Journal of Experimental Psychology:
Human Perception and Performance
2007, Vol. 33, No. 4, 995–1001

0096-1523/07/$12.00 DOI: 10.1037/0096-1523.33.4.995

OBSERVATION

Face Inversion Disproportionately Impairs the Perception of Vertical but not Horizontal Relations Between Features

Valérie Goffaux
University of Maastricht and Université Catholique de Louvain

Bruno Rossion
Université Catholique de Louvain

Upside-down inversion disrupts the processing of spatial relations between the features of a face, while largely preserving local feature analysis. However, recent studies on face inversion failed to observe a clear dissociation between relational and featural processing. To resolve these discrepancies and clarify how inversion affects face perception, the authors monitored inversion effects separately for vertical and horizontal distances between features. Inversion dramatically declined performance in the vertical-relational condition, but it impaired featural and horizontal-relational performance only moderately. Identical observations were made whether upright and inverted trials were blocked or randomly interleaved. The largest performance decrement was found for vertical relations even when faces were rotated by 90°. Evidence that inversion dramatically disrupts the ability to extract vertical but not horizontal feature relations supports the view that inversion qualitatively changes face perception by rendering some of the processes activated by upright faces largely ineffective.

Keywords: face inversion, horizontal relations, vertical relations, configuration, feature

Picture-plane inversion dramatically impairs the recognition of faces (e.g., Hochberg & Galper, 1967) more than other object categories (Yin, 1969). The disproportionate face inversion effect has been replicated in various paradigms, for both familiar and unfamiliar faces (for reviews, see Rossion & Gauthier, 2002; Valentine, 1988). It is generally acknowledged that inversion qualitatively changes face perception by rendering some of the processes activated by upright faces largely ineffective. Whereas upright faces are processed with both local features and their spatial relations or *configuration* (e.g., interocular distance, nose–mouth distance, etc.), inverted faces are mostly discriminated with feature information (e.g., Bartlett & Searcy, 1993; Endo, 1986; Freire, Lee, & Symons, 2000; Leder & Bruce, 1998; Le Grand, Mondloch, Maurer, & Brent, 2001; Mondloch, Le Grand, & Maurer, 2002; Murray, Yong, & Rhodes, 2000; Rhodes, Brake, & Atkinson, 1993; Rhodes, Hayward, & Wrinkler, 2006; Sergent, 1984; Tanaka & Sengco, 1987; for a review, see Maurer, Le Grand, & Mondloch, 2002). Consequently, inverting a face stimulus has become one of the most widely used stimulus transformations to prevent the processing of facial configuration.

However, the view that upright and inverted faces are processed by different mechanisms has been challenged by recent observations that the processing of featural and relational cues can be equally affected by face inversion (Riesenhuber, Jarudi, Gilad, & Sinha, 2004; Yovel & Kanwisher, 2004; see also Sekuler, Gaspar, Gold, & Bennett, 2004). Based on these divergent results, Riesenhuber et al. (2004) proposed that the disproportionate effect of inversion upon relational face processing is due to subjects' expectations when relational and featural manipulations are presented in separate blocks. However, some methodological peculiarities in studies by Riesenhuber et al. (2004) and Yovel and Kanwisher (2004) may explain their failure to replicate larger inversion effects for the processing of relational information as compared with featural information. In the Riesenhuber et al. (2004) study, for instance, featural manipulations concerned the eyes, eyebrows, and mouth, thus probably affecting the relations between these features (e.g., eyes–eyebrows distance) as well. This may explain why large effects of inversion were found in that condition. Most important, when reviewing the existing literature we noticed a stimulus manipulation that could explain why inversion does, or does not, affect the processing of face relations more than the processing of face features. Most studies showed large effects of face inversion when relational modifications were applied at the level of the eyes. A relational manipulation of the eyes area can be done by displacing them in either the horizontal direction (i.e., the two eyes are moved apart or closer) or in the vertical direction (i.e., eyes are moved higher or lower; see Figure 1). Either these horizontal and vertical manipulations at the level of the eyes were confounded in previous experiments (e.g., Goffaux, Hault, Michel, Vuong, & Rossion, 2005; Mondloch et al., 2002; Murray et al., 2000; Riesenhuber et al., 2004; Yovel & Kanwisher, 2004) or only horizontal-relational manipulations were used (e.g.,

---

Valérie Goffaux, Maastricht Brain Imaging Center, Neurocognition, University of Maastricht, Maastricht, the Netherlands; and Unité Cognition & Développement et Laboratoire de Neurophysiologie, Université Catholique de Louvain, Louvain, Belgium; Bruno Rossion, Unité Cognition & Développement et Laboratoire de Neurophysiologie, Université Catholique de Louvain, Louvain, Belgium.

