and Julesz found that the face could still be identified.

The great amount of research that followed the studies of Harmon and Julesz did not decisively support the hypothesis. The main findings were that facial identification requires a wide range of spatial frequencies; and that as blocking is greater (i.e. the size of the squares in the network increases) or the elimination of high spatial frequencies rise, the degree of identification of the face decreases, so that from a certain lower boundary, identification is entirely random (see e.g. Bachmann, 1991; Bruce, 1988; Costen, Parker, & Craw, 1994, 1996; Fiorentini, Maffei, & Sandini, 1983; Sergent, 1986; Uttal, Baruch, & Allen, 1997).

The composite face effects

This series of experiments concerns the perception and memory of a face composed of parts of two different faces. Young, Hellawell, and Hay (1987) showed a participant a face composed of two parts taken from two different faces of two famous people: the upper part of the face (from the middle of the nose to the hair) was taken from one face and the lower part (from the middle of the nose to the chin) was taken from another face. The participant's task was to identify the upper part of the face. The findings showed that identification of the upper parts of the composite face was difficult. In contrast, identification of the upper part alone, of the inverted composite face, or of the upper part in the composite face in which the two parts were misaligned, was relatively easier. These findings were interpreted as supporting the configurational hypothesis, namely an interaction occurs between features that changes their perception, so that the perception of the upper part of the face in the composite face is different from the perception of this part in isolation. Inversion of the face and misalignment impaired the configurational perception, and as a consequence identification of the upper part in these two conditions was easier.

This result was replicated with schematic faces (e.g. Endo, Masame, & Kinya, 1989; Endo, Masame, & Maruyama, 1990) and with unknown faces (e.g. Hole, 1994). Hole notes that Young *et al.* (1987) did indeed attempt to check if the composite face effect could be generalized to unknown faces, but in his opinion their procedure was based on preliminary practice, which made the unknown face familiar. Therefore, Hole showed participants pairs of unknown faces, in some of which the upper part of the two faces of the pair was the same. These pairs were shown upright and inverted. The participants had to decide as quickly as possible if the upper part in each pair was the same or different. The results replicated the findings of Young *et al.* (i.e. the RT for a pair shown upright was longer than for a pair shown inverted), but only when the duration of exposure of the faces was 80 ms; when the exposure was 2 s, the effect was not obtained. Hole suggests that long exposure time allows feature-by-feature comparison, while short exposure time forces the participant to use the configurational strategy of perceiving the face as a whole.

Reinitz and his colleagues (e.g Reinitz, Lammers, & Cochran, 1992; Reinitz, Morrissery, & Demb, 1994) showed at the learning stage a series of line drawings of faces, and at the test stage different kinds of faces, among them 'conjunction faces'—namely faces shown at the first stage of the experiment and composed of the inner part of one face and the outer part of another. The participants' task was to decide if the face they were shown was old or new. The findings (e.g. recognition of an old face was far better than recognition of a conjunction face) were interpreted as supporting the following hypothesis: featural information and configurational information are coded independently, where coding of configurational information requires a greater investment of attention than coding of featural information.

Inversion effects

Memory of faces shown inverted holistically (chin above, hair below) is impaired in comparison with memory of faces shown upright. Compared with upright faces, the impairment in recognition of inverted faces reaches about 25%. Moreover, the decline in recognition of inverted faces is greater than the decline in recognition of other inverted objects, such as houses and aeroplanes (e.g. Yin, 1969; see review and discussion in Valentine, 1988).

This series of experiments investigates not only the effect of holistic inversion on face recognition itself, but also the influence of this variable on diverse facial transformations such as spacing, sizing, feature exchange and the like, depicted in Fig. 1.

Diamond and Carey (1986) explained the inversion effect as follows. When the face is presented upright, the participant's perception is based on two kinds of information, featural and configurational, but when it is presented inverted, his or her perception is based mainly on featural information. This difference in information processing explains the impaired recognition of the inverted face. That is, the inversion effect is explained not by a specific facial cognitive system, but by expertise—specifically, people's expertise with the human face. As supporting evidence, Diamond and Carey show that the inversion effect in pictures of dogs (body profiles) occurs only in expert dog-handlers. People who are not experts with dogs have not learned the configurational information associated with the spatial relations between the various features of a dog.

This research led to several studies that supported the configurational hypothesis. These studies tested whether holistic inversion removes only facial changes caused by

other variables (such as spacing and the Margaret Thatcher illusion), considered configurational variables.

Rhodes *et al.* (1993) found that inversion of a face harmed configurational information, which was activated in the experiment by changing the distance between facial features and the creation of the Thatcher illusion (local inversion) more than in a jumbled face and isolated presentation of facial features. Since the first two facial changes are configurational, it is especially significant that holistic inversion of the face specifically harms recognition of faces that have undergone spacing and local inversion.

Bartlett and Searcy (1993), like Rhodes *et al.* (1993), found that inversion of a face lowers the degree of grotesqueness aroused by faces with local inversion (Thatcherized faces) and faces that have undergone spacing. Inversion did not change the degree of grotesqueness of faces possessing emotionally grotesque expressions.

