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Part-to-whole effects and configural processing in faces

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Abstract

In two experiments, the holistic face effect (Tanaka & Farah, 1993) was investigated by using a learning paradigm with faces which differed in terms of either componential (COMP) or configural (CONF) properties. When full faces had been learned, the expected finding of advantageous recognition of holistic presentations was replicated (Exp. 1). However, when only facial parts had been learned (Exp. 2), this effect was reduced and even reversed, indicating that wholistic superiority with both sorts of faces depends on holistic learning strategies (Leder & Carbon, in press, 2005). These results are in accord with the theory of encoding specificity (Tulving & Thomson, 1973). Moreover, the effects were found for COMP and CONF faces, supporting the hypothesis that holistic and configural processing are two different aspects of face recognition. Furthermore, when the faces were inverted at test inversion effects were not only found for CONF but also for COMP faces, indicating some kind of configural processing for faces that differ in terms of facial components.

Key words: whole-to-part superiority, configural, featural, holistic, face processing, face recognition

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Part-to-whole effects in configural face processing

Faces are amongst the most important visual patterns in our environment. They convey important information about other people, who they are, what they feel, and moreover they provide us with verbal and nonverbal signals (Bruce, 1988). Face recognition has been discussed as a candidate for a specialized processing, which allows the distinction of seemingly unlimited within-class discrimination (Schwaninger, Carbon, & Leder, 2003).

In the present study we address two classes of features which are involved in face recognition: components and configurations. Components are nameable parts of the face, such as eyes, nose and mouth, that vary from face to face. They somehow correspond to *geon*-like geometrical features (Biederman, 1987). These features vary in respect to shape, protuberance, etc. Configural features are the spatial and metric properties, which also distinguish different faces. Examples are the eye-distance and the mouth-nose-distance. This class of information is particularly affected when faces are turned upside down (Bartlett & Searcy, 1993; Leder & Bruce, 2000). It was recently argued that the occurrence of inversion-effects might indicate that configural processing is involved in recognition (Mondloch, Le Grand, & Maurer, 2002).

A different approach in understanding the specificity of face recognition is provided by the holistic processing hypothesis (Tanaka & Farah, 1993). Holistic processing means that faces are processed holistically as templates or Gestalts. Empirical evidence for this hypothesis comes from studies in which parts of a face, such as eyes, nose and mouth, are represented as being part of a whole rather than as explicit parts (Tanaka & Farah, 1993). There is still an ongoing debate whether this kind of whole-to-part-superiority (WPS) is exclusive for faces (Donnelly & Davidoff, 1999; Tanaka & Gauthier, 1997). In a typical test setting concerning holistic representation, full faces are compared with part conditions in recognition tests and reveal a superiority of the full face condition (WPS) (Tanaka & Farah, 1993). Importantly, in these experiments the part conditions need to be distinctive to recognize a specific face.

In the present study we tested whole and part conditions at study *and* test, using faces which differ exclusively in respect to the part versions. In order to better understand the relation between component, configural and holistic processing, the designs of our experiments include componential and configural manipulations with whole and part test conditions.

The relationship between configural and holistic processing approaches is not yet clear. Leder and Bruce (2000, Experiment 5) investigated the recognition of faces which differed in terms of components and configural features. The latter were constructed using eyes, noses etc. that were shared with components of other faces. There was a WPS, and only the configural features showed inversion effects. Tanaka and Sengco (1997) showed that recognition of components was affected when they were embedded in a "new" facial context in which the configuration, e.g. the eye-distance, was changed. Recently, Leder and Carbon (in press, 2005) used photographic faces and showed that recognition of parts which were learned in isolation was difficult when the parts were embedded in full faces. These experiments did not vary configural and component information independently and therefore do not reveal what the role of configural processing might be in whole-to-part effects.

The relationship between configuration and component information is an important issue in understanding and modelling face recognition (Schwaninger, Leder & Carbon, 2003).

Biederman and Kalocsai (1997) proposed that a general recognition model might be based on analyses similar to the *Gabor jet* model approach (Lades et al., 1993), in which information from various spatial scales is integrated. Configuration is then captured by coarse lower frequency analyses. Consequently all information in faces must somehow be derived from similar analyses, but must be integrated into a full description or holistic representation.

