

## **A whole face is more than the sum of its halves: Interactive processing in face perception**

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Facial information is processed interactively. Yet, such interactive processing has been examined for discrimination of face parts rather than complete faces. Here we assess interactive processing using a novel paradigm in which subjects discriminate complete faces. Face stimuli, which comprise unilateral facial information (*hemifaces*) or bilateral facial information from one face (consistent) or two different faces (inconsistent), are shown centrally in a face-matching task. If each half of a complete face is processed independently, accuracy for complete faces can be predicted by the union of accuracies for right and left hemifaces. However, accuracy exceeded this independence prediction for consistent faces (facilitation) and fell below the prediction for inconsistent faces (interference). These effects were reduced or absent for inverted faces. Our findings are consistent with reports of stronger interactive processing for upright than for inverted faces and they quantify effects of interactive processing on the discrimination of complete faces.

It is well established that faces are processed by a specialized mechanism that is not used for the processing of most other objects (Farah, Wilson, Drain, & Tanaka, 1998; Mondloch, Le Grand, & Maurer, 2002, but see Gauthier, Behrmann, & Tarr, 1999). One of the first demonstrations that faces are processed differently than other objects is the *face inversion effect*. Yin (1969) showed that

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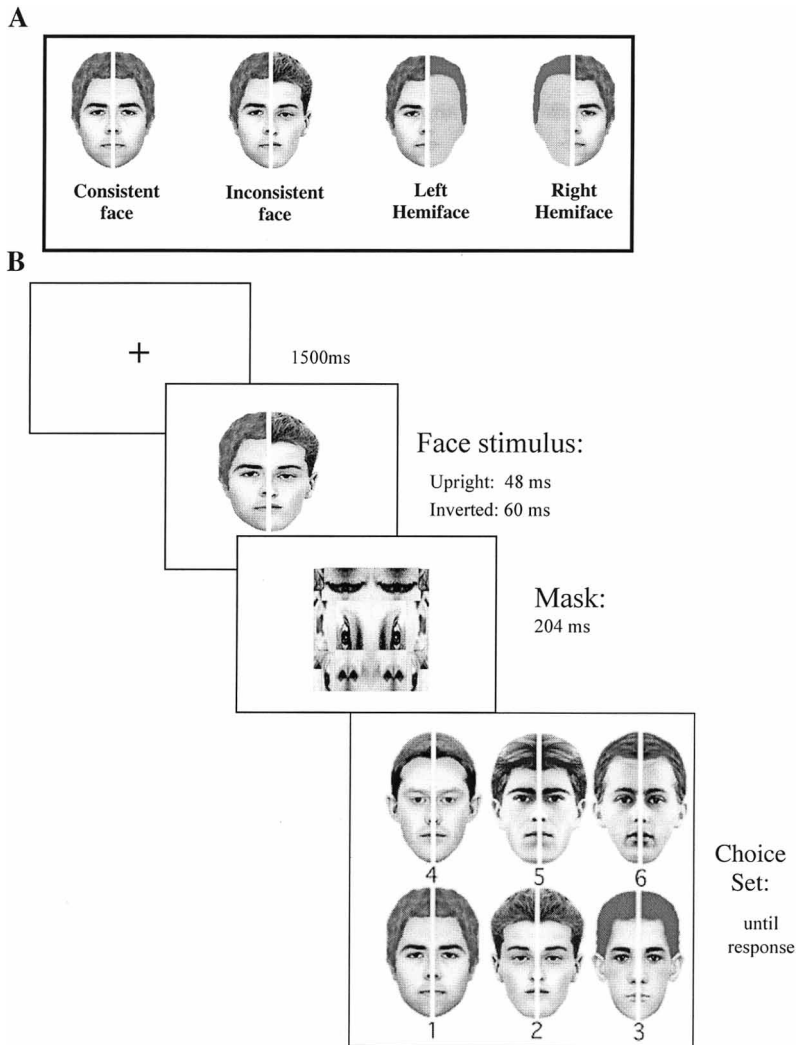
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face recognition is poorer when faces are presented in an inverted relative to upright orientation. Because this inversion effect is much smaller for nonface objects (e.g., houses, scenes), Yin inferred that faces are processed by a specialized mechanism. Recent support for this claim comes from studies using neuroimaging (Kanwisher, McDermott, & Chun, 1997) and electromagnetic recordings of brain (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Liu, Harris, & Kanwisher, 2002; McCarthy, Puce, Belger, & Allison, 1999), which revealed larger neural responses to faces than nonface stimuli in bilateral occipitotemporal regions. The question of whether the face system is specialized only for faces or for any stimulus category for which subjects show expertise (i.e., subcategory discrimination abilities) is hotly debated (Diamond & Carey, 1986; Gauthier, Tarr, Moylan, Skudlarski, Gore, & Anderson, 2000; Kanwisher, 2000). However, most investigators agree that our representation of faces is qualitatively different from the representation of most stimuli for which we show no expertise.