Correspondence concerning this article should be sent to Valérie Goffaux, Department of Neurocognition, Faculty of Psychology, University of Maastricht, Universiteitssingel 40, P.O. Box 616, 6229 ER Maastricht, the Netherlands. E-mail: valerie.goffaux@psp.ucl.ac.be

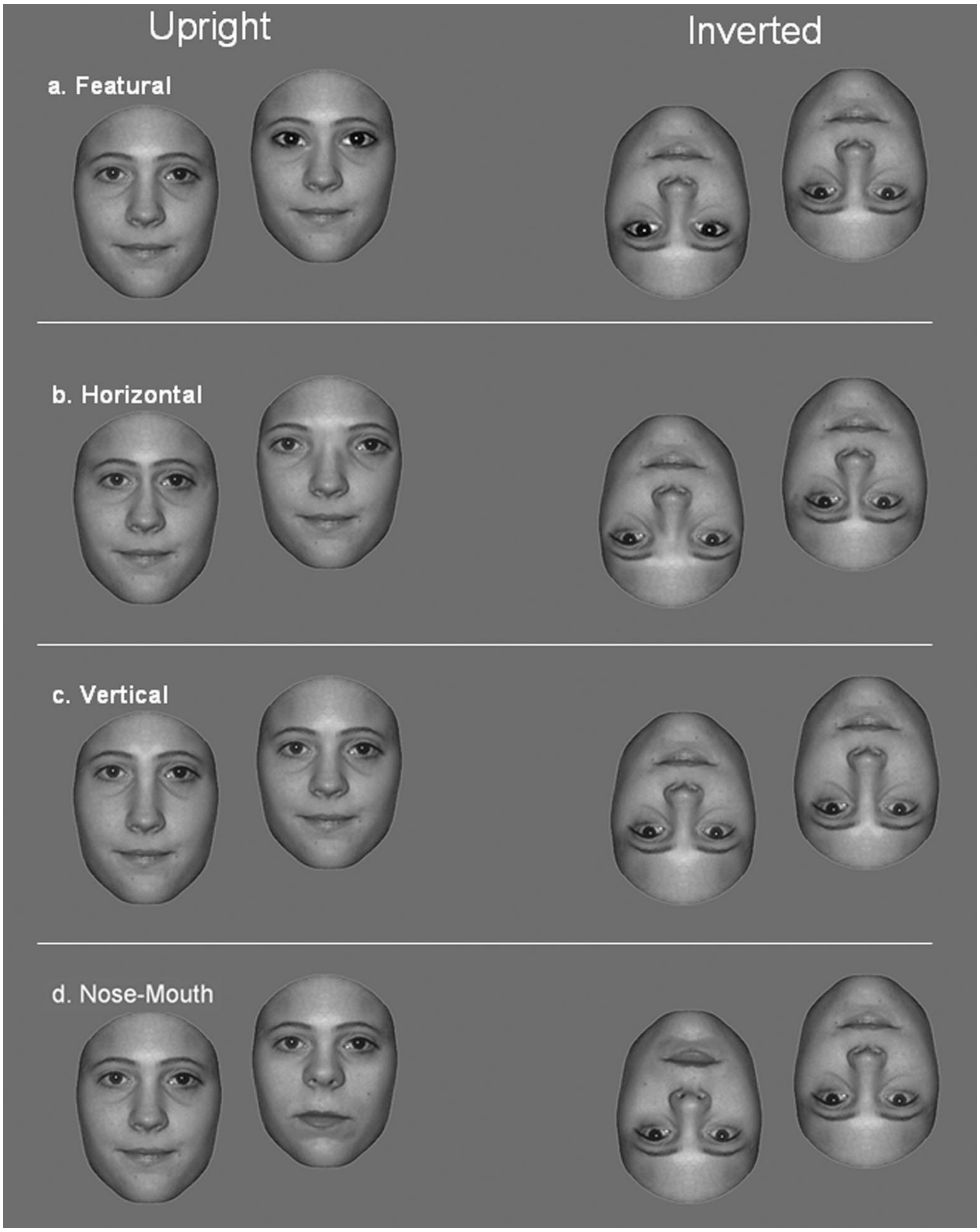

Figure 1. Examples of face pairs in the four experimental conditions. The left (upright) column shows: (a) a featural face pair, in which eye shape and surface differed between target and probe faces; (b) a face pair from the horizontal-relational condition, in which interocular distance varied between target and probe faces by moving each eye by 15 pixels (as in Experiments 2 and 3); (c) a face pair from the vertical-relational condition, in which eye height was manipulated by moving each eye by 15 pixels (as in Experiments 2 and 3); and (d) a face pair in the nose–mouth condition, in which faces differed at the level of lower inner features (nose and mouth). Pairs from the right (inverted) column are identical to those on the left but are displayed upside-down.

Barton, Keenan, & Bass, 2001; Leder, Candrian, Huber, & Bruce, 2001).