In the present study we investigated the relationship of configural and whole-to-part processing of faces by testing recognition of faces which differ only in terms of configural features. These faces were tested in full and part conditions at study and test. We compare these conditions with recognition effects of faces which differ from each other in terms of components. These faces correspond to those for which whole-to-part effects have been shown in the past (e.g., Tanaka & Farah, 1993). To create pure versions of configural information we use schematic faces here (see Figure 1), as in Leder and Bruce (2000). Only rarely have face researchers used pure versions of either sort of information. Most often local features consist of component features from other faces, which are then swapped into an old face (Rhodes, Brake, & Atkinson, 1993; Tanaka & Farah, 1993). Nonetheless, when the nose of a face is exchanged by the nose of a different person's face, not only local features, such as the size, shape or texture of the feature, change, but configural aspects might also be affected. This confoundation might account for the ambiguous results that are sometimes reported when unexpected large effects are found for changes in componential features (Rhodes et al., 1993).

Thus we compared the whole-to-part effects for both kinds of facial manipulation. If configural information is an essential element in whole-to-part or holistic effects because configural information is processed by coarse spatial visual analyzers, then we expect that both conditions interact. While components might be processed quite locally (e.g., Carbon & Leder, 2005, in press) and therefore show only slightly reduced recognition when presented in isolation, this effect should be more profound with configural features, which might require more of the context of a facial whole. Contrarily, Leder and Bruce (2000, Exp.4) report only small whole-to-part effects for parts which contain the critical configural feature. Thus the extraction of configural information might use an information processing filter which is not so much affected by a lack of facial context because it measures simple relations and metrics which do not interact with the availability of other features. In this case whole-to-part effects would be similar for configural faces and component features.

Similar to Leder and Carbon (in press, 2005) we also included part-learning conditions (Exp. 2) to investigate how recognition of schematic features in faces which are composed of clearly separable features is affected by a full face context at test. If a disadvantage for full faces was found at test after parts have been learned, this would shed new light on a possible interplay of features (Macho & Leder, 1998) in full faces.

Importantly, in order to directly assess the amount of configural processing we used upright and upside-down orientation (Mondloch et al., 2002). Moreover, by variation in presentation times we addressed the use of particularly time consuming recognition strategies in recognition of facial wholes and parts. Most studies in face recognition have employed rather unrestricted presentation times at test (Tanaka & Farah, 1993; Farah, Tanaka, & Drain, 1995; Leder & Bruce, 2000; Donnelly & Davidoff, 1999). In the present study, two presentation times were used (Exp.1); a shorter one (2000 ms) and a longer one (8000 ms). Pre-tests showed that 2000 ms still cover a realistic range of reaction time for most participants in similar experiments. Differences between the two conditions would reveal how a restriction in processing time affects configural or component versions.

Experiment 1

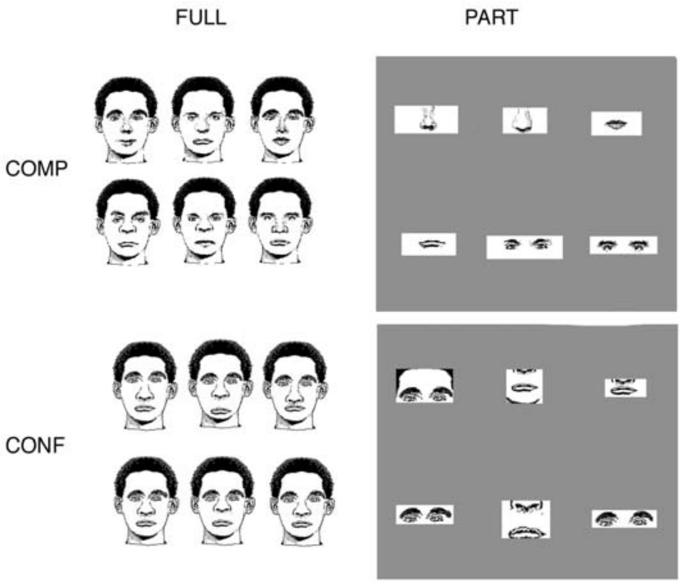
In Experiment 1, whole-to-part effects and inversion effects at test were examined for faces which either differed in respect to configural (CONF) or components (COMP) information and which were tested between-subjects under two presentation time conditions. In the study phase only full faces were shown.