Searcy and Bartlett (1996) likewise found that while holistic inversion of a face reduced the degree of grotesqueness aroused by faces subjected to spacing, inversion did not affect faces that had undergone a change in features alone, such as distortion of the eyes or the teeth. Similarly, Leder and Bruce (1998a) found that while holistic inversion reduced the distinctiveness benefit gained in ratings and memory for faces subjected to changing configural features such as eye distance, inversion did not affect faces subjected to local changes such as thickening and darkening the eyebrow.

These experimental results were interpreted as supporting the configurational hypothesis which suggests that facial information is coded in a dual manner, by two different processes, namely featural and configurational. Faces shown upright are coded dually with emphasis on configurational information, and inverted faces are coded featurally. Holistic inversion, then, eliminates (or considerably diminishes) configurational information. That is, holistic inversion eliminates the effect of configurational variables (e.g. spacing and local inversion), but does not affect featural variables (e.g. isolated presentation, feature exchange and feature distortion). Furthermore, Searcy and Bartlett (1996) suggest that this differential effect of holistic inversion does not correspond with the holistic hypothesis (which proposes that the face is presented in the cognitive system as a single whole unit), because according to this hypothesis inversion should impede coding of both configurational and featural information. (They argue that this differential effect does not correspond with other hypotheses either, such as Valentine's theory (1988, 1991a), because these theories also posit a similar effect of inversion on the two kinds of facial information. See also Leder and Bruce, 1998b).

Similarly, Leder and Bruce (1998b, 2000) propose that face recognition is better explained by appeal to spatial relation between single features (e.g. nose–mouth distance, distance between the eyes) than by appeal to holistic processing. If a face is distinguished by the distance between the eyes, then it has been found that recognition of this face, when its two eyes are shown alone, is better than when one eye is shown within the context of the whole face. Hence, exclusion of an essential part of a spatial relation is not compensated by the context.

Clearly, the interpretation of the above empirical evidence depends on the assumption that holistic inversion does indeed impair configurational information. For this reason, Rakover's experiments that cast doubt on the validity of this assumption are important. Rakover and Teucher (1997) showed that holistic inversion of individual facial features (especially hair and brow, and eyes, which are the most salient features) impairs recognition similarly to inversion of the entire face. That is, elimination of spatial relations between features is not a condition for the inversion effect. Moreover, it

became clear that it is possible to predict with a fairly high degree of accuracy the recognition of a whole face (upright or inverted) with a formula based on recognition of isolated features. (But see a review and experiments that found it difficult to obtain the inversion effect with isolated features in Rhodes *et al.*, 1993, and Leder and Bruce, 2000).

Furthermore, in contrast with the configurational hypothesis, Rakover (1999) found that holistic inversion does not reduce the feeling of strangeness (created by the Margaret Thatcher illusion) in all the variations of the illusion (created by local inversion of eyebrows, eyes, and both features together) in regular faces and in jumbled faces. Moreover, in accordance with Valentine and Bruce (1985), he found that holistic inversion of a jumbled face not only does not reduce strangeness, it greatly increases it.

Whole and part effects

This series of experiments serves to support the holistic hypothesis that the face with all its parts is represented as a single whole in a cognitive system.

Farah (1992) and Tanaka and Farah (1993) inferred from the holistic hypothesis that recognition of an isolated facial feature (e.g. eyes, nose, mouth) is better in the case where the feature is shown in the context of the entire face than when it is shown in isolation, or where the configurational information of the original face has been changed. In the first stage of the experiment, participants learned names (e.g. Larry) for different faces. In the second stage they were shown, for example, (1) two isolated and different noses and the experimenters asked which of the two noses belonged to Larry, and (2) two faces identical except for the noses (the two noses that had appeared in (1)), and the experimenters asked which of the pair of faces belonged to Larry. Recognition in (2) was better than in (1). Furthermore, recognition in (2) was better than in cases where an inverted or jumbled face was shown. In the two latter cases there was no difference in recognition between isolated presentation of the feature and when the feature was shown in the context of the whole face. These researchers also found that this effect, called the 'whole/part advantage (effect)', was not obtained in the case of houses, where the participant was asked to decide which house or door was Larry's. A recent study, however, which replicated the whole/part advantage for faces, also obtained the same advantage for houses. This finding may indicate that houses are also processed holistically (see Donnelly & Davidoff, 1999; see also Davidoff & Donnelly, 1990).

Additionally, Tanaka and Sengco (1997) found that recognition of eyes in the setting of the original face was better than in a facial setting where the eyes were placed farther apart or close together (an experimental effect called the 'old/new configurational advantage'), and better than in the case where the eyes were shown in isolation. Moreover, the spatial change in the eyes affected other features, such as the nose and the mouth, for which they obtained effects similar to the effects with the eyes. These differences disappeared when the face was shown inverted or when houses were shown instead of faces.

Farah *et al.* (1995) taught participants in the first stage of the experiment names of faces under two conditions: (1) the face was shown in whole, and (2) the face was shown in parts (external features, eyes, nose and mouth). In the second stage they showed participants whole faces upright or inverted, and asked them to give their names. While there was no difference between the upright and inverted faces when in the first stage the face had been shown in parts, identification of the upright face was

better than of the inverted face when in the first stage the face had been shown wholly. (A similar effect was obtained for patterns of dots. See also Tanaka and Farah, 1991).