However, because (a) faces have a vertically elongated structure and an organization of features mainly in the vertical axis (eyebrows, eyes, nose, mouth) and (b) inverting a face corresponds to a flip in the vertical axis, we reasoned that face inversion may differentially disrupt the processing of horizontal and vertical relations between features. In fact, by looking at Figure 1, inversion appears to affect the perception of vertical eye displacements dramatically, whereas horizontal displacements are still readily perceived in upside-down faces (see Figure 1 of Yovel & Kanwisher, 2004).

Here we tested this hypothesis in three experiments in which subjects performed a delayed matching task on unfamiliar faces.

Faces were either same or different at the level of eye shape and surface (featural condition), the vertical position of the eyes (vertical-relational condition), or the horizontal position of the eyes (horizontal-relational condition; see Figure 1). We also added a fourth condition in which differences between a pair of faces concerned the lower features (nose–mouth condition), so that subject's attention was not entirely focused on the eyes during the task. In Experiment 1, upright and inverted faces were presented in separate blocks, whereas they were randomly intermixed in Experiment 2 to test the reliability of Experiment 1 effects when subjects cannot activate strategies specific to upright and inverted face processing (cf. Riesenhuber et al., 2004). In Experiment 3, we added a third orientation condition in which faces were tilted at 90° to test whether rotation angle was a critical factor in accounting for the effects observed in Experiments 1 and 2.

General Method

Participants

Sixty-three participants (aged 17–38 years; 24 males, 39 females; 4 left-handed) took part in one of three experiments. There were 26 participants in Experiment 1, 15 participants in Experiment 2, and 22 participants in Experiment 3. All had normal or corrected-to-normal vision.

Stimuli

Twenty full-front grayscale pictures of faces (half males) with a neutral expression were used (see Figure 1). Face stimuli were 190 pixels in width and 250 pixels in height and were pasted onto a gray background. They were free of facial hair, glasses, and hairline in order to remove any external cue to face perception. The inner features of each face (eyes, nose, and mouth in their original spatial relations) were pasted onto a generic face shape (one for each gender), which contained generic external contour and eyebrows. Then each stimulus was modified at the level of a feature (i.e., eyes were exchanged with those of another face and contrast adjusted), at the level of vertical relations (i.e., eyes were moved upward or downward), and at the level of horizontal relations (i.e., smaller or larger interocular distance). The amount of absolute eye displacement was equal in vertical- and horizontal-relational conditions as each eye was moved by 15 pixels in the vertical or the horizontal direction, respectively. Featural, vertical, and horizontal changes applied here (as well as in previous studies) are probably not equivalently representative of the natural variations among human faces. However, these stimulus manipulations were calibrated to obtain comparable performance levels at upright orientation. Stimuli approximately subtended 4° of visual angle in width and 5° in height. The 15-pixel differences in eye absolute position subtended 0.45° in visual angle. In order to maintain subjects' attention to the whole face and not only to upper features, we introduced nose–mouth stimuli, in which nose and mouth were exchanged with those of another face. Twenty faces were obtained for each condition (80 in total), half of which were used in the practice trials and the other half in the experiment (see Figure 1). Inverted faces were vertically flipped versions of these stimuli. Experiment 2 was aimed at replicating Experiment 1 with upright and inverted conditions randomly interleaved. In Experiment 3, faces were presented upright, inverted as well as rotated by 90° counterclockwise.

Procedure

A trial started with a fixation cross (300 ms), followed by a 200-ms blank and the target face for 900 ms. After a 600-ms delay, the probe face was presented until the subject gave his or her response. The target appeared at the center of the screen, and the probe face was randomly jittered from this central position in all (four) oblique directions by 10 pixels, so that subjects could neither rely on persistent retinal images, nor base their responses on local low-level changes in the images. The task was to decide whether the target and probe faces were same or different.

In all three experiments, there were four randomly interleaved stimulus conditions (featural [F], vertical-relational [V], horizontal-relational [H], and nose–mouth [NM]) presented at two orientations (upright and inverted) in Experiments 1 and 2 and at three orientations in Experiment 3 (upright, 90°, and inverted). Half the trials required a "same" response, the other half a "different" response. Each trial was repeated twice, leading to 40 trials per condition (a total of 320 experimental trials in Experiments 1 and 2 and a total of 480 trials in Experiment 3). Resting pauses were provided every 80 trials, along with feedback information on response accuracy. In Experiments 1 and 3, stimulus orientation was blocked, whereas upright and inverted trials were randomly interleaved in Experiment 2. Prior to the experiment, subjects performed 40 practice trials on face stimuli that were not used in the experiment proper. During practice, accuracy feedback was provided every 10 trials. Subjects were informed of the subtlety of changes they had to detect, but no further information was given about the nature of the differences between face stimuli.

Bias-free sensitivity indexes (*d'*) were computed for each subject in each condition in the three experiments. ANOVA and post hoc comparisons were used to analyze the effects of stimulus condition and orientation upon *d'* and response times (RTs).