Method

Participants. Sixteen graduate students and undergraduates from the Freie Universität Berlin were given either course credit or payment for their participation. All participants were tested individually. Mean age was 25.2 years. Ten participants were females.

Materials. Two different stimulus sets were used. Each set contained six faces and six assigned names. Figure 1 shows the stimuli. The faces were made using schematic Mac-a-Mug[3] features.

Figure 1:
Stimuli used in Experiment 1 and 2. On the left side, FULL conditions, on the right side, PART conditions are shown



[3] We were not able to find an actual owner of this program to give credit.

In the configural (CONF) set, each face had identically-shaped local features (eyes, mouth, etc.), but variation arose from the spatial relationships between these different features. In the component (COMP) set, faces differed by having two unique features such as eyes or mouth and shared one of the three features with one of the other five faces. This composition of the COMP was chosen in order to make the task to learn and recognise the faces similar in difficulty to the CONF version. At test conditions half the trials showed part-based or isolated features only. For the configural (CONF) versions half the stimuli consisted of full faces and half the trials showed parts of the face. These parts always included the critical feature because they had been cut out in a way that preserved those parts of the two components that constituted the specific configuration (as in Leder & Bruce, 2000, Exp.4). The different versions are shown in Figure 1. To preclude any bias in favour of a hypothesis concerning differences in feature saliency (between eyes, nose, mouth, see for example O'Donnell & Bruce, 2001) for each face in the COMP versions two part-versions were used at test, so that all unique features were covered. To make the two versions comparable in one statistical analysis all errors were calculated as proportions correct in the two main conditions by sampling data over all features, eyes, noses and mouths in the COMP versions.

At test, two different presentation times were used, 2000 ms and 8000 ms, to investigate whether more restricted times affect some conditions more than others. In both conditions the test stimuli disappeared after the given presentation time. No masks were used as it was only intended to exclude particularly time consuming serial scanning strategies in the 2000 ms condition. Participants ran the two blocks (CONF and COMP) in either shorter or longer presentation time, varying between participants.

Twelve short names were selected, which were randomly assigned to one of two name sets. The names we used were: Sam, Don, Ian, Max, Bob, Rex (Set 1), Ted, Joe, Guy, Ken, Tim, Les (Set 2).

Procedure and design. Participants were tested individually on each of the two sets in one session. The blocks were separated by short breaks. The procedure was very similar to the one used by Leder and Bruce (2000).

The order in which the COMP or CONF faces were learned was counter-balanced across participants, thus half of the participants started with either of the two versions. The allocation of names to faces was also counterbalanced across the sets, so that each face was learned under different names (by different participants). During all blocks the order of trials within each block was randomised by an experimental program.

Study phase. At the beginning of the experiment all faces of one set were shown simultaneously on the screen. The instruction in this pre-exposure stressed that a set of “difficult” faces - difficult due to their high inter-similarity - had to be learned in this experiment. These faces were presented for about 20 seconds to allow the participants to adjust to the difficulty of each discrimination task.

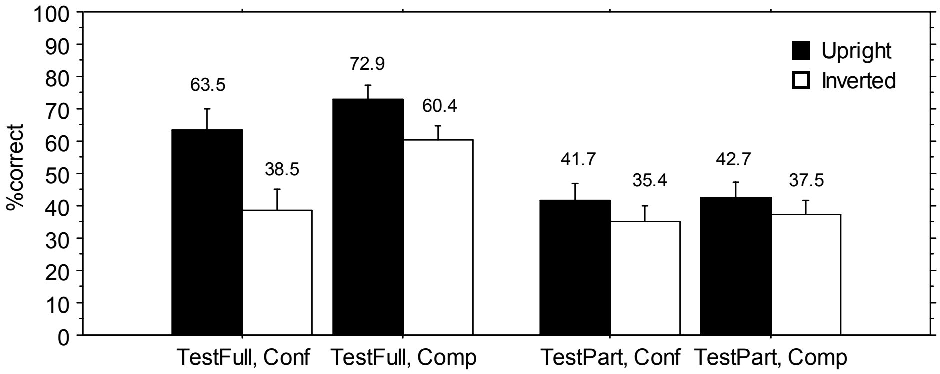
At the beginning of each experimental session participants were told they would be exposed to six different persons' faces, which they should try to learn and later recognize. The session started with five blocks in which each of the six stimuli was presented on the screen for five seconds, together with a short sentence saying "This is... " plus the assigned name. Within each of these blocks the stimuli were presented in a randomised order. A block in which each face was exposed once followed the learning block and the participants' task was to tell the experimenter the name of each face. During this phase each face was shown for five seconds, together with the question "Who is this?" After three seconds the correct name was shown beneath the stimulus to provide feedback. If participants got less than five of the six faces right in this block, the study phase was repeated until each participant met this criterion.