Behavioural studies have characterized the nature of our face representation (Farah et al., 1998; Tanaka & Farah, 1993; Tanaka & Sengco, 1997; Young, Hellawell, & Hay, 1987). These studies suggest that special integrative mechanisms are applied to face processing. For example, Tanaka and Farah (1993) showed that participants are better in recognizing a feature (e.g., Larry's mouth) within a previously learned face (e.g., Larry's face) than when presented alone (the *whole-part effect*). This effect is not observed with scrambled faces, inverted faces, or houses, which suggests that features in upright faces but not other stimuli are represented interactively rather than independently. Similarly, people are poorer in recognizing an upper half or lower half of two different faces when the two halves are fused to make a composite upright face than when the two halves are misaligned or when the fused face is inverted (Young et al., 1987). This *composite face effect* implies that when parts of a composite face are inconsistent (from two different individuals), integrative processing of the upright composite interferes with discrimination of a part.

The foregoing studies show that the accuracy of discriminating face parts depends on the facial context, which implies that face parts are not processed independently. However, these investigations examine the perception of face parts rather than the discrimination of complete faces, which is the focus of the current investigation. Thus, in the current study we presented a face-matching task with four types of faces (Figure 1A): (1) *consistent faces*, in which right and left halves are mirror images (symmetrical along the midline); (2) *inconsistent faces*, in which right and left halves are of two different people; (3 and 4) *left and right hemifaces*, in which a left or a right half-face is combined with a low-contrast, task-irrelevant half-face.

Because performance for hemifaces was critical for deriving accuracy estimates for complete faces, as described below, it is important to assure that similar conscious experiences are produced with the four face types. Further, our



**Figure 1.** (A) The four types of face stimuli in Experiment 1 and 2. Consistent faces are composed of two consistent half faces; inconsistent faces are composed of two inconsistent half faces; left and right hemifaces are composed of a half face combined with a low-contrast, task-irrelevant neutral face. A thin white stripe conceals the inconsistency between the two halves of inconsistent faces and hemifaces such that when these faces are presented briefly and masked, the majority of subjects perceive all stimuli as complete coherent faces (i.e., perceptual completion). (B) A trial sequence consisted of a fixation cross, a face stimulus (consistent face, inconsistent face, right or left hemiface), a poststimulus mask and the presentation of a choice set of six faces until response.

goal in this study was to assess the perception of whole faces rather than face parts. Therefore, we utilized the phenomenon of *perceptual completion* (Milner & Dunne, 1977) to induce a conscious perception of a consistent, complete face for all stimuli by (1) masking midline discrepancies of the two facial halves with a white vertical strip; (2) including a low-contrast, task-irrelevant half face in each hemiface; and (3) presenting stimuli for brief exposure durations followed by a poststimulus mask.

If the two face halves of complete faces are processed independently, accuracy for complete (consistent or inconsistent) faces can be estimated by the union of the *observed* accuracy for left and right hemifaces. Specifically, the probability that an incorrect match response is made to a complete face is the probability that neither half is correctly matched. If the two halves of a bilateral stimulus are processed independently, then the product of probabilities of failure for the left half,  $1 - p(L)$ , and for the right half,  $1 - p(R)$ , specifies the failure rate for the complete face,  $p(W) = [1 - p(L)][1 - p(R)] = 1 - p(L) - p(R) + p(L)p(R)$ . Thus, if matches of the two halves are independent, the success rate is.

$$p(C) = 1 - p(W) = p(L) + p(R) - p(L)p(R).$$

This *estimated* performance for independent processing of the two halves of complete faces is then compared to the *observed* performance for complete consistent and inconsistent faces. If interactive processing is operative, observed accuracy should be higher than the estimated performance for consistent faces (facilitation) and lower than estimate for inconsistent faces (interference). Because previous studies suggest that interactive facial processing applies to upright but not inverted faces (Tanaka & Farah, 1993; Young et al., 1987), we hypothesize that interactive processing will be present for upright faces and reduced or absent for inverted faces.

In Experiment 1, we investigated whether the two halves of upright faces are processed independently or interactively. In Experiment 2, we applied the same methodology with both upright and inverted faces. The independence prediction is made with the assumption that the low-contrast side of hemiface stimuli does not interfere with discrimination of the task-relevant hemiface. In Experiment 3 we addressed this issue by examining hemiface perception as a function of the presence or absence of the low-contrast side and of the level of contrast.