Results

Experiment 1

In Experiment 1, we applied a three-way ANOVA on *d'* and correct RTs with orientation order (upright first or inverted first) as a between-subjects factor as well as orientation (upright vs. inverted) and stimulus condition (F vs. V vs. H vs. NM) as within-subjects factors. Whether subjects began with the upright or inverted condition did not affect performance significantly: *d'*, $F(1, 24) = 0.27$, $p > .61$; RTs, $F(1, 24) = 0.49$, $p > .49$. This factor was not maintained in the following analyses. There was a main effect of orientation both in *d'*, $F(1, 25) = 110.00$, $p < .0001$, and RTs, $F(1, 25) = 13.28$, $p < .001$, as inverted faces were resolved slower and less accurately than upright faces. Stimulus condition significantly affected performance: *d'*, $F(3, 75) = 21.80$, $p < .0001$; RTs, $F(3, 75) = 6.97$, $p < .0003$. The main effects of orientation and stimulus condition were qualified by a significant interaction between the two factors: *d'*, $F(3, 75) = 7.00$, $p < .0003$; RTs, $F(3, 75) = 7.41$, $p < .0002$. For upright faces, *d'*s were remarkably stable across F, V, and H conditions ($ps > .63$; see Table 1 and Figure 2) but declined in the NM condition ($ps <$

Table 1
Results of Experiment 1

	Vertical-relational		Horizontal-relational		Featural		Nose–Mouth	
Stimulus	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Upright								
d'	3.06	±0.24	3.17	±0.24	3.22	±0.22	2.41	±0.2
RT	806	±34	802	±35	802	±33	808	±34
Inverted								
d'	1.36	±0.16	2.55	±0.2	2.47	±0.21	0.50	±0.12
RT	878	±38	813	±35	826	±40	909	±41

Note. Mean and standard errors for bias-free sensitivity indexes (d') and correct response times (RTs) are shown for each stimulus and orientation condition. These values were collapsed for orientation order factor.

.03). Correct RTs did not differ across all four stimulus conditions when presented upright ($ps > .66$). For inverted faces, however, performance dramatically differed across all stimulus conditions in d' and RTs. The NM condition led to the lowest d' ($ps < .0001$), followed by the V condition ($ps < .0001$); however, these latter conditions led to similar mean RTs ($p > .085$). Performance in F and H conditions did not differ significantly ($p > .76$ in d'; $p > .46$ in RTs). Consequently, the inversion effect was significantly larger in both d' and RTs for V and NM conditions with respect to H and F conditions (d', $ps < .04$; RTs, $ps < .0001$; see Table 1 and Figure 2). Inversion effects were of same magnitude across V and NM conditions (d', $p > .53$; RTs, $p > .26$) and across H and F conditions (d', $p > .7$; RTs, $p > .53$).

Experiment 2

In Experiment 2, a two-way ANOVA was applied on d' and RTs with orientation (upright vs. inverted) and stimulus condition (F vs. V vs. H vs. NM) as within-subjects factors. The effect of orientation was significant in both d', $F(1, 14) = 72.47, p < .0001$, and RTs, $F(1, 14) = 73.04, p < .0001$. The main effect of stimulus condition was also significant: d', $F(3, 42) = 26.35, p < .0001$; RTs, $F(3, 42) = 14.09, p < .0001$. The main effects in d' and RTs were qualified by a significant Stimulus × Orientation interaction: d', $F(3, 42) = 8.30, p < .0002$; RTs, $F(3, 42) = 6.76, p > .0008$. When stimuli were presented upright, performance was relatively stable across V, H, F, and NM stimulus conditions ($ps > .06$ in d' and $ps > .76$ in RTs; see Table 2 and Figure 2); however, better sensitivity was obtained in the H as compared with the NM condition ($p < .002$). The H condition was also resolved faster than the NM and V conditions ($ps < .035$). When stimuli were inverted, large differences were found between stimulus conditions for d' and RTs. Sensitivity d' were significantly higher for the H condition as compared with the F condition ($p < .0015$), V condition ($p < .0001$), and NM condition ($p < .0001$). They were also higher in the F condition compared with the V condition ($p < .0001$) and NM condition ($p < .0001$) and in the V condition compared with the NM condition ($p < .0012$). Overall, the inversion effect in d' was the largest in V and NM conditions compared with H and F conditions ($p < .0001$). Inversion effects were of same magnitude across H and F conditions ($p > .61$; see Table 2 and Figure 2) and across V and NM conditions ($p > .73$). Correct RTs for inverted orientation significantly increased from H to F conditions ($p < .021$), from F to V conditions ($p < .04$), and from V to NM conditions ($p < .0065$). The inversion effect on RTs was largest for the NM condition ($ps < .017$), whereas it was of similar magnitude across V, F, and H conditions ($ps > .08$).