Test Phase. After a short break the test block began. During the test block all six names were shown together with a number of 1 to 6 beneath. The numbers indicated which key-number to press on the keyboard for each name. In each trial one test face was presented beneath the list of names. The test stimulus automatically disappeared after either two or eight seconds. Participants were instructed to press the number attached to the name that they thought was the stimulus person's name.

Each face was shown twice in each orientation (upright and inverted) yielding a total of twenty-four trials at test for each version. The order of the stimuli at test was randomised for each participant.

Results and Discussion. The main results in terms of proportion of correct recognition, sampled over subjects and both presentation times, are shown in Figure 2.

Figure 2:
Mean Results of Experiment 1. The mean percentage of correct recognition rates is shown for upright and inverted presentation and the two different sizes at test of the COMP and the CONF versions. The data are sampled over the two presentation times. Error bars are standard errors of the mean



Two separate analyses were conducted. First, we tested whole-to-part effects with an analysis of variance (ANOVA) that included all experimental factors. Inversion effects are rather difficult to interpret for part-based presentations. Therefore, in a second analysis we tested inversion effects in an ANOVA considering the full-face conditions only.

For the first analysis, the mean values of each participant were submitted to a four-way mixed-design ANOVA using VERSION (COMP versus CONF), SIZE at test (FULL versus PART) and ORIENTATION (UPRIGHT versus INVERTED) as within-subjects factors. PRESENTATION TIME (2000 versus 8000 ms) varied as a between-subjects factor.

There were main effects of ORIENTATION, $F(1, 14) = 34.464$, $p < .001$, $\eta_p^2 = .711$, and TESTSIZE, $F(1, 14) = 30.218$, $p < .001$, $\eta_p^2 = .683$. Moreover, there was a significant interaction between VERSION and TESTSIZE, $F(1, 14) = 4.915$, $p = .044$, $\eta_p^2 = .260$, and between ORIENTATION and TESTSIZE, $F(1, 14) = 5.372$, $p = .036$, $\eta_p^2 = .277$. The analysis revealed neither a main effect nor any interaction of the factor PRESENTATION TIME.

Concerning the whole-to-part-superiority, there was a main effect of full faces being better recognized than parts, a result which is in accordance with the general prediction of the holistic processing hypothesis. Full faces contained valuable information for the recognition of a target. In the COMP versions this was at least one additional distinctive component (eyes, nose or mouth), an important difference between the stimuli used here and those used by Tanaka and Farah (1993), who used shared features only. Importantly, both face versions, CONF and COMP, showed whole-to-part effects. As the CONF faces were also subject to these effects, it can be excluded that configuration is identical with holistic representation. However, there was also a significant interaction between VERSION and TESTSIZE.

As can be seen in Figure 2, both part versions were recognised equally well (CONF= 38.5%, COMP = 40.1%). The interaction is due to higher performance in the COMP versions. If the base rate of recognition in the COMP and CONF faces is generally different, then an interpretation of the size of a WPS is not warranted. However, from Figure 2 it is apparent that the difference between full and part presentation was always greater for the COMP than for the CONF versions. This similarity between COMP and CONF versions indicates that configural processing, as it was tested here, is presumably based on a context-independent processing of metric features. This is in accordance with Leder and Bruce`s (2000) claim of relatively local processing of configuration.