## EXPERIMENT 1: INTERACTIVE FACE PROCESSING FOR UPRIGHT FACES

### Methods

*Subjects.* Twenty-four right-handed University of Chicago students and employees (12 males; age range: 18–26) participated in Experiment 1. The subjects received \$10/hour for their participation.

*Stimuli and apparatus.* Frontal views of faces of six young males were selected from the University of Stirling face database (<http://pics.psych.stir.ac.uk/>). All stimuli from a given poser were constructed from only a single half of the poser's face and its mirror image. For some posers, we used the left half and for others, the right half. Facial images (Figure 1A) were constructed as follows. Six consistent faces were made by combining each half-face with its mirror image. Six right and six left hemiface stimuli were made by combining each half-face (or its mirror image) with a standard female half-face in which contrast was reduced to 33% to limit the influence of the task-irrelevant half-face. Thirty inconsistent faces were comprised of the 15 combinations of each half-face with the half-faces of the other five posers and the mirror images of these combinations. The choice set comprised the six consistent faces. Each face subtended  $3.2^\circ$  of visual angle horizontally.

As mentioned above, a white vertical midline strip of  $0.2^\circ$  horizontal visual angle was included to conceal the inconsistency of the two halves of hemiface stimuli and inconsistent faces. The midline strip was also added to consistent stimuli and to the faces in the choice stimuli. Subjects were not informed that stimuli included hemifaces and inconsistent faces, and most subjects (74%) expressed no knowledge during debriefing of the bilateral inconsistency in these face types. The rest of the subjects (26%) suspected that some stimuli were not consistent only towards the end of the experiment.

All faces were equated for luminance, length, and width. Stimuli were presented on a 17-inch monitor ( $1024 \times 768$ , 85 Hz, Mac Std Gamma) under control of PsyScope 1.2 (Cohen, MacWhinney, Flatt, & Provost, 1993) and viewed from a distance of 45cm, which was controlled by a chinrest.

*Procedure.* Participants were introduced to the experiment by signing a consent form in which they were given general information on the experiment. They then completed a nine-item handedness questionnaire. Subjects were not informed that some face stimuli were inconsistent. A trial sequence included a fixation plus sign for 1000 ms, a circle that replaced the plus sign for 500 ms (warning cue), a 24 ms interstimulus interval, a central face stimulus (consistent, inconsistent; right or left hemiface) for 60 ms and a symmetrical rectangular pattern mask of scrambled facial features ( $4.3^\circ$  high by  $3.4^\circ$  wide) for 204 ms. After the disappearance of the mask, the six choice faces were presented (Figure 1B). Subjects chose the correct face by pressing the corresponding 1–6 key on the computer keyboard. No subject experienced conflict or ambiguity in matching inconsistent faces. Apparently, one hemiface of inconsistent stimuli dominated perception<sup>1</sup> on each trial of inconsistent faces.

<sup>1</sup> There was a higher proportion of correct identification of the left side (23.8%) than the right side (16.9%) of inconsistent faces,  $t(23) = 1.91$ ,  $p = .07$ , in Experiment 1, and for left side (28.8%) than the right side (18.8%) for upright,  $t(23) = 3.09$ ,  $p < .01$ , but not inverted faces in Experiment 2.

The task began with a practice block, which included 24 unmasked consistent faces to familiarize subjects with the 6 faces. The experimental task consisted of four blocks, each including 6 consistent faces, 6 right hemifaces, 6 left hemifaces, and 30 inconsistent faces in a random order in each block.

