A feature-inversion effect: can an isolated feature show behavior like the face-inversion effect?

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Published online: 17 May 2012
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Abstract The face-inversion effect (FIE) is explained by the configural-processing hypothesis. It proposes that inversion disrupts configural information processing (spatial links among facial features) and leaves the processing of featural information (eyes, nose, and mouth) comparatively intact. According to this hypothesis, an inverted isolated facial feature cannot show a feature-inversion effect—that is, behavior similar to the FIE—since all the spatial links between it and the other features in a face are eliminated; that is, the configural information is removed. The findings of the present study, which show that isolated eyes do exhibit the feature-inversion effect, support the extended configural-processing hypothesis. This proposes that inversion also impairs processing of the configural information within the eyes themselves. Removal of the brows in whole faces tended to interfere with processing of the configural information in the upright position but to facilitate processing in the inverted position.

Keywords Face perception · Face recognition · Face-inversion effect

According to the face-inversion effect (FIE), perception and recognition of a face are better when a face is presented upright than when it is presented inverted. This effect is greater in faces than in nonface objects (buildings, cars) (e.g., Rakover, 2002; Valentine, 1988) and is obtained in experimental tasks of perception and recognition alike (e.g., Freire, Lee, & Symons, 2000; Rossion & Gauthier, 2002). It is explained by the *configural-processing* hypothesis, which proposes that inversion

disrupts configural information processing (spatial links among facial features) and/or holistic information (facial information is perceived as a whole Gestalt) and leaves the processing of featural information (eyes, nose, and mouth) comparatively intact (e.g., Bartlett, Searcy, & Abdi, 2003; Leder & Bruce, 2000b; Leder & Carbon, 2006; McKone & Yovel, 2009; Rakover, 2002; Tanaka & Farah, 2003).

According to the configural-processing hypothesis, an inverted isolated facial feature cannot show a feature-inversion effect—that is, behavior similar to the FIE—since all the spatial links between it and the other features in a face are eliminated; that is, the configural information is removed. Nevertheless, Rakover and Teucher (1997) found that some isolated features (hair and forehead, eyes) showed a feature-inversion effect. Hence, one may suggest that the configural information is not crucial for obtaining an FIE. (For a critique of this conclusion, see Bartlett et al., 2003, and for a response, see Rakover, 2011.)

One way to save the configural-processing hypothesis is to assume that (1) an isolated facial feature is in itself a visual form made up of certain components (e.g., an eye is composed of eyebrow, eyelid, eyeball, pupil, etc.) and their spatial links and (2) inversion also impairs recognition of an isolated facial feature because it disrupts processing of the spatial links between the feature's components (e.g., inversion disrupts the configural information within the eyes themselves). This proposal, which may be viewed as the *extended configural-processing* hypothesis, can handle Rakover and Teucher's (1997) findings by pointing out that processing the spatial links *within* a facial feature is no less important than processing the spatial links *between* facial features. A spatial change *between* facial features requires at least two features (e.g., interocular distance, nose–mouth distance), whereas a spatial change *within* a feature requires at least two components (e.g., eye – brow, eyes' tilt).

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The present study included two experiments. Experiment 1 tested the extended configural-processing hypothesis, and Experiment 2 examined the role of the eyebrows in processing the eyes presented in upright and inverted positions. The main goal of Experiment 1 was to test empirically the following three predictions derived from the extended configural-processing hypothesis: The inversion of isolated eyes (including brows) will show a feature-inversion effect; spatial changes made within isolated eyes (i.e., a change of the configural information within each eye) will be detected better in the upright position than in the inverted position; and featural changes made within isolated eyes (blackening the brows or the irises) will be detected to the same degree in upright and inverted positions. (Note that the last prediction is also made by the configural-processing hypothesis.)