However, different from the findings presented by Leder and Bruce (2000, Exp.4) our results suggest that the FULL faces in the CONF versions were recognised significantly better than the PART versions. In the Leder and Bruce (2000) study there was a trend for the isolated features to be recognized slightly worse, which was not significant. Experiment 1 reveals that the WPS is stronger for COMP faces. The full COMP faces contain additional features, while the CONF faces contain only a more or less redundant context. Thus, the critical aspect responsible for the WPS might not be the pure quantity of contextual information, but the quality and relevance of this information. This interpretation is in accordance with the findings of Leder and Carbon (in press, 2005), who found strong learn-test compatibilities as well.

In order to test inversion effects in Experiment 1, an additional three-way mixed-design ANOVA was conducted, using VERSION (COMP versus CONF) and ORIENTATION (UPRIGHT versus INVERTED) as within-subjects factors and PRESENTATION TIME as a between-subjects factor. Only full faces at test were included in this analysis. The analysis revealed main effects of ORIENTATION, $F(1, 14) = 21.808$, $p < .001$, $\eta_p^2 = .609$, and VERSION, $F(1, 14) = 6.482$, $p = .0233$, $\eta_p^2 = .316$. Moreover, there was a strong trend towards an interaction between VERSION and ORIENTATION, $F(1, 14) = 4.500$, $p = .0522$, *n.s.*, which indicates that there were stronger orientation effects for CONF faces than for COMP faces. Nevertheless, as tests of simple main effects of orientation on both levels of VERSION showed, there was not only a significant inversion effect for CONF faces, $F(1, 14) = 20.160$, $p < .001$, $\eta_p^2 = .590$, but also an inversion effect for COMP faces, $F(1, 14) = 8.400$, $p = .0117$, $\eta_p^2 = .375$. The fact that even in the COMP version there were inversion effects is in accordance with the interpretation that components contain at least some - probably locally processed - configural information. These results shed light on the involvement of configural processing when faces differ in respect to components.

Presentation time variation in Experiment 1 produced no effect. Although the interpretation of a null-effect should be made with caution due to the given statistical power, the study at least reveals that the short presentation times did not negatively affect the recognizability of full or part conditions. Thus, recognizing faces from relevant componential or configural features proceeds relatively fast and not through particularly time-consuming strategies, at least not in the limited time range investigated here.

Experiment 2 aimed to test the hypothesis that the quality rather than the amount of extra-information is critical in producing WPS effects. In Experiment 2 part conditions were also used in the study phase. Different from Leder and Carbon (in press, 2005) CONF and COMP faces were used in order to investigate which of the two classes is more affected by embedding the part in a whole face at test.

If the whole versus part superiority is due to critical additional information, then the superiority should vanish when the information is not familiar from the study phase. This is somehow similar to the variation of holistic and non-holistic learning conditions in Farah, Tanaka and Drain's (1995) study, in which the latter were operationalized by presenting the constituting features of a face in a spatial arrangement in which each element was presented in isolation on a separate slide. In their experiment – in accordance with our hypothesis here - no inversion effects were found when explicit configural features had not been present in the encoded versions.

Experiment 2

In Experiment 2 inversion and WPS effects were examined for the same two sets of faces as in Experiment 1. Moreover, PART and FULL conditions were also varied in the study phase. As there was no effect of presentation time in Experiment 1, only the shorter presentation time was used in Experiment 2.

Method

Participants. Sixteen graduate students and undergraduates from the Freie Universität Berlin participated for course credit. None of them had taken part in Experiment 1. Mean age was 22.9 years. Ten participants were female.

Materials and procedure. The same CONF and COMP versions as in Experiment 1 were used. Presentation time was held constant at 2000 ms.

