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Face-specific configural processing of relational information

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Face processing relies on configural processing, which is thought to be particularly disrupted by inversion. We compared inversion effects in recognition experiments for three types of stimuli, using faces (Experiment 1) and houses (Experiment 2). Stimuli varied by their colour only (*colour*), by the spatial relations between components (*relational*), or by the *components* themselves (eyes, mouths, doors). For faces, *relational* versions revealed strong inversion effects, *component* versions moderate, and *colour* versions no inversion effect. Recognition of houses revealed no inversion effects at all. We suggest that the inversion effects observed for faces in the *component* condition are due to relational changes, which must accompany any change in components. This proposal may account for the rather inconsistent effects of inversion reported in the literature. Furthermore, we suggest configural processing seems to be somehow face-specific.

It is often assumed that processing of faces is somehow special as it involves the efficient use of relational information (Leder & Bruce, 2000). In the present study, we investigate whether processing of relational information (distances between local components) is also involved when faces differ by components, since some types of componential differences (e.g. shape changes) might affect relational information (e.g. distance between edge of nose and corner of eye) even if the location of the feature's centre does not change.

Faces contain different classes of information (Bartlett & Searcy, 1993; Leder & Bruce, 1998, 2000; Rhodes, Brake, & Atkinson, 1993). All faces consist of components such as eyes, noses, and mouths, which can differ from each other in terms of shape, size, protuberance, and so on. Due to the first order spatial arrangement of these components (i.e. eyes above nose), faces also differ in respect to an individual spatial arrangement (Rhodes, 1988), which we call relational information. The processing of

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such relational information (such as the eye distance or nose–mouth distance) for face recognition is often called configural processing.

Inversion specifically disrupts the processing of this kind of information in faces (Bartlett & Searcy, 1993; Carbon & Leder, 2005; Carbon, Schweinberger, Kaufmann, & Leder, 2005; Leder & Bruce, 1998, 2000; Leder & Carbon, 2004; Rhodes *et al.*, 1993). For example, turning faces upside down reduce effects of distinctiveness based on the relation between individual features (Leder & Bruce, 1998). As a consequence, faces that appear grotesque when viewed normally (because of unusual arrangements of the features) do not look correspondingly grotesque when viewed upside down (Bartlett & Searcy, 1993; Carbon & Leder, 2005; Carbon *et al.*, 2005; Murray, Yong, & Rhodes, 2000).

In a precursor to the present study, Leder and Bruce (2000) tested inversion effects for faces that differed either in respect to relational information or in a combination of relational and component information. They found that inversion deficits were predicted primarily by differences in relational information. As a result of this and of other studies (e.g. Mondloch, Le Grand, & Maurer, 2002), the size of inversion effects has come to be regarded as an index of the amount of configural processing that takes place in any particular task.

In the present study, we tested faces varying in respect to three different classes of information – faces that share the same shape of local parts and spacing between these parts but which differ in colour (*colour*); faces with common individual features in terms of shape and colour but which differ in the spacing between these features (*relational*); faces whose individual components (eyes, nose, and mouth) differ but whose spatial layout remains constant (*component*). Our intention was to compare the final condition with conditions that are known to produce large (*relational*) or no inversion effects (*colour*).

Our study was necessary because of the ambiguity of effects when faces are constructed using changed components. Some experiments in the literature have revealed that exchanging facial components with those from other faces can produce inversion effects (e.g. Rhodes *et al.*, 1993). More recent findings by Yovel and Kanwisher (2004) have demonstrated that the processing of faces for which components or relations between these components were varied, did show highly similar activation patterns in fMRI data. However, other evidence suggests that feature-based processing of faces is hardly affected by inversion (Carbon & Leder, 2005; Collishaw & Hole, 2000; Freire, Lee, & Symons, 2000; Murray *et al.*, 2000). Of course, faces differing in components also inevitably differ in respect to relational information. For example, a longer nose affects the relative size of the nose–mouth distance. According to Collishaw and Hole, faces differing in terms of relational information only will be processed exclusively in terms of configuration. If such faces are inverted, configural processing is strongly impaired, making it difficult to differentiate them. Faces differing in terms of components, on the other hand, will be processed both in terms of configuration and features (Leder & Carbon, 2004). Because featural processing is hardly affected by inversion, the ability to discriminate between such faces, when inverted, will remain relatively high.