In addition, the present study examined the effects of two relevant variables on the FIE and feature-inversion effect. The first concerned a face context effect: Would the effect of inversion on the eyes be obtained to the same degree with and without the context of the whole face? The results of the research on the effects of the context of a face or its parts on feature recognition have been inconsistent: no effects (e.g., Leder & Bruce, 2000b; Leder, Candrian, Huber, & Bruce, 2001), positive facilitative effects (e.g., Leder & Carbon, 2004; McKone & Yovel, 2009), and negative effects (e.g., Leder & Carbon, 2005). The second concerned a task effect: Would a feature-inversion effect be obtained in both perception and recognition tasks? Clearly, there are cognitive differences between a perception task (where two stimuli are presented simultaneously) and a recognition task (where two stimuli are presented successively). Several studies have proposed that the FIE involves a memory component (e.g., Leder & Bruce, 1998; Valentine, 1988).

Experiment 2, which was a partial replication of Experiment 1, examined the role of the brows in perception and recognition of the eyes by removing their brows. The experiment focused on the relation between the reduction in the configural information (as a result of the brows' removal) and processing the isolated eyes versus the eyes in a whole face.

Experiment 1

Method

Participants, stimuli, design, and procedure Seventy-two participants (mean age, 24.34 years; 41 females, 31 males) were shown two sets of stimuli on a computer screen. The eye set was generated from 70 different black-and-white pictures of isolated eyes and brows. The face set was generated from 70 different black-and-white pictures of whole faces. The eyes (and brows) in the eye set were cut off from the faces in the face set by means of Adobe Photoshop 7.0

ME (i.e., the eyes were identical in both sets). The eye set consisted of 40 different sets of two pairs of eyes. Each of the two pairs contained one original pair of eyes and another pair that was either the original pair itself or the original pair with a change (see Fig. 1). The eye set consisted of the following seven kinds of manipulations: (a) *identical eyes* (10 sets of two identical [original] pairs of eyes), (b) *interocular distance decreased* (5 sets of two pairs of eyes, one original and the other with interocular distance decreased by 25 %), (c) *interocular distance increased* (5 sets of two pairs of eyes, one original and the other with interocular distance increased by 25 %), (d) *eyebrows elevated* (5 sets of two pairs of eyes, one original and the other with each eyebrow elevated by 25 % of the eye – brow distance), (e) *eyes tilted downward* (5 sets of two pairs of eyes, one original and the other with eyes [without the brows] rotated downward by 15°), (f) *eyebrows blackened* (5 sets of two pairs of eyes, one original and the other with eyebrows blackened), and (g) *irises blackened* (5 sets of two pairs of eyes, one original and the other with irises blackened). These manipulations deal with identical eyes (a), between-configural changes [(b) and (c)], within-configural changes [(d) and (e)], and featural changes [(f) and (g)].

The face set was constructed identically to the eye set: There were 40 different pairs of faces, where each pair of faces consisted of an original face and another face that was either identical to the original face or the original face with a pair of eyes on which a change was made. The changes were identical to those made in the eye set (see Fig. 1).

Fig. 1 A sample of two pairs of eyes, the original pair and its variation, in seven kinds of manipulation

The experiment was designed as three factors with repeated measurement on the last: A (task: perception vs. recognition) $\times$ B (stimulus: isolated eyes vs. whole face) $\times$ C (position: upright vs. inverted). The two sets above were presented to four different groups ($n = 18$ for each). The eye set was presented to the eyes/perception group, in which each two pairs of eyes were presented simultaneously, and to the eyes/recognition group, in which each two pairs were presented successively. Similarly, the face set was presented to the face/perception and the face/recognition groups. In these four groups, the sets were presented in two positions, upright and inverted; each pair of stimuli was presented twice, once in each position. Hence, the participants were presented with 80 pairs of stimuli (40 upright and 40 inverted). The order of the pairs within a set was randomized for each participant, as were the left/right positions of the stimuli in the perception groups and the first/second appearance of the stimuli in the recognition groups.