Experiment 3

In Experiment 3, a two-way ANOVA was applied on d' and RTs with orientation (upright vs. inverted vs. 90°) and stimulus condition (F vs. V vs. H vs. NM) as within-subjects factors. Main effects of orientation and stimulus condition were significant on d', $F(2, 42) = 91.85$, $p < .0001$ and $F(3, 63) = 36.85$, $p < .001$, respectively and correct RTs, $F(2, 42 = 26.99, p < .0001$, and $F(3, 63) = 10.32$, $p < .0001$, respectively. The interaction between orientation and stimulus condition was also significant in both d', $F(6, 126) = 10.3, p < .0001$, and RTs, $F(6, 126) = 2.98, p < .009$. When faces were presented upright, sensitivity was better for H and F conditions, as compared with V and NM conditions ($ps < .0001$; see Table 3). Also, d' was marginally larger for the H than the F condition ($p < .045$), whereas it did not differ between V and NM conditions ($p > .015$). Correct RTs were overall stable across stimulus conditions ($ps > .063$; see Table 3), except that the V condition was resolved slower than the H condition ($p < .017$). The detrimental effect of inversion with respect to upright condition was larger for V and NM conditions with respect to H and F conditions in both d' and RTs ($ps < .013$), whereas it did not differ between V and NM conditions ($ps > .606$ in d' and RTs), nor between H and F conditions ($ps > .18$ in both d' and RTs). A similar pattern was observed for the 90° rotation, which had the most detrimental effect on V and NM conditions, with respect to H and F conditions ($ps > .0001$). Again, equal d' decreases with 90° rotation were observed for V and NM conditions ($p > .53$) and H and F conditions ($p > .73$), respectively. The d' effects that were due to inversion and to 90° rotation were of similar magnitude in H and F conditions ($ps > .25$). In V and NM conditions, however, inversion led to a larger sensitivity decline (1.50 ± 0.26 on average) than 90° rotation (1.06 ± 0.03 on average; $ps < .003$). The increase of correct RTs with 90° rotation did not differ largely across stimulus conditions ($ps > .07$); it was only marginally larger in V and NM conditions than in the H condition ($p = .11$ and $p = .067$, respectively).