In the present study, we investigate whether faces differing from each other in terms of components sometimes show inversion deficits precisely *because* of the involvement of relational information. We investigate this proposal in Experiment 1 and extend the investigation to a different class of stimuli (houses) in Experiment 2.

Previous studies comparing faces with other objects, such as houses, have revealed rather ambiguous results (see McKone & Kanwisher, 2005). Tanaka and Farah (1993) reported effects of holistic processing with faces but not with houses. In contrast, Donnelly and Davidoff (1999) used a number of different experimental tasks and stimuli and found holistic effects for faces, houses and simplified houses. In the present experiments, we offer an approach which attempts to maximize the similarity between house and face stimuli, using artificial line-drawn examples of both.

A final point addressed in the present study concerned presentation times at test. Many previous studies investigating inversion effects allow subjects unlimited time to make decisions (Leder & Bruce, 2000; Tanaka & Sengco, 1997). This may encourage unusual, strategic methods of solving the problem of recognition, which are time-consuming, and not necessarily related to normal face processing. In the present study, we manipulate the presentation time in order to examine this possibility.

EXPERIMENT 1

In Experiment 1, recognition of three different sets of faces (*colour*, *relational*, and *component*) was tested in upright and inverted orientation, with presentation time varying between participants.

Method

Participants

Eighteen undergraduates (15 female) from the Freie Universität Berlin participated for course credit or payment. All participants were tested individually. The mean age was 25.8 years.

Materials

Three stimulus sets were used. Each set contained six faces and six assigned unique names. Figure 1 shows examples of the stimulus used.

The faces were created using schematic Mac-a-Mug features (these stimuli were used in order to allow construction of comparable schematic house stimuli, see below). In the *colour* set (see Fig. 1A), faces differed from each other only in respect to colour information. All faces had the same-shaped mouths, eyes and noses, and hair, but differed in the colour assigned to individual components (see Leder & Bruce, 2000). Lee and Perrett (1997) investigated the role of colour in the identification of familiar faces and concluded from their results that 'colour information is helpful when differentiating

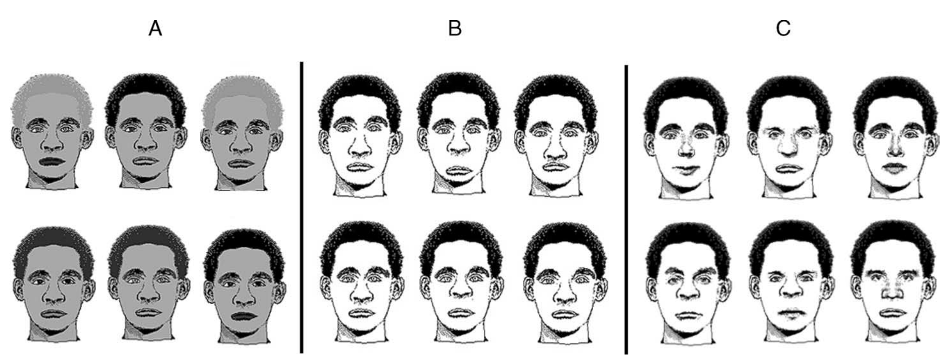

Figure 1. Stimuli used in Experiment 1. (A) The *colour* face set, (B) *relational*, (C) *component*.

between stimuli' (p. 748). Although each colour value was shared by at least one other face, each face had a unique combination of different colour values. Hues that occur naturally in faces were used (e.g. beige, brown, red), but values were selected which could easily be distinguished from each other. In the *relational* set (see Fig. 1B), each face had identically shaped local features (eyes, mouth etc.) but varied according to the spatial relation between these different features. These faces were identical to those used by Leder and Bruce (Experiment 1). In the *component* set (see Fig. 1C), each face had two unique components (eyes, mouth or nose) and one that was shared with one of the other five faces. Pre-tests revealed that this makes the task of learning and recognizing the faces similar in difficulty to the two other versions.