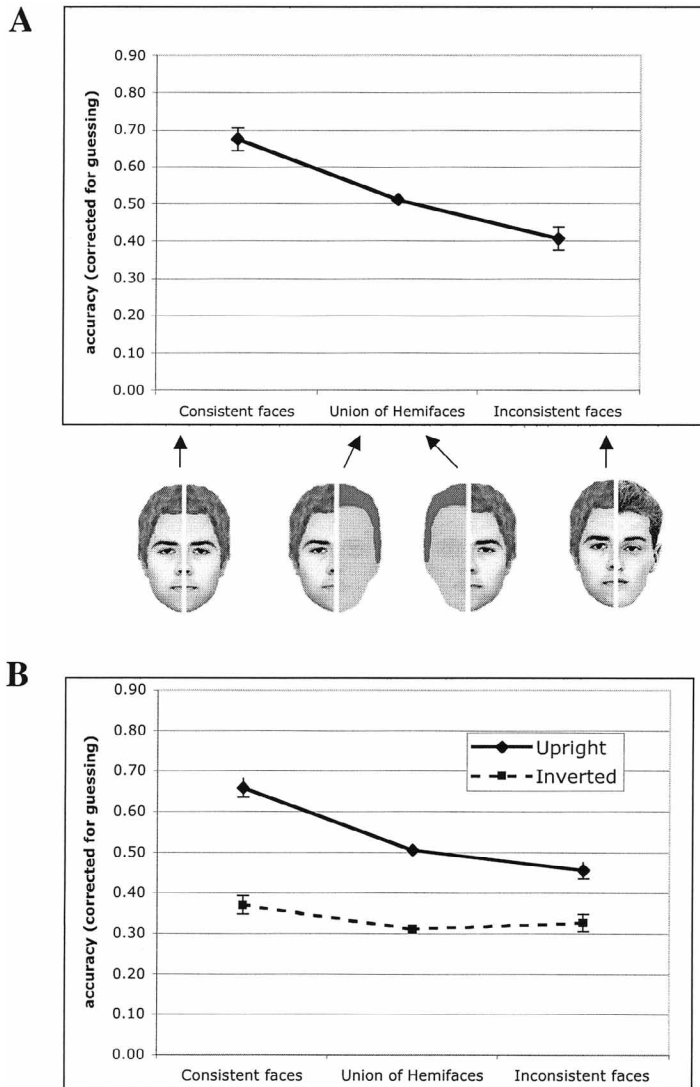
*Data analyses.* We computed the proportion of matches corrected for guessing for each of the four face types using the following formulas: For consistent faces and hemifaces:  $p(\tilde{M}) = p(M) - [p(W)/5]$ , where  $p(\tilde{M})$  is the proportion of matches corrected for guessing,  $p(M)$  is the observed proportion of correct matches, and  $p(W)$  is the observed proportion of wrong responses. For inconsistent faces, in which two out of the six faces are correct matches:  $p(\tilde{M}) = p(M) - [p(W)/2]$ . The predicted performance for independent processing of the two halves of consistent and inconsistent faces is  $p(L \cup R) = p(R) + p(L) - p(R)p(L)$ , where  $p(L)$  is the proportion of matches of left hemifaces and  $p(R)$  is the proportion of matches of right hemifaces.

## Results and discussion

As described above, we used each subject's accuracy (corrected for guessing) for upright left hemifaces (mean = 36.0%) and right hemifaces (mean = 25.8%)<sup>2</sup> to specify the subject's performance given independent processing of complete consistent and inconsistent faces [using the formula  $p(L \cup R) = p(R) + p(L) - p(R)p(L)$ ]. Performance for consistent faces (67.5%) was higher than the predicted performance given independent processing (51.2%),  $F(1, 23) = 28.42$ ,  $p < .0001$ , which demonstrates facilitation in the processing of consistent faces. Similarly, performance for inconsistent faces (40.5%) was lower than the predicted performance given independent processing (51.2%),  $F(1, 23) = 11.36$ ,  $p < .005$ , which demonstrates interference in the processing of inconsistent faces (Figure 2A). Both findings imply that the perception of bilateral faces entails interactive processing of the two face halves. Although inconsistent faces are consciously perceived as consistent, the conflict of information in their two halves is extracted by interactive processors and interferes with perception.

Previous studies suggest that interactive processing occurs for upright but not inverted faces (e.g., Farah et al., 1995; Young et al., 1987). Thus, in Experiment 2, we examined these effects for both upright faces and inverted faces. If interactive processing is greater for upright than inverted faces, then facilitation and interference effects should be greater for upright than inverted faces.

<sup>2</sup> Performance for left hemifaces was higher than for right hemifaces,  $t(23) = 2.81$ ,  $p < .01$ .



**Figure 2.** (A) Results in Experiment 1. The union of accuracy for hemifaces provided an estimation for accuracy under the assumption of independence. Higher performance was found for consistent faces (facilitation). Lower performance was found for inconsistent faces (interference). Error bars represent the standard error of the difference from the independence prediction for consistent and inconsistent faces. These effects implicate interactive processing of the two halves of complete faces. (B) Results in Experiment 2. The union of accuracy for upright hemifaces and for inverted hemifaces estimate accuracy for complete faces under the assumption of independence. Higher performance was found for upright consistent faces (facilitation). Lower performance was found for upright inconsistent faces (interference). Reduced facilitation was found for inverted consistent faces. No interference was found for inverted inconsistent faces. Error bars represent the standard error of the difference from the independence prediction for consistent and inconsistent faces. Strong interactive processing was thus present for complete faces when viewed upright but not when viewed in an inverted orientation.

## EXPERIMENT 2: INTERACTIVE PROCESSING FOR UPRIGHT VERSUS INVERTED FACES

### Methods

*Subjects.* Forty-eight right-handed University of Chicago students or employees participated in Experiment 2 (age range: 18–29). Twenty-four subjects (9 males) were presented with upright face stimuli and 24 subjects (10 males) were presented with inverted face stimuli. Subjects received \$10/hour for their participation.