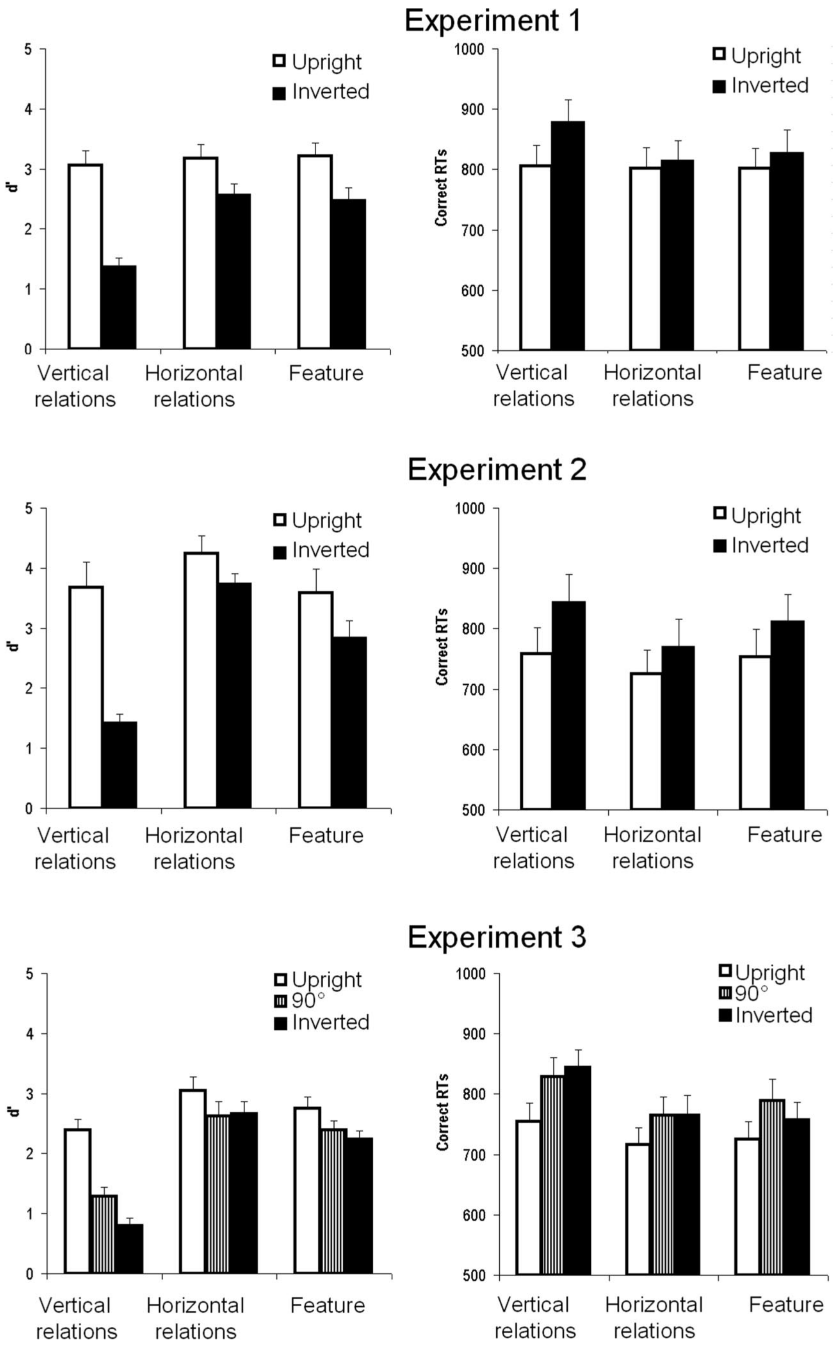

Figure 2. Graphic illustration of bias-free sensitivity indexes (*d'*; left panel) and correct response times (RTs; right panel) of the three experiments. Bars represent standard errors.

General Discussion

These experiments unequivocally show that picture-plane inversion or rotation dramatically disrupts the processing of vertical relations between features, whereas its effect on the processing of horizontal relations is moderate and equal to what is observed for the processing of local features. The disproportionate inversion effect for vertical relations was robust through various experimental settings. In Experiment 1, whereas we observed equal performance between conditions at upright orientation, the perception of vertical-relational changes was disproportionately affected by face rotation. These results were replicated whether orientation was blocked or not (Experiment 2). The disproportionate inversion effect for vertical configural changes was thus not related to upright conditions being unequal with respect to performance (Yovel & Kanwisher, 2004),

Table 2
Results of Experiment 2

	Vertical-relational		Horizontal-relational		Featural		Nose–Mouth	
Stimulus	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Upright								
d′	3.67	±0.42	4.25	±0.28	3.58	±0.41	2.8	±0.23
RT	759	±43	726	±39	753	±46	759	±40
Inverted								
d′	1.41	±0.16	3.72	±0.19	2.83	±0.29	0.69	±0.11
RT	843	±48	769	±47	811	±46	916	±59

Note. Mean and standard errors for bias-free sensitivity indexes (*d′*) and correct response times (RTs) are shown for each stimulus and orientation condition. These values were collapsed for orientation order factor.

nor to subjects' expectations (Riesenhuber et al., 2004). In fact, our findings are in agreement with these two previous studies, as we report equal inversion effects for horizontal-relational changes and featural changes. However, the conclusions of those authors that inversion does not affect facial configuration more than features do not hold when considering the vertical relations between features. Overall, our results strongly support the claim that face inversion disrupts relational processes more than featural processes (Maurer et al., 2002) and shows that this is mostly due to vertical relations between features no longer being perceived efficiently once a face is inverted.

As indicated in the introduction, in most experiments, horizontal and vertical displacements of the eyes are combined in the stimuli and/or confounded in the analyses (e.g., Freire et al., 2000; Goffaux et al., 2005; Mondloch et al., 2002; Murray et al., 2000; Yovel & Kanwisher, 2004). However, a careful review of the literature provides some hints of such dissociation. Studies using horizontal changes only (e.g., Leder et al., 2001) generally induced smaller inversion effects than those combining both types of relational changes (e.g., Leder & Bruce, 2000). Testing whether face regions would be differentially affected by inversion, Barton and colleagues (Barton et al., 2001; Barton, Zhao, & Keenan, 2003) compared the sensitivity to horizontal displacement of the eyes separately from vertical displacement of the mouth. They observed larger decrements for mouth displacements, that is, vertical relations, than eye displacements, that is, horizontal relations. However, these differences may be due to the displacement direction rather than to the face region under study (eyes vs. mouth). Here, we found that inversion affects vertical more than horizontal relations using the same feature, that is, the eyes, which are the only face part that can be manipulated in both directions while conserving the facial aspect of the stimulus. Yet, Barton et al.'s findings are informative regarding the generalization of our findings because they indicate that inversion disrupts the vertical-relational processing of face features other than the eyes.