Eighteen short names were selected, which were randomly assigned to one of three name sets. The names we used were Sam, Don, Ian, Max, Bob, Rex (Set 1), Ted, Joe, Guy, Ken, Tim, Les (Set 2), and Fred, Eric, Rudi, Jim, Will, Ron (Set 3).

Procedure and design

Participants were tested individually on each of the three sets in one session, while the blocks were separated by short breaks.

The order in which the *colour*, *relational*, or *component* faces were learned was counterbalanced across participants, thus one third of the participants started with each of the three versions. The allocation of names to faces was counterbalanced across the three sets, so that each face was learned under different names (by different participants).

Across all blocks, the experimental programme randomized the order of trials within each block at test.

Study phase

All the faces of one set were shown simultaneously for 20 seconds at the beginning of the experiment, in order to show subjects the level of similarity between them. Participants were told they would be exposed to six different people's 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. All instructions were given in German.

Within each of these blocks, the stimuli were presented in a randomized order. After five learning blocks, a test block followed, in which participants saw each face for five seconds together with the question 'Who is this?' After 5 seconds, the correct name was shown beneath the stimulus to provide feedback. If participants got less than five of the six faces right, a learning block was repeated until this criterion was met.

Test phase

After a short break, the test block began. During the test block, all six names were shown together with a number 1 to 6 beneath. Each number represented a certain name. In each trial, one test face was presented beneath the list of names when the participants pressed the space bar. Depending on the presentation time condition the test stimulus automatically disappeared after either two or eight seconds. Participants were instructed to press the number corresponding to the stimulus person's name. Each face was shown twice in each orientation (upright and inverted), yielding a total of 24 trials at test for each version. The order of the stimuli at test was randomized for each participant. Participants ran all three blocks under either shorter *or* longer presentation times, which varied between participants.

Results and discussion

Results in terms of recognition rates as percentage correct of Experiment 1 are shown in Table 1. A mixed-design ANOVA used *version* (colour, relational and component) and *orientation* (upright vs. inverted) as within-subjects factors, and *presentation time* (short vs. long) as a between-groups factor. The analysis revealed main effects of *version*, $F(2, 32) = 17.69$, $p < .0001$, $\text{MSE} = 6,049.0$, $\eta_p^2 = .525$, and *orientation*, $F(1, 16) = 28.13$, $p < .0001$, $\text{MSE} = 4,325.7$, $\eta_p^2 = .637$, and a significant interaction between these two factors $F(2, 32) = 9.82, p < .001$, $\text{MSE} = 1,112.0$, $\eta_p^2 = .380$. There was no effect of *presentation time*, and this factor did not interact with the other two. We further analysed the interaction between *version* and *orientation* by testing the simple main effects of *orientation* for each condition of *version*. The analyses revealed that *orientation* was only significant for the *relational* version, $p < .0001$, and for the *component* version, $p = .0118$, but there was no effect of *orientation* for the *colour* version, $p = .4011$. Figure 2 shows the mean proportion of correct identifications at test in Experiment 1 in all three conditions and both orientations, combined for both presentation times.

Table 1. Recognition rates and standard deviations (*SDs*) in Experiment 1 (faces)

PT	Orientation	Colour	*SD*	Relational	*SD*	Component	*SD*
2,000 ms	Up	94.4	11.0	83.3	14.4	88.9	11.8
2,000 ms	Inv	92.6	12.1	53.7	15.1	71.3	22.1
8,000 ms	Up	92.6	11.4	74.1	24.8	82.4	11.4
8,000 ms	Inv	90.7	14.7	55.6	27.0	75.9	11.4

Bonferroni-adjusted post-tests revealed that faces differing in *colour* were better recognized than faces differing in *components* ($p = .0043$). However, faces differing in *components* were better recognized than *relational* faces ($p = .0043$).

Thus, Experiment 1 replicated the findings of Leder and Bruce (2000) showing that inversion effects do not occur if faces differ only in terms of local colour information but that large inversion effects occur if faces differ from each other only in terms of relational information. Most importantly, in direct comparison, faces that differ from each other in terms of components show smaller though significant effects of inversion. This suggests that componential change carries with it corresponding relational change, which, in turn, produces inversion effects. Experiment 1 suggests that the processing of relational information in components contributes to the effect of inversion. Consequently, this finding might account for the sometimes unexpectedly large effects of inversion that occur when 'swapped' components were compared with changes of pure relational information (Rhodes *et al.*, 1993). However, it is important to stress that inversion effects that are based on different baselines of upright performance should not be interpreted as absolute measures (see Yovel & Kanwisher, 2004).