*Stimuli and apparatus.* Stimuli and apparatus were the same as in Experiment 1 with the following exceptions. First, a set of inverted faces, otherwise identical to upright faces, were presented to one group of subjects. Second, pilot studies revealed that when hemifaces are presented for 48 ms, perceptual completion is obtained when the contrast level of the standard half-face is reduced to 20%. Therefore, in Experiment 2 we presented the upright face stimuli for 48ms and employed 20% contrast instead of 33% as was used in Experiment 1.

*Procedure.* Procedures were the same as in Experiment 1 with the following exceptions. Each task consisted of a practice block and nine experimental blocks. Each block included 12 consistent faces, 12 right hemifaces, 12 left hemifaces, and 15 inconsistent faces. The procedure was the same for upright and inverted faces except that faces, including those in the choice set, were presented in a different orientation. Further, in an attempt to obtain similar levels of performance in the two conditions, upright faces were presented for 48 ms (compared to 60 ms in Experiment 1) and inverted faces for 60 ms. We could not employ exposures less than 48 ms for upright faces because discrimination was too poor, nor longer than 60 ms for inverted faces because subjects then detected the inconsistency in the two halves of inconsistent faces and hemifaces.

### Results and discussion

Figure 2B shows performance (corrected for guessing) for upright and inverted faces. As described previously, we used each subject's accuracy for upright left hemifaces (mean = 35.2%) and right hemifaces (mean = 29.8%)<sup>3</sup> and likewise for inverted left hemifaces (mean = 16.6%) and right hemifaces (mean = 18.5%) to specify that subject's performance for independent processing of complete

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<sup>3</sup> Performance for left hemifaces and right hemifaces did not differ for either upright,  $t(23) = 1.54$ ,  $p = .13$ , or inverted faced,  $t(23) < 1$ .



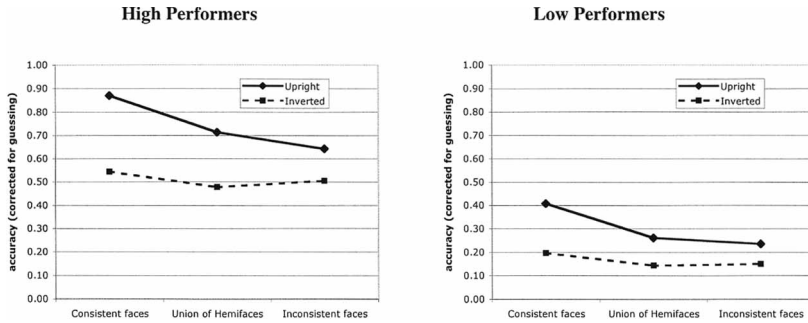
consistent and inconsistent faces [using the formula  $p(L \cup R) = p(R) + p(L) - p(R)p(L)$ ].

*Consistent faces.* Performance was higher for upright consistent faces (65.8%) than the union of performance for upright left and right hemifaces, which specifies the level of performance given independent processing of the two halves of complete faces (50.6%),  $F(1, 24) = 31.57, p < .0001$ . This finding means that the two face halves are processed interactively rather than independently. Although consistent inverted faces also yielded higher performance (37.0%) than the union of performance for inverted left and right hemifaces (31.0%),  $F(1, 23) = 6.79, p < .02$ , the effect was larger for upright than inverted faces: Face type (consistent vs. union of hemifaces)  $\times$  Orientation interaction:  $F(1, 46) = 8.00, p < .01$  (Figure 2B).

*Inconsistent faces.* Performance for inconsistent upright faces was lower (43.9%) than the union of performance for the two upright hemifaces (49.0%),  $F(1, 24) = 7.25, p < .02$ , which reflects interference between the inconsistent face halves. Such interference, however, was not present for inverted faces (32.7% for inconsistent inverted, 31.0% for the union of two inverted halves),  $F(1, 23) = 0.64, p = .43$ : [Face type (inconsistent vs. union of hemifaces)  $\times$  Orientation interaction,  $F(1, 46) = 5.34, p < .05$  (Figure 2B).

In summary, in Experiment 2 we replicated the findings from Experiment 1 of interactive processing for upright faces, and we further demonstrated that such interaction is much reduced for consistent inverted faces and is absent for inconsistent inverted faces. These findings suggest that interactive processing with faces is orientation dependent and, like many perceptual phenomena with faces, is found with upright but not with inverted faces.