We do not consider the dissociation between vertical and horizontal relations as providing an ultimate answer to the recent empirical inconsistencies observed on the effect of face inversion. Other methodological factors most likely influence the performance on featurally and relationally manipulated faces. A crucial aspect in such studies is that experimental conditions do not excessively diverge from natural viewing to avoid the implication of unusual processing strategies. For instance, Sekuler et al. (2004) stimulated an observer during thousands of discrimination trials with two pairs of face stimuli embedded in Gaussian noise. By means of a response classification procedure, they showed that the same cues, mostly the eyes and eyebrows, were used whether the faces were presented upright or upside-down. However, presenting

Table 3
Results of Experiment 3

	Vertical-relational		Horizontal-relational		Featural		Nose–Mouth	
Stimulus	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Upright								
d′	2.38	±0.18	3.05	±0.23	2.75	±0.2	2.08	±0.13
RT	754	±31	715	±29	725	±29	748	±28
90°								
d′	1.28	±0.16	2.62	±0.25	2.39	±0.16	1.08	±0.13
RT	828	±33	764	±31	790	±36	830	±31
Inverted								
d′	0.8	±0.12	2.66	±0.16	2.23	±0.14	0.57	±0.11
RT	844	±28	765	±33	756	±30	829	±30

Note. Mean and standard errors for bias-free sensitivity indexes (*d′*) and correct response times (RTs) are shown for each stimulus and orientation condition.

the same stimuli over thousands of trials in noise rather than full faces lacks ecological validity because it likely encourages part-based analysis (see Endo, 1986; Valentine, 1988). In other words, revealing local information through noise is bound to disrupt relational processes for faces, and this may explain why subjects used identical local face information to resolve upright and inverted faces in Sekuler et al.'s (2004) experiment.

A further source of discrepancy across inversion experiments comes from the variability of featural manipulations. In some studies, the surface information of features (hue or brightness, e.g., Leder & Carbon, 2006; Murray et al., 2000) is modified, whereas in others the features are exchanged between different faces, implying both shape and surface changes (e.g., Freire et al., 2000; Goffaux et al., 2005). Changing surface and/or shape in feature information may modulate the magnitude of inversion effect, because the processing of surface cues likely resists stimulus inversion more than the processing of shape information (cf. Leder & Bruce, 2000). In other studies, featural changes are so extensive (eyes, eyebrows, and mouth in Riesenhuber et al., 2004; eyes and mouth in Yovel & Kanwisher, 2004) that they largely affect face configuration as well. In the present experiments, we observed only moderate orientation effects on the processing of local feature cues (e.g., eyes) presumably because shape differences were minimal and the eyes–eyebrows distances were not modified.

The reasons why inversion disproportionately disrupts vertical, as compared with horizontal, relations still remain to be clarified. The fact that inversion switches the whole face structure in the vertical direction may indeed determine the orientation of the most disrupted spatial relations. If this account were correct, the perception of vertical and horizontal relations should substantially vary across different angles of rotation. However, the larger effects of rotation found here for face vertical relations also held when faces were tilted at 90° (Experiment 3), thus indicating that the disproportionate vulnerability of vertical relations observed in the present experiments is due more to their significance for face processing than to purely geometrical aspects. In other words, the inversion effect on face perception seems to be object-based rather than view-based.

Because the axis of face elongation is vertical and the spatial organization of features is also mostly vertical, it may be that vertical relations are more significant for upright face discrimination than horizontal relations (see also Haig, 1984). Hence, the aspect ratio typical of an individual face is mainly provided by vertical relations. Lee and Freire (1999) illustrated how displacing features in the vertical plane dramatically affects the perception of overall face shape in upright, but not inverted, orientation. In contrast, horizontal relations mainly define the universal property of bilateral symmetry. Face information might thus be redundant more across than along the vertical axis. The functional dissociation between vertical and horizontal-relational processing appears early in development; newborns are more sensitive to vertical structural properties than to bilateral symmetry of face-like patterns. For example, Turati, Simion, Milani, and Umilta (2002) observed an innate preference for patterns that were asymmetrical in the vertical plane (i.e., with more elements in upper than lower part), whereas bilateral (a)symmetry did not affect newborn inspection of stimuli.

Finally, a point that should be addressed is the generalization of our observations to other object categories. As indicated in the introduction, effects of inversion are notoriously larger for faces than objects (Yin, 1969). However, the recognition of all object categories suffers from plane rotation (Tarr & Pinker, 1989). A number of factors have been proposed to account for the larger effect of inversion observed for faces, such as visual homogeneity of the category, mono-orientation, bilateral symmetry, and visual expertise with the stimulus class (e.g., Diamond & Carey, 1986; Gauthier & Tarr, 1997). Our observations suggest that critical factors in getting large effects of inversion may also be the presence of a dominant vertical axis of elongation and the presence of internal features arranged mainly along the vertical axis. Supporting this suggestion, it is interesting to note that the only category besides faces that shows large effects of inversion is the human body (Reed, Stone, Bozova, & Tanaka, 2003).

References

Bartlett, J. C., & Searcy, J. (1993). Inversion and configuration of faces. *Cognitive Psychology, 25,* 281–316.

Barton, J. J., Keenan, J. P., & Bass, T. (2001). Discrimination of spatial relations and features in faces: Effects of inversion and viewing duration. *British Journal of Psychology, 92,* 527–549.