Moreover, in order to exclude the possibility that turning components upside down produces inversion deficits in itself, we explored a different sort of components in Experiment 2, using houses instead of faces.

The differences in presentation times at test in Experiment 1 did not affect the results for any of the versions. This is in accordance with the assumption that extraction

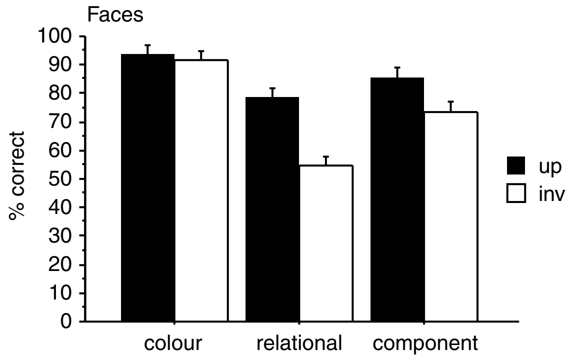

Figure 2. Results of Experiment 1. The percentage of correct recognition, sampled over participants, are shown for upright and inverted presentation of the different versions, combined for the two presentation times. Error bars show 95% confidence intervals according to the calculation proposed by Loftus and Masson (1994) for repeated measures.

of either type of information does not require particularly time-consuming scanning strategies, which exceed 2,000 ms and presumably proceed relatively fast and automatically.

In order to test whether the effects found in Experiment 1 are specific to faces, houses were used in Experiment 2 as a comparison stimulus class. Again, three versions were used, which were constructed following the same rules as in Experiment 1. Although houses consist of different parts than do faces, the three sets (as illustrated in Fig. 3) again differ in their *colour* distributions (Fig. 3A), in respect to *relational* information alone (Fig. 3B), or in respect to *components* (Fig. 3C).

EXPERIMENT 2

Method

Participants

Eighteen undergraduates (13 female) from the Freie Universität Berlin participated either for course credit or payment. None had participated in Experiment 1. All participants were tested individually. The mean age was 25.9 years.

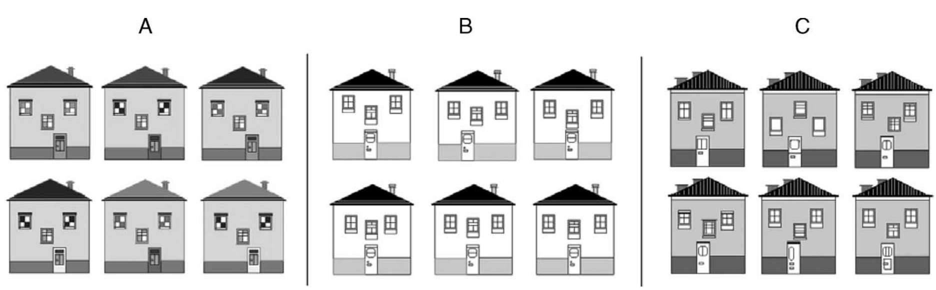

Figure 3. Stimuli used in Experiment 2. (A) The *colour* house set, (B) *relational*, (C) *component*.

Materials

As in Experiment 1, three stimulus sets were used. Each set contained six houses and six assigned names. Figure 3 shows the stimuli.

The houses were constructed using the same rules as were used for the faces in Experiment 1. In the *colour* set (see Fig. 3A), all houses differed from each other only in respect to colour information. Again, each colour value was shared by at least one of the other houses in the set, but each house had a unique combination of different colour values. In the *relational* set (see Fig. 3B), the houses had identically shaped local features (door, windows) but varied according to the spatial relationships between these features. In the *components* set (see Fig. 3C), each stimulus had two unique features (door, window) and, as in Experiment 1, one feature which was shared with one of the other five stimuli. The components differed in their internal structure of elements, all located at the same area in the house to prevent the occurrence of first-order relational information (Rhodes, 1988).