*Possible effects of different performance levels for upright versus inverted faces.* Despite the longer exposure duration of inverted than upright faces, performance was better for upright than inverted faces for all face stimuli,  $F(1, 46) = 9.18, p < .005$ . Our pilot studies showed that *perceptual completion* does not reliably occur when face stimuli are presented for more than 60 ms, in that subjects tend to detect the inconsistency between the two halves of hemifaces. Therefore, we could not further increase the exposure duration for inverted faces to equate performance with upright faces. Because upright and inverted faces yielded different performance levels, it is important to ensure that the different patterns of response to upright and inverted faces is not due to a scaling effect. To determine whether the larger facilitation and interference for upright than inverted faces might be due to differences in performance levels, we divided subjects by a median split in each condition into high and low performers, based on their average performance across the four face types. As shown in Figure 3, the pattern of results in the two groups was very similar. This



**Figure 3.** Median split analysis in Experiment 2. In both the high-performance group and the low-performance group, a similar pattern of deviation from predicted values was found for consistent and inconsistent faces. These findings imply that the higher degree of interactive processing implicated with upright faces than with inverted faces is not due to different overall performance levels for upright and inverted faces.

was confirmed in a repeated-measures ANOVA with performance group (high, low) and orientation as between-subjects factors and face type (consistent, union of hemifaces, inconsistent) as a within-subject factor revealed neither an interaction of face type with performance group,  $F(2, 90) < 1$ , nor a three-way interaction of Face type, orientation, and performance group,  $F(2, 90) < 1$ . Thus, the greater interactive processing of upright than inverted faces, as measured by departures from the independence prediction, was not influenced by performance level.

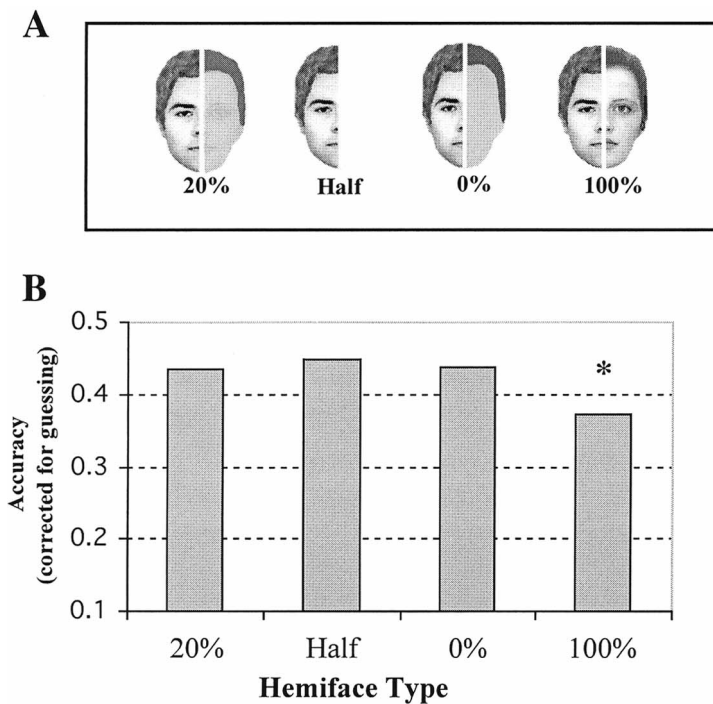
### EXPERIMENT 3: INFLUENCE OF LOW-CONTRAST STANDARD FACE ON PERCEPTION OF THE EXPERIMENTAL HEMIFACE

#### Method

Although the relative contrast level of the standard face included in the hemiface stimulus was minimal, this face could conceivably have interfered with processing of the task-relevant half-face. If so, performance for hemifaces would underestimate accuracy for half-faces in complete faces, such that  $p(L \cup R) = p(L) + p(R) - p(L)p(R)$  might underestimate accuracy of independent processing of the two halves. To determine whether performance for our low-contrast hemifaces is influenced by low-contrast information included in the standard face, we presented subjects with half-face stimuli with four types of information on the other side, as shown in Figure 4A: *20%*: Standard face at 20% contrast, as in Experiment 2; *blank*: No stimulus on the other side; *0%*: Standard face at 0% contrast; *100%*: Standard face with contrast not manipulated. If a standard contrast level of 20% faces is not interfering with perception of the experimental

face, we should see no difference between performance for the 20%, 0%, and blank conditions. However, when contrast of the standard face is at 100%, the standard face is expected to interfere with perception of the experimental face. Such findings would assure that the union of performance for right and left hemifaces with 20% contrast is a valid specification of performance for complete faces given independent processing of the two halves.

*Subjects.* Twelve right-handed Northwestern University students (4 men, age range: 18–20) participated in the study as part of their Introduction to Psychology course requirements.



**Figure 4.** Face stimuli and corresponding results in Experiment 3. **(A)** The four types of face stimuli. **(B)** Accuracy for the four types of faces. Accuracy was significantly lower for 100% contrast hemifaces ( $*p < .05$ ) than for the three other types of hemifaces. Accuracy did not differ significantly between 20% contrast, blank, and 0% contrast faces. These findings suggest that hemiface stimuli in Experiment 2 (which included 20% contrast task-irrelevant facial information on one side in order to promote perceptual completion) produced no undue interference. Therefore, accuracy results for hemifaces does not underestimate performance under the assumption of independent processing in the two hemispheres.