Barton, J. J., Zhao, J., & Keenan, J. P. (2003). Perception of global facial geometry in the inversion effect and prosopagnosia. *Neuropsychologia, 41,* 1703–1711.

Diamond, R., & Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology: General, 115,* 107–117.

Endo, M. (1986). Perception of upside-down faces: An analysis from the viewpoint of cue saliency. In H. D. Ellis, M. A. Jeeves, F. Newcombe, & A. M. Young (Eds.), *Aspects of face processing* (pp. 53–58). Dordrecht, The Netherlands: Martinus Nijhoff.

Freire, A., Lee, K., & Symons, L. A. (2000). The face-inversion effect as a deficit in the encoding of configural information: Direct evidence. *Perception, 29,* 159–170.

Gauthier, I., & Tarr, M. J. (1997). Becoming a "Greeble" expert: Exploring mechanisms for face recognition. *Vision Research, 37,* 1673–1682.

Goffaux, V., Hault, B., Michel, C., Vuong, Q. C., & Rossion, B. (2005). The respective role of low and high spatial frequencies in supporting configural and featural processing of faces. *Perception, 34,* 77–86.

Haig, N. D. (1984). The effect of feature displacement on face recognition. *Perception, 13,* 505–512.

Hochberg, J., & Galper, R. R. (1967). Recognition of faces: An explanatory study. *Psychological Science, 9,* 619–620.

Leder, H., & Bruce, V. (1998). Local and relational aspects of face distinctiveness. *The Quarterly Journal of Experimental Psychology: Section A, 51,* 449–473.

Leder, H., & Bruce, V. (2000). When inverted faces are recognized: The role of configural information in face recognition. *The Quarterly Journal of Experimental Psychology: Section A, 53,* 513–536.

Leder, H., Candrian, G., Huber, O., & Bruce, V. (2001). Configural features in the context of upright and inverted faces. *Perception, 30,* 73–83.

Leder, H., & Carbon, C.-C. (2006). Face-specific configural processing of relational information. *British Journal of Psychology, 97,* 19–29.

Lee, K., & Freire, A. (1999). Effects of face configuration change on shape perception: A new illusion. *Perception, 28,* 1217–1226.

Le Grand, R., Mondloch, C. J., Maurer, D., & Brent, H. P. (2001, April 19). Early visual experience and face processing. *Nature, 410,* 890.

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences, 6,* 255–260.

Mondloch, C. J., Le Grand, R., & Maurer, D. (2002). Configural face processing develops more slowly than featural face processing. *Perception, 31,* 553–566.

Murray, J. E., Yong, E., & Rhodes, G. (2000). Revisiting the perception of upside-down faces. *Psychological Science, 11,* 492–496.

Reed, C. L., Stone, V. E., Bozova, S., & Tanaka, J. (2003). The body-inversion effect. *Psychological Science, 14,* 302–308.

Rhodes, G., Brake, S., & Atkinson, A. P. (1993). What's lost in inverted faces? *Cognition, 47,* 25–57.

Rhodes, G., Hayward, W. G., & Wrinkler, C. (2006). Expert face coding: Configural and component coding of own-race and other-race faces. *Psychonomic Bulletin and Review, 13,* 499–505.

Riesenhuber, M., Jarudi, I., Gilad, S., & Sinha, P. (2004). Face processing in humans is compatible with a simple shape-based model of vision. *Proceedings in Biological Sciences, 271*(Suppl. 6), S448–S450.

Rossion, B., & Gauthier, I. (2002). How does the brain process upright and inverted faces? *Behavioral and Cognitive Neuroscience Reviews, 1,* 63–75.

Sekuler, A. B., Gaspar, C. M., Gold, J. M., & Bennett, P. J. (2004). Inversion leads to quantitative, not qualitative, changes in face processing. *Current Biology, 14,* 391–396.

Sergent, J. (1984). An investigation into component and configural processes underlying face perception. *British Journal of Psychology, 75,* 221–242.

Tanaka, J. W., & Sengco, J. A. (1987). Features and their configuration in face recognition. *Memory and Cognition, 25,* 583–592.

Tarr, M. J., & Pinker, S. (1989). Mental rotation and orientation-dependence in shape recognition. *Cognitive Psychology, 21,* 233–282.

Turati, C., Simion, F., Milani, I., & Umilta, C. (2002). Newborns' preference for faces: What is crucial? *Developmental Psychology, 38,* 875–882.

Valentine, T. (1988). Upside-down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology, 79,* 471–491.

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology, 81,* 141–145.

Yovel, G., & Kanwisher, N. (2004). Face perception: Domain specific, not process specific. *Neuron, 44,* 889–898.

Received November 29, 2005
Revision received August 11, 2006
Accepted August 21, 2006 ■

Instructions to Authors

For Instructions to Authors, please consult the February 2007 issue of the volume or visit www.apa.org/journals/rep and click on the "Instructions to authors" link in the Journal Info box on the right.