In the eyes/perception group, participants were informed that they would be presented with two pairs of eyes and brows simultaneously for 10 s. They were asked to decide whether the two pairs of eyes and brows were identical or different. If the participants decided that they were identical, they should rank them 0, and if different, they should rank them with 1–5, where 1 indicated a *small difference* and 5 a *large difference*. Similar instructions were given to the participants in the face/perception group; they were asked to concentrate on the eye area and decide whether the two pairs of eyes and brows of the two faces were identical or different. In the eyes/recognition group, participants were informed that they would be presented with two pairs of eyes successively, the first pair for 5 s and then (after 2 s) the second pair for 10 s; within that time, the participants were asked to decide whether or not the remembered pair of eyes and the perceived pair were identical, ranking pairs of eyes the *same* (0) and pairs of eyes *different* (1–5) (as described above). Similar instructions were given to the participants in the face/recognition group; they were asked to concentrate on the eye area and decide whether the two pairs of eyes and brows of the two faces were identical or different. All participants performed two practice trials.

Results and discussion

Only percent correct (%correct) is reported here, since analysis of the ranking data was similar to that for %correct. (See Table 1 and Fig. 2, which present the most important findings.) An A (task: perception vs. recognition) $\times$ B (stimulus: isolated eyes vs. whole face) $\times$ C (position: upright vs. inverted) ANOVA with repeated measurements on factor C was applied to %correct for each of the seven manipulations. To test the differences between upright and inverted positions

in %correct, t -tests based on the appropriate ANOVA's MSE at $\alpha = .05$ were used. Only significant differences, which are relevant to the FIE and feature-inversion effect, are reported. This ANOVA was applied to B'' , a nonparametric index for bias detection, in Experiments 1 and 2 (see Macmillan & Creelman, 2005). The results suggest that the %correct findings cannot be explained by an appeal to the participants' tendency to make *same* (or *different*) judgments.

Identical eyes (a) and within-configural changes (e) For recognition of *identical eyes* (manipulation a), %correct was better in the upright than in the inverted position for isolated eyes, $t(68) = 2.20$, and for whole faces, $t(68) = 3.71$. [A stimulus (isolated eyes, whole faces) $\times$ position (upright vs. inverted) ANOVA with repeated measurements on the last factor applied to recognition of *identical eyes* revealed that %correct of recognition was higher in the upright than in the inverted position, $F(1, 34) = 34.1$ $p < .001$, $\eta^2 = .501$, and in whole faces than in isolated eyes, $F(1, 34) = 4.81$ $p < .05$, $\eta^2 = .124$.]

For *identical eyes* (over task and stimulus), %correct was better in the upright than in the inverted position, $F(1, 68) = 9.07$ $p < .01$, $\eta^2 = .118$.

The difference between upright and inverted position for %correct of *identical eyes* (over stimulus) was better in recognition than in perception, $F(1, 68) = 8.38$ $p < .01$, $\eta^2 = .110$.

For *eyes tilted downward (e)*, %correct was better in the upright than in the inverted position for isolated eyes [$t(68) = 3.24$ for perception, $t(68) = 4.22$ for recognition] and for whole faces [$t(68) = 2.48$ for perception]. [A stimulus (isolated eyes, whole faces) $\times$ position (upright vs. inverted) ANOVA with repeated measurements applied to perception of *eyes tilted downward* revealed that %correct for perception was higher in the upright than in the inverted position, $F(1, 34) = 13.9$ $p < .001$, $\eta^2 = .290$.]

For *eyes tilted downward* (over task and stimulus), %correct was better in the upright than in the inverted position, $F(1, 68) = 28.40$ $p < .001$, $\eta^2 = .295$.

The difference between upright and inverted positions in %correct for *eyes tilted downward* (over tasks) was better in isolated eyes than in whole faces, $F(1, 68) = 4.44$ $p < .05$, $\eta^2 = .061$.

Between-configural changes (b) For *interocular distance decreased (b)*, %correct was better in the upright than in the inverted position for whole faces, $t(68) = 2.77$.