Farah *et al.* (1998) show in same–different matching experiments that faces are represented holistically. For example, similarity judgment of a nose in a pair of faces is affected by the perception of the whole face; and by a mask consisting of a whole face more than a mask made of parts of a face (a jumbled face). The masks followed a brief presentation of a pair of target faces. These holistic effects have been obtained in upright faces but not in inverted faces, words or houses. These experiments are particularly important because they show directly that faces are perceived and encoded holistically.

Similar to these are other experimental effects, namely the face superiority effect, in which recognition of part of the face (nose) was found to be better when in the first stage the nose had been shown in the setting of a normal face than in the setting of a jumbled face (e.g. Homa, Haver, & Schwartz, 1976); object superiority effect, in which parts of faces or chairs were recognized better when they appeared in the setting of a whole face or object than in the setting of a jumbled face or object, or in isolation (e.g. Davidoff & Donnelly, 1990); and the face detection effect, where a visual pattern of a normal face was detected as a face faster than a jumbled face (e.g. Purcell & Stewart, 1988).

Caricatures

As previously stated, while anti-caricatures reduce the uniqueness of a face, caricatures magnify the special way in which a certain face differs from the facial norm (the average face). Caricatures sharpen and highlight the spatial relations, namely the configuration characteristic of a given face. A large number of findings support this hypothesis: there are caricatures that are recognized as well as veridical representations of the face, and are better recognized than anti-caricatures (a phenomenon called 'caricature equivalence'); and there are caricatures that are better recognized than veridical representations (a phenomenon called 'caricature advantage' or the 'superportrait effect') (e.g. Benson & Perrett, 1991, 1994; Carey, 1992; Rhodes, 1996; Rhodes & Tremewan, 1994; Stevenage, 1995a, 1995b). In addition, Stevenage (1995b) found that identification of a picture of a target face at the test stage was better if at the first stage participants had learned to name a caricature of this face than if at the first stage they had learned to name a veridical representation of this face. Similarly, Calder, Young, Benson, and Perrett (1996) found that in comparison to veridical and anti-caricatured faces, caricatured faces increase the speed of deciding whether a name is familiar or not (i.e. self-priming)—a finding that has been interpreted as demonstrating caricature advantage. While these findings tend to support the configurational hypothesis, the following studies cast doubts.

Rhodes and Tremewan (1994) tested whether holistic inversion impairs caricatures. If caricatures change configurational information, then one may hypothesize that inversion will impair recognition of caricatures. The results did not support this hypothesis. It is possible, therefore, that the effects of caricatures arise from their distinctiveness, which results from the distortions that caricatures create in a face. Carey's (1992) data do not support this possible interpretation, since it was easier to identify anti-caricatures than lateral caricatures. (A lateral caricature is a special kind of caricature that increases the distance between a point on the norm face (N) and a point on the target face (F) in the following way. If we assume that the distance between N and

F is N- - - - - - - - - -F, then (1) a 50% caricature is created when this distance is increased by half (N- - - - - - - - - - - - - - -F), (2) a 50% anti-caricature is created when this distance is decreased by half (F- - - - -N), and (3) a 50% lateral caricature is created when F is moved by half of this distance but at a right angle to the vector connecting N and F.) Although the lateral face changed by an amount identical to the caricatures and anti-caricatures, the lateral face was identified most poorly. This finding supports the norm-based coding hypothesis or model, and not the distinctiveness hypothesis. In addition, Rhodes, Byatt, Tremewan, and Kennedy (1996) found that recognition of caricatures is independent of the initial distinctiveness of the face of which the caricature was made. However, note that Benson and Perrett (1994) found that recognition of caricatures of typical faces requires a higher degree of caricaturing than distinctive faces.

Consequently, Rhodes *et al.* (1998) tested which of the following two hypotheses or models was more fitting to the results of an experiment in which participants were shown caricatures, anti-caricatures and lateral faces: the norm-based coding model or the absolute coding (exemplar-based) model. (These models are based on Valentine's, 1991a, 1991b, multidimensional face space framework. In contrast with the norm-based coding model described above, the absolute coding model posits that a face is represented as a point in this space.) The results supported the absolute coding model. For example, one of the most important results that can be explained only by the norm-based coding model, in which anti-caricatures are better identified than lateral caricatures, was not obtained in this experiment. The results were interpreted as supporting the hypothesis that caricatures increase the degree of distinctiveness of a face, a condition that leads to enhanced remembering. Still, it should be stressed that in this experiment the result called caricature advantage, in which caricatures are better identified than veridical representation, was not obtained either. The authors note that apparently expertise is a necessary condition for obtaining such results. For example, Rhodes and McLean (1990) found that caricature advantage in drawings of birds only in participants who were ornithologists.

One reason for the inconsistencies in the findings regarding distinctiveness and caricatures may be that distinctiveness itself is a relational concept involving deviations from a norm face. Another reason, a partial one, is that the lateral caricatures used by Carey (1992) were incorrectly scaled to the norm (see Moscovitch, Winocur, & Behrmann, 1997; note 1; Rhodes *et al.*, 1998, p. 2309).

Prototype formation

The norm-based hypothesis assumes that the facial norm or prototype is created in a cognitive system as a result of extensive exposure to, and interaction with, a very large number of faces. The experiments attempt to discover how a prototype is created and the place of featural-configurational information in this process. Several studies show the 'prototype effect' according to which presentation of a series of faces at the learning stage generates a central value, a prototype, which is identified at the test stage as a face that had appeared at the learning stage, even if it was in fact a new face. That is, the imaginary prototype, the entire existence of which was in the participant's mind, was identified as a real face that had been seen earlier.