*Stimuli.* We presented four types of upright left and right hemifaces (see Figure 4A): (1) Hemifaces in which the contrast of the standard face was reduced to 20% of the original face (20%). (2) Half-faces in which no information was presented in the opposite visual field (*blank*), (3) hemifaces in which the contrast of the standard face was reduced to 0% and appeared as a solid grey area (0%), and (4) hemifaces in which we did not reduce the contrast of the standard face (100%). The faces subtended  $2.57^\circ$  by  $3.81^\circ$  and the mask,  $3.67^\circ$  by  $4.28^\circ$  of visual angle. The choice set included the same faces that were presented in Experiments 1 and 2. The stimuli were generated by Superlab on a Power Macintosh 7100 and were presented on a 17-inch monitor ( $832 \times 624$ , 75 Hz) viewed from a distance of 60 cm, which was controlled by a chinrest.

*Procedure.* Participants were introduced to the experiment by signing a consent form in which they were given general information on the experiment. They then completed a nine-item handedness questionnaire. Subjects were told that some of the faces would include information only in one visual field. A trial sequence consisted of the appearance of a fixation plus sign for 1000 ms, a zero that replaces the plus sign for 500 ms (a warning cue) followed by a central face for 53 ms, and a symmetrical rectangular pattern mask of scrambled facial features (same mask that was used in Experiment 1) for 200 ms. After the disappearance of the mask, the six choice faces were presented at the bottom of the screen. The faces were numbered 1–6, and subjects were asked to choose the correct face by pressing the corresponding 1–6 key on the computer keyboard. The subject's response initiated the next trial.

The task began with a practice block, which included 24 unmasked consistent faces to familiarize the subjects with the faces. The experimental task consisted of eight blocks of 48 trials/block, separated by a 1 min rest between blocks. Each block included six left and six right hemifaces of each type (half-faces, 0% hemifaces, 20% hemifaces, 100% hemifaces) presented in a randomized order. Each poser in each type was presented once as a left and once as a right hemiface. The entire session lasted approximately 30 min.

## Results

A main effect of hemiface,  $F(3, 33) = 3.30$ ,  $p < .05$ , reflects lower performance (accuracy corrected for guessing) for 100% hemifaces (37.1%) than for 20% hemifaces (43.7%), 0% hemifaces (44.8%), or half-faces (43.6%) (Figure 4B). Most importantly, performance for 20% hemifaces did not differ from performance for 0% hemifaces ( $p = .68$ ) or half-faces ( $p = .96$ ), which suggests that the low-contrast standard does not interfere with perception of the task-relevant hemiface and therefore does not underestimate performance for half-faces.

## GENERAL DISCUSSION

The view that special integrative mechanisms are applied to the processing of faces is well accepted by many investigators (Farah et al., 1998; Moscovitch, Winocur, & Behrmann, 1997). Previous studies that directly assessed this issue measured the discrimination of face parts (Tanaka & Farah, 1993; Young et al., 1987) and showed that the perception of a part is influenced by the context in which it appears, which implies that a particular face part is not represented independently but interactively with other parts. In order to understand the interactive or holistic nature of face perception, however, it is also important to investigate the extent to which interactive processing of facial parts occurs in discrimination of complete faces.

Consistent with the view that face processing entails special integrative mechanisms, we found that a whole face is more than the sum of its halves. Specifically, upright faces evoke strong interactive processing of the two sides of the face, which facilitates discrimination of bilaterally consistent faces. Although people seldom view bilaterally inconsistent faces outside of the laboratory, we also showed that interactive processing of the two sides of such faces interferes with face discrimination.

In contrast, when faces are inverted, interactive processing is weak (for consistent faces) or absent (for inconsistent faces). These observations are in agreement with many findings of integrative processing of upright but not inverted faces (Farah, Tanaka, & Drain, 1995). Our studies not only reveal that the discrimination of bilateral faces is strongly influenced by interactive processing of parts when faces are upright and not when they are inverted, but also provide a quantitative specification of the magnitude of the effects of interactive processing on face perception.