For *interocular distance decreased* (over stimulus and position), %correct was better in the upright than in the inverted position, $F(1, 68) = 5.00$ $p < .05$, $\eta^2 = .068$.

Featural changes (f) For *eyebrows blackened (f)*, %correct perception was better in the upright than in the inverted position for whole faces, $t(68) = 2.15$.

Table 1 Percent correct as a function of manipulation (seven manipulations), task (perception, recognition), and position (upright, inverted) in isolated eyes and whole faces (Experiment 1)

Experiment 1	Isolated Eyes				Whole Faces			
	Perception		Recognition		Perception		Recognition	
	Upright	Inverted	Upright	Inverted	Upright	Inverted	Upright	Inverted
(a) Identical eyes	73.89	71.67	54.44	43.89	59.44	61.11	73.89	56.11
(b) Interocular distance decreased	56.67	50.00	72.22	65.56	77.78	57.78	75.56	76.67
(c) Interocular distance increased	61.11	50.00	72.22	64.44	78.89	77.78	80.00	82.22
(d) Eyebrows elevated	33.33	35.56	56.67	58.89	34.44	32.22	34.44	48.89
(e) Eyes tilted downward	98.89	84.44	95.56	76.67	100.00	88.89	98.89	95.56
(f) Eyebrows blackened	88.89	85.56	76.67	80.00	97.78	88.89	76.67	75.56
(g) Iris blackened	95.56	92.22	94.44	92.22	98.89	98.89	91.11	94.44

Fig. 2 Percent correct as a function of manipulation (identical eyes and eyes tilted downward), task (perception, recognition), position (upright, inverted) in isolated eyes and whole faces (Experiment 1)

Some of these results tend to support the extended configural-processing hypothesis (*identical eyes, eyes tilted downward*), and others accord with the configural-processing hypothesis (*interocular distance decreased*). The nonoccurrence of FIE for *interocular distance increased* may be explained in that participants are more sensitive to *interocular distance decreased* than to the former manipulation (e.g., Haig, 1984). It is also seen that the effect of inversion occurred in both tasks (perception and recognition).

Nevertheless, the findings raise two important questions. First, why was detection of *eyebrows elevated* in isolated eyes not better in the upright than in the inverted position? Second, why, for whole faces, was perception of *eyebrows blackened* better in the upright than in the inverted position? The answer to these questions seems to involve the unique role that the eyebrows play in processing of the eyes (e.g., Goffaux & Rossion, 2007; Rock, 1973; Sekunova & Barton, 2008). Sadr, Jarudi, and Sinha (2003) found that the removal of the eyebrows from pictures of famous people greatly reduced their identification.

Given these points, Experiment 2 was an attempt to investigate the role that the brows play in processing the eyes by replicating Experiment 1 without the brows—that is, by removing the brows.

Experiment 2

What is the effect of the brows' removal on processing the two kinds of stimuli—isolated eyes versus eyes in a whole face—in inverted and upright positions? The answer is suggested by the *removal* hypothesis: While the decrease in the configural information (as a result of the brows' removal) interferes with normal activity of the cognitive system when the face appears in the upright position, this decrease helps the cognitive system to cope with the unusual appearance of the face in the inverted position. The basis of this hypothesis is this: (1) I refer to configural information as *net links*, which are spatial links among facial components, including those between and within facial features; (2) I suggest that recognition of faces tends to decrease with the removal of facial information (e.g., Leder, 1996; Leder & Bruce, 2000a).

Given this, the following two predictions are made. First, the brows' removal interferes with processing the eyes in the whole faces more in the upright position than in the inverted position. In this position, the cognitive system has to handle the absence of an important piece of configural information (the brows' spatial links) that it has learned over many years. But in the inverted position, the cognitive system has to

invest less effort to deal with a reduced amount of configural information.