The results of Solso and McCarthy's (1981) experiment showed that human memory may compose previous facial representations into an entirely new representation, which is mistakenly identified as a face seen previously. At the learning stage participants were shown three faces composed of three out of the four features (hair, eyes,

nose and chin, and mouth) of the prototype (a 75% face), four 50% faces and three 25% faces (the prototype was not shown at this stage). At the test stage, the participants identified the prototype with greater certainty than they identified the 75% faces, a result that was repeated after a month and a half. Similarly, Inn, Walden, and Solso (1993) interpret a prototype as composed of the most frequent features, and recognition of the prototype increased with age.

Malpass and Hughes (1986) found that the prototype was a new synthesis of facial features that appeared at the learning stage. Furthermore, they found that the mode of these features, from which the prototype was composed, explained the experimental results better than the average.

Bruce, Doyle, Dench, and Burton (1991) showed at the learning stage a series of faces produced by moving the internal features of the face towards the brow or the chin, a manipulation that changes the configuration of the entire face. For example, moving the internal features towards the chin creates a young look, while moving these features towards the hair creates an old look. In these experiments also an imaginary prototype was created, which was identified at the test stage as a face that had appeared at the learning stage. They interpreted their results by way of two possible processes: one that creates a prototype, an average based on all similar faces, and another that keeps separate all the faces, the exemplars, that are distinct from each other. (The latter process involves a model that assumes representation in memory is exemplar- or instance-based, and the prototype is that face with the greatest degree of similarity to the other faces in the group.)

Cabeza, Bruce, Kato, and Oda (1999) found higher recognition of a prototype when faces are created by varying the location of the internal features within the same view than when the study faces are in different views created by varying head-angle. In accordance with Bruce *et al.*'s (1991) interpretation, they propose that while an averaging mechanism is responsible to the former finding, an exemplar-based process is responsible to the latter finding.

Expertise in face perception and other forms

The experiments tested whether featural information develops differently from configurational information. The basic hypothesis, which I call the 'expertise' hypothesis, is that mastery of configurational information requires lengthy training over a prolonged period (about 10 years for faces or dogs), so its effect on face perception and recognition is later, coming after featural information (see summaries and detailed discussions in Bruce & Young, 1998; Carey, 1992, 1996; Carey & Diamond, 1994; Chung & Thomson, 1995; Ellis, 1992; Gauthier & Tarr, 1997; Johnson & Ellis, 1995; Stevenage, 1995a; Tanaka & Gauthier, 1997). It is noteworthy that a considerable number of these studies describe different and variegated processes in the development of face perception and memory; I shall not discuss these processes here as they touch on our topic only slightly.

The findings are equivocal, as is, therefore, the support for the expertise hypothesis. In general, it may be said that even infants show sensitivity to the human face, and with age face recognition becomes better (at about age 12 there is a certain decline in remembering). These are basic findings. The question is whether this development is based on differential development of featural and configurational information. Compared with naïve participants (e.g. children who are not experts in facial configuration), do experts (e.g. participants aged 10 and older) evince more intense use of

configurational information in appropriate and commonly accepted tests? Note here that although most studies assume that children up to age 10 are naïve, not all studies support this assumption. For example, Ellis (1992) reports that compared with older children (10 and older), younger children actually perceive a caricature of a famous face as representing this face. This finding runs counter to the expertise hypothesis.

While Stevenage (1995a) suggested two tests for expertise, holistic inversion and caricature advantage, I examine a wider range of tests and effects, such as composite faces and the whole/part advantage. By means of these tests, two principal questions linked to the expertise hypothesis were examined: (1) Do experts and non-experts differ in perception and remembering of faces? (2) Do they differ in perception and remembering of faces and of non-facial objects?

Faces

The phenomenon that inversion of the face impedes face recognition in adults more than in children is considered as evidence for the featural to configurational development (e.g. Carey & Diamond, 1977; Goldstein, 1975; Goldstein & Chance, 1980). Carey and Diamond (1977) found that children up to age 10 recognized inverted faces as well as upright faces, and that they tended to rely on items (paraphernalia), such as a hat or scarf, far more than adults. They interpreted these and other findings as supporting the expertise hypothesis that from age 10 a transition occurs from reliance on featural information to reliance on configurational information in face recognition. However, these findings do not harmonize with several facts which indicated, among other things, that children perceive and remember faces holistically, and that adults too use featural information (e.g. Baenninger, 1994; Flin, 1985; Pedelty, Levine, & Shevell, 1985). Following Carey and Diamond (1977), Baenninger (1994) conducted several experiments, and found that adults and children relied more on configurational than featural information in face recognition. Carey (1992, 1996) and Carey and Diamond (1994) tried to test the expertise hypothesis by use of a composite face. If indeed a transition occurs in face perception from childhood to adulthood, then we should expect that the impediment to identification of the upper part of a composite face will be greater in adults than in children, because adults rely on configurational information far more than children. Carey and Diamond (1994) found that the composite face effect was obtained to the same degree in children aged 6 and 10 as in adults, for both known and unknown faces. The expertise hypothesis, then, does not win support from this test. In contrast, these researchers found that children were not influenced by holistic inversion of composite faces in the way that adults were.