The same names as in Experiment 1 were used, which again were randomly assigned to one of three name sets. Again, as in Experiment 1, two different presentation times at test were used, 2,000 ms and 8,000 ms.

Procedure and design

As in Experiment 1 participants were tested individually on each of the three sets in one session. The blocks were separated by short breaks. The order of the blocks was balanced and the task at learning was described to subjects as being about learning who owned which house. Presentation time was manipulated between subjects.

Results and discussion

Table 2 shows the mean recognition rates as percentage correct in Experiment 2. A mixed-design ANOVA was run, using the mean recognition rates sampled over participants with *version* (colour, relational, and component) and *orientation* (*upright* vs. *inverted*) as within-subjects factors, and *presentation time* (2,000 ms vs 8,000 ms) as a between-subjects factor. The analysis revealed a main effect of *version*, $F(2, 32) = 6.46$, $p = .0044$, $\mathrm{MSE} = 2,055.7$, $\eta_p^2 = .288$, but no other effect was significant. Figure 4 shows the mean proportion of correct identifications at test in Experiment 2 in all three conditions and both orientations, again combined for the two presentation times. Bonferroni-adjusted post-tests revealed that houses differing in shape (*component*) were better recognized than *relational* versions ($p < .005$) and *colour* versions were better recognized than *relational* houses ($p < .05$), but no other differences were significant.

Table 2. Recognition rates and *SD*s in Experiment 2 (houses)

PT	Orientation	Colour	*SD*	Relational	*SD*	Component	*SD*
2,000 ms	Up	88.0	17.2	68.5	13.7	89.8	13.7
2,000 ms	Inv	80.6	19.1	67.6	16.4	86.1	20.0
8,000 ms	Up	87.0	16.7	87.0	11.1	96.3	11.1
8,000 ms	Inv	85.2	25.3	82.4	15.8	93.5	9.1

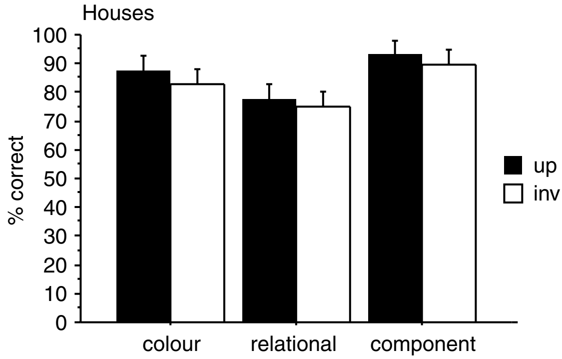

Figure 4. Results of Experiment 2. The mean proportion (sampled over participants) of correct recognition are shown for upright and inverted presentation of the different versions, combined for the two presentation times. Error bars show 95% confidence intervals according to the calculation proposed by Loftus and Masson (1994) for repeated measures.

The aim of Experiment 2 was to investigate whether the sensitivity to relational information in upside down faces is also found with houses. In contrast to Experiment 1, there were no inversion effects with houses, suggesting that orientation sensitivity for objects differing in relational information is somehow face-specific. This result supports the hypothesis that configural processing, which is affected by inversion, seems to be restricted to face stimuli. However, as we only used faces and houses in the present study, we cannot exclude the possibility that further object classes exist, which might show effects similar to the faces used here.

The results are in accordance with theories that propose that faces are special due to the efficient use of relational information, which is efficiently adapted to the usual upright orientation. However, whether this effect was due to expertise or whether the effect is inherently specific to faces cannot be answered on the basis of the experiments presented here.

As in Experiment 1, there was neither a general effect nor a significant interaction with presentation time, but the raw data in Table 2 show a difference in the performance for the *relational* versions. In order to test whether the data reveal a hint of time sensitive processing, we examined the simple main effects of *presentation time* for the different levels of *version*. The analyses revealed that *presentation time* was significant for the *relational* version, $p = .0163$, but not for the other versions, $p\text{s} > .2749$. Although this effect should be interpreted with caution (due to a lack of an overall effect), these differences at least indicate that configural processing might require more time, and that the ability to process relations has not been developed via expertise, or is not inherently present. When the same analyses of the simple main effects of *presentation time* were run for the corresponding factor *version* no significant differences were found at all, $p\text{s} > .6828$.