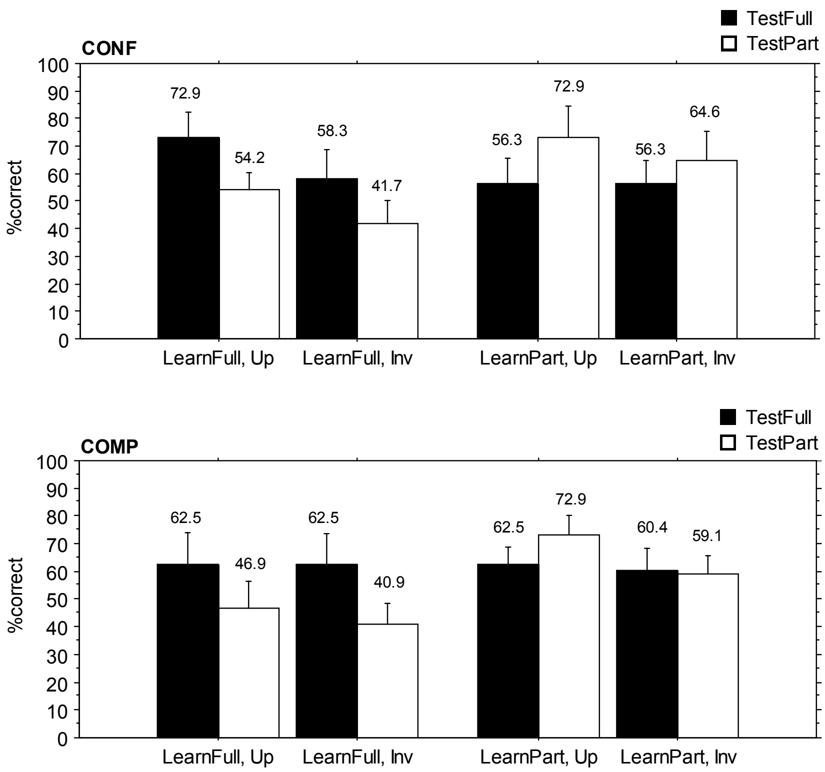
Different from Experiment 1 half the participants learned the isolated parts which had been used in Experiment 1 at test. All participants were tested with all versions, full faces and isolated parts, in both orientations. In the COMP versions, each participant learned both features, the individual eyes, noses and mouths not shared with other faces (see Figure 1), at study. Stimuli were presented in randomised order with the appropriate name. Therefore, participants in these conditions were exposed to twice as many learning trials. By mistake one image was empty at test, so the total number of isolated features in the inverted COMP conditions was 11 instead of the planned 12.

Results and Discussion. Figure 3 shows the mean correct rates in all conditions in Experiment 2 for the different LEARNSIZE conditions (LEARNPART versus LEARNFULL).

The data were submitted to a four-way mixed-design ANOVA with LEARNSIZE as between-subjects factor, and TESTSIZE, the size at test (TESTPART versus TESTFULL), VERSION (CONF versus COMP), and ORIENTATION (UPRIGHT versus INVERTED) as within-subjects factors. The analysis revealed no main effect of LEARNSIZE, $F(1, 14) < 1$, *n.s.*, and no effect of VERSION, but a significant main effect of ORIENTATION, $F(1, 14) = 5.835$, $p = .030$, $\eta_p^2 = .294$. Most important, there was a significant interaction of TESTSIZE and LEARNSIZE, $F(1, 14) = 17.489$, $p < .001$, $\eta_p^2 = .555$.

The aim of Experiment 2 was to directly test whether the amount of correspondence between LEARNSIZE and TESTSIZE affects the occurrence of whole-to-part effects. Indeed, information in the learning phase was critical for the whole-to-part differences. Full faces were recognized better than part versions only when full faces had been learned. When part versions had been learned, then part versions were superior at test. This is in accordance with the findings of Leder and Carbon (in press, 2005) and was found here also for faces which differed only in respect to configural features.

Figure 3:
Mean Results of Experiment 2 – CONF versions (3a) and the COMP versions (3b). The mean percentage of correct recognition for PART and FULL faces (in the learning as well as the test phase) for the two learning conditions separately for upright and inverted trials at test. Error bars are standard errors of the mean



A full-face version at test decreased the recognizability of facial parts after parts had been learned (see the LEARNPART conditions). Thus, as in Leder and Carbon (in press, 2005), under certain circumstances whole faces disrupt recognition of facial parts. Most important, this effect does not depend on either face version, thus, both CONF and COMP versions showed this pattern. More generally, the level of performance in those conditions that had not been learned (inverted or/and different size at test) showed the expected decrease in performance. These findings underline the claim of Biederman and Kaloscai (1997) that faces are very sensitive to the exact learning conditions.