The fact that these two effects, composite face and inversion, are independent of each other led Carey and Diamond (1994) to suggest two processes in face recognition: one is holistic coding, expressed in the composite face effect and in the whole/part advantage, and the other is expertise, expressed in the inversion effect. As holistic coding is not connected to expertise, Carey and Diamond (1994) suggest that Tanaka and Farah's (1993) whole/part advantage should also be obtained for all ages. Tanaka (in a personal communication to Carey and Diamond (1994)) reported that this result was indeed obtained in an experiment. Recently, Tanaka, Kay, Grinnell, Stansfield, and Szechter (1998) used the whole/part advantage procedure and found that indeed children and adults encode faces holistically. Hence, these findings do not support the hypothesis regarding the transition from featural information to configurational.

Non-face forms

If in experts of non-face forms we obtain effects similar to experts in faces, then it becomes possible to suggest a uniform explanation for all the facial and non-facial effects by a general visual process, which undergoes specialization for complex visual stimuli that share a common configuration. Empirical results are not unequivocal, as we shall see below.

The inversion effect and sensitivity to configurational information were found in experts on dogs and birds (e.g. Diamond & Carey, 1986; Rhodes & McLean, 1990; Tanaka & Taylor, 1991). However, Tanaka, Giles, Szechter, Lantz, Stone, Franks, and Vastine (as reported in Tanaka & Gauthier, 1997) found that experts in biological cells, cars and dogs' faces responded in a test of the whole/part effect like naïve participants. That is, expertise did not seem to have an effect on holistic recognition. This lack of uniformity of findings may stem from the fact that in daily life it is difficult to make a clear-cut distinction between experts and non-experts. Therefore, special interest lies in the series of experiments conducted by Isabel Gauthier and her colleagues, who tested the expertise hypothesis by means of artificial and computerized creatures called 'greebles' (e.g. Gauthier & Tarr, 1997; Gauthier, Williams, Tarr, & Tanaka, 1998; Tanaka & Gauthier, 1997). Here the expertise variable can be controlled experimentally.

The greebles themselves are three-dimensional objects whose degree of complexity is somewhat like that of a face. They consist of a body on which are mounted three parts that can be changed, as can the spatial relations between them. Gauthier and Tarr (1997) tested whether, compared with naïve participants, experts (i.e. participants who had been thoroughly and extensively trained (for 7–10 hours) in distinguishing and identifying greebles) would evince similar behaviour in face recognition in a test of Tanaka and Farah's (1993) whole/part advantage and of Tanaka and Sengco's (1997) old/new configurational advantage, described above. The findings were partly similar: in the test of the whole/part advantage, namely a condition in which a certain part of a greeble was shown in the setting of the original greeble (which had appeared in the learning stage), recognition was better than in the condition where the part appeared alone (although other results led the researchers to suggest that not expertise but a property of the greebles' group themselves was behind this result); and in the test of the old/new configurational advantages, the speed at which a part of the greeble was recognized in a condition where this part appeared in the setting of the original greeble, was faster than in the condition where the greeble setting had undergone spacing. These results were obtained with greebles presented upright, not inverted. Gauthier *et al.* (1998) replicated and expanded these results partially. No clear-cut differences were found between experts and naïve participants in the two tests of Tanaka and his colleagues, except with one out of the three parts of the greebles. A difference was found between expert and naïve participants in the composite test and in the inversion test, and even in the recognition of 'negative greebles' where light and shade were reversed. In all these cases similar results to those in tests with faces were obtained.

In sum, it seems that there is some support for the expertise hypothesis since experts in both non-face objects and in faces occasionally behave alike in memory tasks.

Discussion

Hypotheses and findings: Four difficulties

Given the above findings, can one discern the hypotheses that have been refuted or the most efficient hypothesis that account for most of the findings? I think not. There are

two major reasons for this conclusion: first, no hypothesis has received a *coup de grâce*, and secondly, there are four conceptual and methodological problems that seem to interfere with proposing a straightforward answer to this question.

The results of the studies reviewed here do not support any of the above hypotheses unequivocally. Consider the configurational hypothesis: some of the above findings regarding featural exchange, spacing and sizing, low spatial frequencies, composite face effects, inversion effects and caricatures do not support this hypothesis. For example, low spatial frequencies are not the only source for face perception: holistic inversion impairs recognition of isolated features too, it does not eliminate the feeling of strangeness in all of the variations of the Thatcher illusion and it does not impair recognition of caricatures. It is not clear that caricatures alter only configurational information, and expertise does not affect composite face recognition. Similar things can be said about the other hypotheses (for details see the above review). In fact, all of the above hypotheses won empirical support to some degree, in some task or other, and no experiment delivered the *coup de grâce* to any one of the hypotheses.

There seem to be two major reasons for this state of affairs. First, the results support the hypothesis that in face perception and remembering, all kinds of information are of great importance—featural, configurational, holistic and normative. The results cannot be explained by featural information, configurational, holistic or norm information alone. I discuss this idea in the next section. The second reason stems from four conceptual and methodological problems, which, as mentioned above, pose difficulties in inferring unambiguous experimental conclusions.