Second, a much weaker prediction than the foregoing is suggested for isolated eyes. The reason is this: The number of the eliminated spatial links between the brows and other components of the isolated eyes is much smaller than the number of spatial links between the brows and other components of the eyes and of the whole face (i.e., the former is just a part of the latter).

Method

Participants, stimuli, design, and procedure Fifty-six participants (mean age, 24.70 years; 41 females, 15 males) took part in Experiment 2. The experiment was a replication of Experiment 1 (with 14 participants in each of its four groups), except for the following three differences. First, the eyebrows of all the eyes in the five manipulations in Experiment 1—(a), (b), (c), (e), and (g)—were removed by means of Adobe Photoshop 7.0 ME. Second, instead of the *eyebrows elevated* (d) and *eyebrows blackened* (f) manipulations, the following manipulations were made: *tilted eyes upward* (d') the brows were removed in all five sets of two pairs of eyes, with eyes rotated upward by 15° in only one pair; *eyebrows removed in one pair* (f) 5 two pairs of eyes, one original [with brows] and the other with eyebrows removed. And finally, participants were informed that some of the pairs contained eyes without brows.

Results and discussion

Table 2 presents all the results of Experiment 2, and Fig. 3 presents the most important findings. The first part of the statistical analysis follows that of Experiment 1, and the second part investigates the effect of the brows' removal (Experiment 1 vs. Experiment 2) on eyes' processing in upright and inverted positions (see Table 2 and Fig. 3).

Part 1 of the analysis

Within-configural changes (d' and e) For perception of isolated eyes *tilted upward* (d'), %correct was better in the upright than in the inverted position, $t(52) = 2.85$.

For perception and recognition of isolated eyes *tilted downward* (e), %correct was better in the upright than in the inverted position, $t(52) = 2.48$ and $t(52) = 2.13$, respectively (see Fig. 3a).

For whole faces, no significant differences in %correct for eyes *tilted upward* and *downward* between the

Table 2 Percent correct as a function of manipulation (seven manipulations), task (perception, recognition), and position (upright, inverted) in isolated eyes and whole faces (Experiment 2)

Experiment 2	Isolated Eyes				Whole Faces			
	Perception		Recognition		Perception		Recognition	
	Upright	Inverted	Upright	Inverted	Upright	Inverted	Upright	Inverted
(a) Identical eyes	70.00	63.57	56.43	53.57	66.43	63.57	62.14	61.43
(b) Interocular distance decreased	40.00	31.43	65.71	58.57	51.43	37.14	67.14	64.29
(c) Interocular distance increased	51.43	47.14	61.43	57.14	62.86	54.29	67.14	68.57
(d) Tilted eyes upward	100.00	85.71	92.86	88.57	94.29	88.57	100.00	97.14
(e) Eyes tilted downward	95.71	85.71	94.29	87.14	94.29	95.71	94.29	97.14
(f) Eyebrows removed in one pair	68.57	58.57	91.43	91.43	78.57	78.57	88.57	85.71
(g) Iris blackened	94.29	92.86	91.43	92.86	100.00	97.14	91.43	87.14

upright and inverted positions were found in any of the four groups.

For *eyes tilted upward* (over task and stimulus), %correct was better in the upright than in the inverted position, $F(1, 52) = 7.32$, $p < .01$, $\eta^2 = .123$.

The difference between upright and inverted positions (over stimulus) in %correct of *eyes tilted downward* tended to be greater for isolated eyes than for whole faces, $F(1, 52) = 8.04$, $p < .01$, $\eta^2 = .134$.

Between-configural changes (b) For *interocular distance decreased* (b) (over task and stimulus), %correct was better in the upright than in the inverted position, $F(1, 52) = 5.74$, $p < .05$, $\eta^2 = .099$.

Part 2 of the analysis

To investigate the effect of the brows' removal on perception and recognition, a (brows: with vs. without) $\times$ (position: upright vs. inverted) ANOVA with repeated measurements on the last factor was applied to the data (isolated eyes and whole faces).