The learning condition was important and was a requisite for the occurrence of WPS. The distraction due to a new context at test reveals that both sorts of information, when learned as parts, were disrupted by a FULL face context at test.

General Discussion

In the present studies we investigated whole-to-part effects with a focus on configurally distinctive faces. In both experiments we compared them with faces differing in components. Experiment 1 revealed that whole-to-part superiority (WPS) is found for both sorts of faces. Thus it seems that configural information in faces, which was defined here as the spatial relations between cardinal features, is not per se processed in a holistic way. Rather, both configural and component-based information are involved in face recognition and are presumably both part of the holistic representation. These findings are in accordance with a model of face recognition in which analyses at different scales are involved. Features, be they configural or componential, are presumably both processed with local analysers (Lades et al., 1993; Leder & Bruce, 2000; Carbon & Leder, in press, 2005) and are then integrated and located in a coarse representation. Biederman and Kaloscai (1997) discussed that this processing of faces might best be achieved with either rigid or individual lattices, which allow to match an image with a memory representation. Here we have shown that configuration is presumably one of the rather local features processed from faces. Our results also confirm that those processes in which configural properties are derived show whole-to-part effects and therefore cannot easily be matched with the full faces. Moreover, the well-known sensitivity to orientation for configural and metric information was also replicated here (Leder & Bruce, 2000; Rossion & Gauthier, 2002).

Both experiments together also revealed that WPS depends on the learning condition. Wholes were better recognized for both sorts of faces, configurally or componentially distinctive ones, but recognition rates of faces which varied according to components was better in Experiment 1 but not in Experiment 2. Most important, Experiment 2 revealed that part-based recognition can be superior when a part-based learning preceded. This is clear evidence for an encoding-specificity effect in face recognition (Tulving & Thomson, 1973). In Experiment 2 this effect was larger for configurally distinct faces. Thus, WPS in the studies presented here might be due to the amount of overlapping information that full faces provide in respect to the learned stimuli. This is not the only demonstration that whole-to-part relations rely on the availability of configural information. For example, Farah, Tanaka and Drain (1995) found a holistic effect only when full faces had been learned. Tanaka and Sengco (1997) proposed that configuration might be an essential part of a face representation. The data of the present studies further support this hypothesis.

Faces contain a number of different features, components as well as configurations. The latter consist of the spatial relations between the cardinal features, such as eyes, noses and mouths, the distances between these features and the facial outlines in general, as well as smaller scale relations between outlines of features and the surrounding parts. Future work will reveal whether these different types of configural information are dissociable.

It is still one of the shortcomings in the literature on face processing that no psychophysical measures for similarity of features in faces exist. This will be one of the challenges in future research, presumably requiring a large number of psychophysical studies. Concerning the present study, any interpretation of differences between the CONF and COMP faces should consider that it cannot be excluded that these face versions might per se be different in validity and distinctiveness.

Concerning the restriction of presentation time in Experiment 1, it has to be discussed that we did not employ masks. We were not interested in using conditions of a kind of first impression (Locher, Unger, Sociedade, & Wahl, 1993) as this is not subject of theories of either holistic or configural processing. Although O'Donnell and Bruce (2001) for example did find presentation time effects only for the eye region, future studies with even more controlled time conditions might reveal interesting effects. Our results support the interpretation that the findings from previous studies supporting the configural-relational (Leder & Bruce, 2000) or holistic position (Tanaka & Farah, 1993; Farah et al., 1995) were not unrealistic through the use of rather unrestricted presentation times.

Critical is the use of schematic faces, whose application might reveal conditions in which face processing is not investigated at its best! For example, Leder (1996) presented studies in which differences in the weighting of features were found between photographic stimuli and schematic line drawings. However, concerning the aim of the present study schematic faces offered better control of clearly distinctive classes of facial information. Importantly, the findings in the whole-to-part test conditions with configural features are very similar to those reported by Leder and Carbon (in press, 2005), who used photographic material and components only.

To conclude, the results of our experiments offer evidence suggesting that configural and holistic processing are different types of processing which produce differential whole-to-part effects and which can be studied when both sorts of information are systematically separated.

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