The 'intrinsic connection' problem

An important element, discussed at the beginning of the article, which makes it difficult to answer our question, is the difficulty in defining the two terms, featural and configurational information—namely, if every configurational change alters featural information, and vice versa, then no wonder it is hard to answer our questions.[1] However, it is possible that this difficulty is theoretical, and that in practice it is possible to discriminate between featural and configurational information (e.g. Bartlett & Searcy, 1993; Leder & Bruce, 1998a, 1998b; Rhodes *et al.*, 1993; Searcy & Bartlett, 1996). While this suggestion may be useful, note that, in these experiments, changing an individual feature to make it salient could transform a recognition task into a detection task, which is easy to perform even under holistic inversion.

Holistic inversion

One of the most important experimental manipulations that appears in most of the experiments reviewed above is holistic inversion. The basic assumption is that inversion conceals configurational and holistic information, but does not affect featural information. This assumption is used to explain a fairly large number of effects. The question raised (i.e. the 'inversion question') is why should inversion conceal configurational information? Clearly nothing has changed in the facial stimulus when the face is turned

[1] Furthermore, if a face is conceived of as composed completely of features (where e.g. the space between the eyes is viewed as a feature called the 'nasal bridge'), then any change in a face is both featural and configurational-holistic at the same time.

upside down. Even if we move the eyes farther apart, place the nose nearer to or farther from the mouth, or join two different parts of faces into one composite face, inversion of the face still will not change a thing in the stimulus pattern itself. What changes is something in the viewer's cognitive system. The change is in the observer, not in the inverted stimulus. The question is, what is it that changes in the cognitive system?

All answers to this question, in one form or another, are lodged in the everyday fact that from birth we are exposed to an enormous number of faces that appear before our eyes upright (e.g. Bruce, 1988; Goldstein & Chance, 1980; Rock, 1973, 1974; Valentine, 1988, 1991a, 1991b). However, except for adding this observation to the assumption that inversion impairs configurational information, researchers did not propose detailed solutions to the inversion question. For example, Diamond and Carey (1986), as stated, suggested three conditions for the inversion effect in any group of objects: (1) sharing a common configuration; (2) individuation of different objects belonging to the same category according to the 2nd-orp; and (3) expertise in (2). However, they too did not discuss in detail the process responsible for the elimination of configurational information by holistic inversion. Given the importance of this manipulation, if we do not know why and how a certain process impairs only configurational information, then it would be difficult to answer our question.

Nevertheless, there are few proposals that can be viewed as preliminary attempts to answer the inversion question. More cells in the temporal cortex of the monkey are tuned to upright orientation than to inverted orientation. The former cells display greater ease of recognition than the latter cells. Some of the cells in the temporal cortex are sensitive to configuration and they respond less to jumbled face or body parts (for a review and discussion see Perrett & Ashbridge, 1998).

Rock (1973, 1974) suggests that in the attempt to cope with an inverted face, the cognitive system is hard-pressed to accomplish mental rotation of all parts of the face; and Goldstein and Chance (1980) suggest that a developed schema suffers from rigidity, which prevents the schema from coping efficiently with an inverted face. Following these proposals and the hierarchy of schemas hypothesis, I suggest that schemas, which exist in our cognitive system, can cause errors in recognition of inverted faces, since we perceive and interpret visual stimuli according to these schemas. When a face is inverted, we try to cope with it by matching the face to schemas that have developed for faces and features that are upright. We scan the inverted face's salient features and organize them within the most suitable schema. As an illustration of this suggestion, consider the 'cat-woman' in Fig. 2.

Fig. 2 shows visual stimulus perceived as the face of a woman. But when this stimulus is inverted, though nothing has been changed in the stimulus itself, we do not see the inverted face of a woman: rather we see a new configuration of a cat. We see a cat because the salient features of the inverted figure are organized within a cat schema. Anyone who never in his life had had the pleasure of seeing cats, lions or leopards would not perceive this configuration as the face of a cat. (Note here that such a double inversion effect (man–woman) appears also in Rock (1974, p. 85). Rock does not interpret this effect as I do, but as supporting the hypothesis that faces are recognized on the basis of their upright retinal orientation.)

Shared configuration and norm

A very important argument states that because all faces share the same configuration, the distinction between different faces comes about by means of configurational

Figure 2. The 'cat-woman'.

information and the relationship between a face and the facial norm (e.g. Diamond & Carey, 1986; Rhodes, 1996). Although this assumption has empirical support, the following problems are worth noting.

First, the inversion effect is obtained also in stimuli that do not share a common configuration such as print or handwriting (e.g. Bruyer & Crispeels, 1992).

Second, not only do human faces share the same configuration, so do the faces of monkeys. Yet for all that, one would not tend to say that the distinction between human and monkey faces is made principally by means of configurational information. (Note here that regarding pictures of faces of people, monkeys and gorillas, Phelps and Roberts (1994) found that the inversion effect occurs in people and monkeys, but not in pigeons.) I suggest, therefore, according to the hierarchy of schemas hypothesis, that much of the distinction between different faces is owing to the variability of every facial dimension (e.g. different noses and mouths). That is, faces are also distinguished by the kind of features they possess.

Third, how does one determine shared configuration? In order to answer this

question one has to determine first what is meant by common configuration: everyday facial features, types of grey surfaces, types of lines and contours, etc. The problem is, how far do these possibilities play a role in face perception and memory.