Neither the composite face effect nor the whole-part effect shows interactive processing in inverted faces, whereas we find a small degree of interactive processing in inverted consistent faces, although considerably less than in upright faces. The processing of face parts (eyes, nose, and mouth in the whole-part experiment and upper part of the face in the composite face experiment) is evidently not influenced by other parts in inverted faces. In contrast, when a consistent bilateral face is processed as a single unit, as in our study, then even when the face is inverted, processing of the two halves is interactive to some extent. This finding is in agreement with a recent report by Moscovitch and Moscovitch (2000) of a *super inversion effect* for fractured faces (i.e., faces in which segments of a face were separated outward). In particular, recognition of fractured inverted faces was much worse than recognition of intact inverted faces. Because the perception of the relations among face parts is disrupted in fractured faces, this super inversion effect implies, as do our observations, that inverted intact faces (when bilaterally consistent) are processed interactively to some extent.

Another earlier finding that could be taken to be inconsistent with our findings is a failure to find interference with bilaterally inconsistent faces in an investigation of composite face effects (Hole, 1994). However, as mentioned above, in studies of the composite face effect subjects focused on only the left or right hemiface, thus discouraging interactive processing of the two halves. In contrast, subjects in our study analysed faces in a more typical way in focusing on and perceiving complete faces, which is clearly associated with interactive processing of the two halves. The presence of interactive processing in our vertically split faces highlights the importance of investigating the perception of whole faces (not only face parts) to discover mechanisms of face perception.

Because performance for hemifaces is used to predict performance for complete faces under the independence assumption, it is important to generate similar conscious perceptions of complete faces for all face stimuli. The illusion of face completeness was accomplished by (1) including low-contrast facial information on the opposite side of hemifaces, (2) superimposing a vertical midline mask for all faces to occlude midline inconsistency, (3) presenting stimuli briefly, and (4) using a poststimulus mask. Consequently, complete faces were perceived by virtue of *perceptual completion*. The results of Experiment 3 allowed us to exclude the possibility that low-contrast facial information in hemifaces interfered with the perception of the relevant facial information, which could have produced an underestimate under the independence hypothesis of performance for complete faces. Performance did not differ between these hemifaces and half-faces that included no information on the opposite side of the face. Thus, our paradigm yielded valid estimates for discrimination accuracy, based on independent processing of the two face halves but with hemiface stimuli that evoked a perception of complete faces.

Because upright faces yield superior discrimination performance compared to inverted faces, the possibility of scaling effects must be considered—different results for upright and inverted faces may merely reflect differences in task difficulty. Our median-split analysis rules out this interpretation (see Figure 3). The similar pattern of results for high and low performers suggests that our inferences concerning interactive processing for upright but not inverted faces was not based on an artifact of performance levels, but rather reflects integrative mechanisms that are applied to upright faces similarly at multiple performance levels.

Interactive processing in our experiments, in which each half of the centrally presented face stimuli is directly projected to a different hemisphere, depended on interhemispheric integration. Two recent studies investigated interhemispheric communication for faces by comparing performance for bilaterally redundant (i.e., a face on each side of fixation) versus unilateral face presentations (Mohr, Landgrebe, & Schweinberger, 2002; Schweinberger, Baird, Blumler, Kaufmann, & Mohr, 2003). A bilateral advantage (better performance on bilateral than unilateral presentations) was observed for familiar but not

unfamiliar faces (Mohr et al., 2002) and for face recognition but not discrimination of facial expression (Schweinberger et al., 2003). These studies, however, did not examine the question of whether the two hemispheres work independently or interactively. In fact, Marks and Hellige (1999) reported that the two hemispheres work independently in response to bilaterally redundant presentations. These findings, however, pertain to the processing of two identical stimuli, one on each side of fixation. The same conclusion apparently does not hold for single face stimuli presented at fixation, such that each face half is processed in a different hemisphere. Although the human face generally has a high degree of bilateral symmetry, the nature of collaboration between the two hemispheres is quite different for a pair of bilaterally redundant stimuli versus central face presentations. Likewise, Luh and Levy (1995) found that error patterns in identifying centrally presented syllables were only weakly predicted by unilateral error patterns for the left and right visual fields, which had strong predictive value for error patterns of bilaterally redundant syllables. These findings highlight differences between processing parafoveal objects versus a single, central object. Investigations with two complete stimuli presented simultaneously at parafoveal locations may be less appropriate than investigations with central object presentations for revealing the nature of interactive processing.

We propose that perceptual synthesis of stimulus parts is a fundamental property of specialized face processing mechanisms that underlies interactive effects in our investigation. Whether the same or different specialized mechanisms are the source of the whole-part face effect (Tanaka & Farah, 1993) and the face composite effect (Young et al., 1987) is a question for future research. Another issue of considerable importance concerns the uniqueness or not of faces in eliciting integrative processing. Central questions are whether such integration inherently greater for faces than for all other objects, or whether it is present to the same extent when perceptual expertise is acquired for some class of nonface objects (Diamond & Carey, 1986, Gauthier et al., 2000). A strategy similar to that used in the present study may be useful for determining the extent to which faces may or may not be unique in eliciting integrative processing.

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