Isolated eyes For recognition of *identical eyes* (a) (over brows), %correct was better in the upright than in the inverted position, $F(1, 30) = 7.61$, $p < .01$, $\eta^2 = .202$.

Whole faces In comparison with the with-brows condition, %correct for recognition of *identical eyes* under the without-brows condition decreased in the upright position (by 11.75 %) but increased in the inverted position (by 5.32 %), $F(1, 30) = 9.05$, $p < .01$, $\eta^2 = .232$.

In comparison with the with-brows condition, %correct for perception of *eyes tilted downward* under the without-brows condition decreased in the upright position (by

5.71 %) but increased in the inverted position (by 6.82 %), $F(1, 30) = 5.35$, $p < .05$, $\eta^2 = .151$ (see Fig. 3b).

For perception of *interocular distance decreased* (over brows), %correct was better in the upright than in the inverted position, $F(1, 30) = 7.64$, $p < .01$, $\eta^2 = .203$, and %correct (over position) was better under the with-brows condition than under the without-brows condition, $F(1, 30) = 4.37$, $p < .01$, $\eta^2 = .127$.

The major findings of Experiment 2 are as follows. Detection of within-configural information changes (*eyes tilted upward or downward*) was better in the upright than in the inverted position for isolated eyes, whereas no such differences were found for whole faces. Removal of the brows has contrasting effects. In whole face presented upright, processing the configural information in eyes without brows was impaired more than in eyes with brows (a result that accords with that of Sadr, Jarudi, & Sinha, 2003). However, in the inverted position, processing the configural information in eyes with brows was impaired more than in eyes without brows.

General discussion

The main findings of the present study can be summarized as follows. (1) Inversion impaired the configural information in isolated eyes for *identical eyes* and for *eyes tilted downward or upward*. These findings support the extended configural-processing hypothesis. (2) The brows' removal had two opposing effects: It impaired processing of the eyes' configural information (*identical eyes*, *eyes tilted downward*) in upright whole faces but improved processing of this information in inverted faces. These findings support the removal hypothesis.

The present findings and those of Rakover and Teucher (1997) tend to support the extended configural-processing

Fig. 3 **a** Percent correct as a function of manipulation (eyes tilted upward and downward), task (perception, recognition), position (upright, inverted) in isolated eyes (Experiment 2). **b** Percent correct as a function of manipulation (identical eyes and eyes tilted downward), task (perception, recognition), position (upright, inverted), and brows (with [Experiment 1] vs. without [Experiment 2]) in whole faces. (The differences due to the brows $\times$ position interaction are significant. See the text)

hypothesis. However, these findings do not accord with various findings reported in the literature: A large feature inversion effect occurred when the feature appeared in a whole face, but not in isolation (see MacKone & Yovel, 2009). Although some of the present results (Experiment 1) also accord with the literature's findings (*interocular distance decreased*), the present study suggests a different picture: A fairly large upright–inverted difference (12.46 % on average over both experiments) for isolated eyes was found. In Experiment 1, this difference was similar to that for eyes in whole faces, and in Experiment 2, in several cases, the upright–inverted differences for isolated eyes (*eyes tilted downward and upward*) were greater than those for eyes in whole faces.

The findings have an important implication for the problem of representing facial configural information. McKone and Yovel (2009) suggested two main ways of representation: (1) *distances between major blobs* (i.e., distances between nameable features such as eyes and nose) and (2) *distances between local landmarks points (along contours or radiating from each point)*. They preferred representation (2) because it allows a better fit to the data and accords with certain theoretical arguments (see pp. 791–795). Similarly, it is suggested here that representation (2) permits one to take into account the spatial links within and outside the eyes (i.e., in the whole face). One may suggest that net links comes near to representation (2).

Acknowledgments I am grateful to Shmuel Ahituv, Maor Dvir, and Rinat Philipp for their help in running the experiments, analyzing the data, and preparing the figures.

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