Norm and prototype are theoretical concepts intended to describe some abstract facial pattern (e.g. the average) representing a group of faces. As the facial norm is a calculated, abstract concept, the following problem arises. Since the norm can be applied to every face, it transpires that any change in the target face simultaneously creates a change in respect of the norm. For example, assume that the norm distance between the eyes is 2.5 cm, that the distance between the eyes of the target face is 2 cm, and that we set them 6 cm apart. This spacing simultaneously changes both the specific configuration of the target face owing to the additional 4 cm separation, and the configuration of the target face in relation to the norm owing to the creation of an additional difference of 3.5 cm. The question is, which of these two changes influences perception and memory of the face?

Operational definitions

The studies reviewed above start from operational assumptions about the connection between experimental manipulations and the featural and configurational facial information. For example, as stated, the researchers assume that spacing, holistic inversion and the Thatcher illusion are associated with configurational information, while featural exchange, isolated presentation, sizing and jumbled face are associated with featural information. While the operational definition allows researchers to get on with the job, it is not based on so solid a connection between theoretical concepts and observations as, for example, the connection in physics between the concept of distance and the observation. In psychology, the connection between the theoretical concept and the observation is based on common sense, previous experimental results and theoretical implications (see discussion in Rakover, 1990).

Tanaka and Farah (1993) and Tanaka and Sengco (1997) attempted to close the concept-observation gap and to operationally define holistic recognition in terms of the whole/part advantage procedure, described above, in which identification of an isolated feature is compared with identification of this feature when it appears in the setting of the target face (e.g. Tanaka *et al.*, 1998, p. 481; Tanaka & Sengco, 1997, p. 583). This raises a problem, since it is not clear how to treat new results generated by a slightly different procedure. According to this strict operational definition approach, a different procedure captures a different theoretical concept or process. However, if the operational definition suggests only a partial interpretation of the theoretical process, new findings do not necessitate the new theoretical process and they may be interpreted in terms of the original theoretical process (e.g. Rakover, 1990).

In sum, it seems difficult to answer the question regarding the relation between hypotheses and empirical findings for the following reasons. There is an intrinsic connection between featural and configurational information; it is not clear why holistic inversion eliminates configurational and holistic information; the conceptual definitions of shared configuration and norm are vague; and the operational definition of holistic recognition is too narrow.

Future research

While one option for researchers is to continue to design experiments aimed at a definitive answer to our question, I think that other approaches may be more profitable.

In this section, I suggest two directions for future research. The first is to develop what I call the 'task–information' approach, and the second is to look for new methods for discovering how the cognitive system represents facial information. One example of such a new important method is 'Principal Component Analysis' (PCA) (for other examples see Biederman & Kalocsai, 1998; Hancock, Bruce, & Burton, 1998). In the present section, I briefly discuss the latter two possibilities, since they attempt to handle multiplicity of facial information that may propose solutions to part of the above difficulties.

An outline of the 'task–information' approach

As mentioned above, it seems reasonable to assume that the cognitive system uses all kinds of facial information at its disposal to cope with a given perceptual and memory task. I believe that a fairly elaborate triple interaction exists among the cognitive processes, the facial information and the kinds of experimental manipulations and tasks used. This triple interaction is handled by other theoretical approaches as well (e.g. Bruce & Young, 1986). A major difference between Bruce and Young's model and the task–information approach is in the emphasis on components. Both deal with the information that can be extracted from a face, but while Bruce and Young's model laid more emphasis on the appropriate cognitive processes, the task–information approach stresses the importance of the tasks.

Certain studies in the literature can be interpreted as attempting to uncover the nature of the triple interaction as well as the task–information interaction. In some studies, a theoretical effort was made to predict when configurational and holistic information will be used, and when featural information will be used. For example, Bartlett and Searcy (1993), Rhodes *et al.* (1993), Leder and Bruce (1998a) and Searcy and Bartlett (1996), who support the dual (featural and configurational) hypothesis about representation of facial information, found that spacing and the Thatcher illusion were associated with configurational information, while a jumbled face, isolated features and changes in isolated features were associated with featural information.

Tanaka and Farah (1993) and Tanaka and Sengco (1997), who support the holistic hypothesis, found that identification of a facial feature was better in the setting of the original face than in the setting that had undergone spacing or than identification of an isolated feature. Furthermore, Tanaka and Sengco suggest that superiority studies and whole/part advantage studies are based on two different processes, mainly because with the superiority effects one does not obtain the whole/part advantage, whereby recognition of part of the face in the setting of the face is higher than recognition of the isolated part, and because similar results were obtained for objects and words for which shared configuration could not be found (e.g. Enns & Gilani, 1988; Wheeler, 1970). Nevertheless, Tanaka and Gauthier (1997) believe that it is still difficult to find a simple explanation for the findings indicating that the whole/part advantage is obtained with such stimuli as upright faces, biological cells, cars and greebles, but not with stimuli such as jumbled and inverted faces, houses and faces of dogs.

In some studies, researchers tried to reveal the nature of the interaction between expertise, and configurational and holistic information. Tanaka and Gauthier (1997) suggest that while sensitivity to configurational changes is a function of expertise, the whole/part advantage occurs in both naïve and expert participants; Rhodes and Tremewan (1994) hold that while the caricature advantage effect is obtained among experts with faces presented upright, the caricature equivalence effect does not

require expertise and appears in upright and inverted faces; and Carey (1996) and Carey and Diamond (1994) propose that the composite face effect is not associated with age, while the facial inversion effect is a function of expertise. These researchers call the expertise variable the 'mystery factor', and suggest that while configurational and holistic information is coded from an early age, expertise is based on coding in relation to the facial norm, which develops over time and is expressed in the inversion effect.