GENERAL DISCUSSION

The main goal of our study was to show that inversion deficits can be used as indicators of configural processing. Experiment 1 revealed that inversion effects give evidence of configural processing when the faces differ from each other in respect to their components. Recognition of these faces showed significantly smaller inversion deficits than recognition of faces that differ only in respect to relational information. We take this as evidence for a smaller reliance on configural processing. Consequently, the results of Experiment 1 explain why swapping components in faces sometimes produces reliable inversion effects. Swapping features not only produces variation in local shape features, but also changes relational features. Note that Leder and Bruce (2000, Experiment 5) demonstrated that isolated components show no inversion effects, whereas isolated configural features do (e.g. the area of the mouth and the nose which contain the relational distance between both components). This was probably found because isolating components disrupts their relations with other features.

In contrast, recognition of houses in Experiment 2 did not show any effect of inversion. In all conditions, houses were recognized in a way that is not disrupted by upside down presentation. In sum, it therefore seems that the results of both experiments also reveal the costs of processing faces, which is found in the orientation sensitive encoding. In this respect, the differential results in the *relational* versions of houses and faces are most interesting. While faces show the often-replicated inversion deficits, houses do not.

Inspection of the stimuli reveals an important difference between the two classes of objects. Faces that differ in relational information, somehow look different and are distinguishable not because we explicitly see the specific relational information (narrow eyes, lowered mouth) but because they create an individual impression. This higher-order representation is probably built on a structure of relations between the constituent elements. This assumption is in accordance with Diamond and Carey's (1986) view of higher-order information in faces. Thus, the resulting percept has a kind of holistic quality. The different relational information is integrated into a whole face impression. These impressions are sensitive to orientation, as can be seen when Fig. 1 is turned upside down. We do not assume that this effect requires a strict holistic representation such that faces cannot be parsed into parts (Leder & Carbon, 2005; Tanaka and Farah, 1993). For example, Leder, Candrian, Huber, and Bruce (2001) found inversion deficits for different eye-distances in matching tasks and Leder and Bruce (2000) found that parts of the face that cover the distinctive configural parts can be recognized in isolation and do show inversion effects.

Why is the same kind of processing not used for the recognition of houses? Figure 3B reveals that *relational* versions of houses do not elicit the same kind of higher-order impressions. The houses of this set look very similar. We suppose that the perceiver learns these houses by explicitly detecting the critical relational information. This information is then encoded as parts of the house. At recognition, the perceiver scans the houses (upright or inverted) until he or she detects the critical feature. This strategy allows a processing that is rather orientation-invariant. The finding of Experiment 2 also supports this assumption, as *relational* houses were better recognized under the longer presentation time (Table 2). We interpret this as suggesting a recognition strategy that is more time consuming, and presumably based on sequential scanning. Thus, a comparison between the two-object classes as investigated here is in accordance with an integration of relational information into a higher-order representation in faces, while the same features in houses are treated rather like orientation-independent 'local features'.

Concerning presentation time, there were no effects with faces, but a specific effect with houses – yet only in a selective analysis of the *relational* houses. Recently, Carbon (2003) has found evidence for a slightly delayed processing of configural compared with local information in faces. Because effects were found here with houses but not with faces, this might be interpreted in two ways: on the one hand, it could be assumed that the ability to process relations in houses has not been developed via expertise. On the other hand, relational information might not be present inherently in houses. However, for future studies, a further restriction of presentation time in the test phase seems to be warranted and shorter presentation times might be used to uncover the time course of processing of component and relational information.

To summarize, we have shown that components in faces probably consist of orientation-sensitive, relational information as well as orientation insensitive features such as local shape and texture. Our results suggest that 'componential' features should be distinguished from purely 'local' features, such as colour. Componential features may be defined locally, but have configural effects, whereas genuinely local features do not. Moreover, the use of orientation-sensitive relational information is not mandatory. It is applied in the processing of faces but not with objects such as houses (see also Yovel & Kanwisher, 2004).

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