In the same vein, illustrating the interaction between memory tasks and cognitive processes, Wells and Hryciw (1984) found that while character assessments of faces improved recall in a recognition test, physical assessments of facial features were helpful in a test of target-face reconstruction, a test based on the application of the identikit technique. These authors believed that character assessments are suitable for recognition processes, and facial feature assessments are suitable for face reconstruction with the identikit. Wells and Turtle (1988) expanded this hypothesis and found accordingly that while assessment of the facial character improved the accuracy of face recognition, assessment of facial features enhanced accuracy in the verbal description of the face.

Finally, note that Cabeza *et al.* (1999) propose two different processes (averaging mechanism and approximation mechanism) for prototype generation, depending on the tasks to be performed.

In view of the above, how may one proceed in developing the task–information approach? While a complete answer is beyond the scope of the present article, I propose that the following should be taken into consideration. A task, which displays a face, presents a particular question that can be answered by appeal to particular facial information. For example, the question 'What is the emotional state of this face?' demands an answer different from the question 'Is this Ruth's face?' The task's demand can be answered from the information supplied by the face. The issue is then whether the face does supply the information demanded by the task. Hence, the match between the task's demand and the information supplied by the face is an important factor in the cognitive processes of a person observing a face (i.e. in the developing of the task–information approach). Similarly, Schyns (1998) developed a theoretical framework, called diagnostic recognition, whereby the interaction between task constraints (the visual information needed by the task to classify the presented object into perceptual categories) and object information (information that the object provides, e.g. shape and colour) creates diagnostic clues by means of which recognition is accomplished. As a simple example, one may look at the change in the importance of nose length for various tasks. When the task is identification of a person (Mary) from a profile, nose length will be of great importance because Mary has a long nose. But if the task is to decide if the picture is a human face or not, nose length will be of slight importance.

Facial representation: Principal Component Analysis (PCA)

In many respects, the problem of featural vs. configurational information in faces discussed above stems from the following predetermined theoretical approach: we tend to perceive facial features and their configuration in terms of their linguistic description. Can we circumvent this approach and by this, hopefully, also circumvent the featural vs. configurational problem? PCA seems to suggest an affirmative answer, since PCA does not determine the facial features and their configuration *a priori*, but *a posteriori*, on the basis of a statistical analysis of multidimensional facial information.

While a description of PCA is far beyond the scope of this article, the following brief discussion gives the reader the general idea of this method and its relevance to the article's topics (for a description and mathematical discussion see Jordan, 1986; Turk & Pentland, 1991; Valentin, Abdi, O'Toole, & Cottrell, 1994; for a lucid description of PCA see Dunteman, 1989). PCA is a statistical method, which may be described and formulated as a neural net, and which is designed to treat multidimensional information—information obtained from a large number of measurements conducted on a large number of people. This method is somewhat similar to others, for example factor analysis and discriminant analysis. These methods provide economical ways of reducing multidimensional information to a number of variables, dimensions and factors, which are similar to principal components.

In general, PCA suggests a way of converting a large collection of N variables, which are interdependent in a high correlational relationship (over a large number of participants) to a small group of K independent variables ($K < N$), namely principal components (called eigenvectors or eigenfaces), so that this small group will represent appropriately the information represented by N. First, the PCA is presented with a large number of faces, namely computerized face images, and then it derives a number of principal components that differentiate among these face images and give the best fit between the derived facial information and the original information.

The PCA neural-net model is able to suggest explanations to a number of interesting facial effects such as the discrimination between old and new faces, the other-race effect, and the reconstruction of a whole face from a face with hidden parts (e.g. the eye area) (See e.g. Hancock, Burton, & Bruce, 1996; O'Toole, Abdi, Deffenbacher, & Valentin, 1995; O'Toole, Deffenbacher, Valentin, & Abdi, 1994; Turk & Pentland, 1991; Valentin, Abdi, O'Toole, & Cottrell, 1994). This success establishes the model not only as a satisfactory and promising way of understanding face recognition, but also a way of discovering the important dimensions whereby it is possible to represent faces. Furthermore, PCA, as a method of representation of facial information, can be applied and contributed to models of face recognition. For example, PCA instantiates the dimensions in Valentine's (1991a, 1991b) multidimensional face space model, and furnishes the inputs of facial information in the IAC neural-net model of Burton, Bruce, and Hancock (1999).

In summary, what are the main conclusions of this review? The following three points should be stressed. First, it seems that it is very difficult to attain the goal of explaining all facial phenomena by appeal to one kind of facial information such as featural or configurational. Secondly, there are four obstacles to achieving this explanatory goal: the intrinsic connection, the holistic inversion, the shared configuration and norm, and the operational definition. And finally, future research should consider the following two lines of research: (1) the task–information approach that stresses that the cognitive system uses different kinds of facial information so as to satisfy the informational demands of different tasks; and (2) the statistical method PCA that provides a new way to represent visual facial information that has been found very efficient in explaining many effects of face perception and recognition.

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