

Face Recognition: A General or Specific Right Hemisphere Capacity?

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Face-recognition ability has been claimed to be qualitatively different from other pattern-recognition abilities. One argument for this claim is the finding of a significant right hemisphere advantage for the recognition of upright but not inverted faces. However, this argument is justified only if this orientation-sensitive pattern is unique to faces. In the present study, comparable patterns of orientation-sensitive involvement of the right hemisphere are found for the recognition of faces and houses. This finding is interpreted as evidence for a right hemisphere schema formation capacity that is applied not only to upright faces but also to other familiar classes of stimuli in their canonical upright orientation. It is suggested that any greater right hemisphere involvement in the recognition of upright faces is due to our greater expertise at recognizing faces than other stimulus types. We also find evidence that only a subset of right-handed adults show orientation-sensitive right hemisphere involvement in the recognition of faces and houses: in particular, those dextrals with a characteristic hemispheric arousal asymmetry in favor of the right hemisphere. In contrast, dextrals with a characteristic arousal asymmetry in favor of the left hemisphere do not show significant visual field asymmetries for faces or houses in either upright or inverted orientations. © 1988 Academic Press, Inc.

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A critical component of our interactions with others is the ability to recognize faces. One aspect of this ability involves initial encoding and representation of a previously unfamiliar face in a manner that allows for subsequent recognition of that face as one that is familiar (Young, Hay, & Ellis, 1985). Although the recognition of members of other classes of visual stimuli (e.g., houses, cars) has similar processing requirements, it has been argued that our ability to recognize faces is "special," or in some sense unique (Hay & Young, 1982). Various arguments have been used to support this view, including the prodigiousness of our face-recognition ability, its susceptibility to transformations such as inversion, the uniqueness of its developmental history, and the uniqueness of its biological underpinnings. Several recent reviews of the existing evidence, however, show that none of these arguments is entirely convincing (Davidoff, 1986; Ellis & Young, in press; Levine, in press).

For example, one finding that has been used to support the view that face processing is special is adults' greater ability to individuate faces than members of other stimulus classes (Bahrick, Bahrick, & Wittlinger, 1975; Goldstein & Chance, 1971; Yin, 1969). However, Davidoff (1986) convincingly argues that the prodigiousness of face recognition ability does not confer special status on this ability. Rather, our highly developed face-recognition ability may only reflect our ability to develop expertise when it is important to differentiate among exemplars in a domain, and when we have early and extensive experience with that domain.

A second finding that has been used to support the view that face processing is special is the greater effect of inversion on face recognition than on the recognition of other classes of monooriented stimuli (e.g., houses, airplanes) (Scapinello & Yarmey, 1970; Yin, 1969; Carey & Diamond, 1977). For normal adults, inversion results in about a 30% decrement for the recognition of faces, but only a 10% decrement for the recognition of other stimulus types (Yin, 1969). The larger inversion effect for faces has been attributed to faces being represented more in terms of configurational information than from other stimulus types (e.g., houses), and to configurational information being particularly disrupted by inversion (Carey & Diamond, 1980). However, several investigators (e.g., Davidoff, 1986; Flin, 1985) have called this interpretation into question, noting that in studies of the inversion effect (e.g., Yin, 1969; Scapinello and Yarmey, 1970) face and nonface stimuli have not been equated for familiarity, complexity, or for similarity of exemplars within the sets. Moreover, in a recent study of the inversion effect, professional dog show judges showed comparable inversion effects for the type of dog they were expert at judging and faces (Diamond & Carey, 1986). Thus, the size of the inversion effect may be determined by expertise level rather than by stimulus type (face vs. nonface).

A third line of evidence that has been used to support the view that

face recognition is special is based on the development of face recognition ability during infancy and childhood. As early as several minutes of age, infants are reported to look more at a schematic face than at a scrambled or blank face (Goren, Sarty, & Wu, 1975; Ambrose, 1960; Haaf & Bell, 1967). However, it is not known whether this early preference is attributable to an innate sensitivity to the coherence of forms or whether it reflects a face-specific ability. Infants may show a similar preference for normal vs. scrambled cars, dogs, etc. Similarly, the finding that infants are better at discriminating upright than inverted faces by 5 months of age (Fagan, 1972, 1979) may reflect a general sensitivity to the orientation of complex visuospatial stimuli rather than a face-specific ability.

Even if there is an innate face-specific ability, its elaboration may depend on experience with faces during development. In fact, studies of children's ability to recognize previously unfamiliar faces have shown that face-recognition ability has a rather protracted developmental course. For example, the magnitude of the inversion effect for faces does not reach the adult level until age 10, followed by a fall-off until age 14, and a subsequent recovery to the adult level (Carey & Diamond, 1977, 1980; Flin, 1980). This developmental course is mainly attributable to age changes in the ability to recognize upright faces, as the ability to recognize inverted faces changes much less across age (Carey, Diamond, & Jaaskela, unpublished manuscript). Surveying a large set of abilities, Carey and Diamond (1980) report that the only other abilities with developmental curves similar to face recognition are voice recognition (Mann, Diamond, & Carey, 1979) and tonal memory (Spreen & Gaddes, 1969). Because these abilities, like face recognition, differentially involve the right cerebral hemisphere, it is possible that this developmental course reflects aspects of brain maturation that affect face recognition as well as other specialized abilities of the right hemisphere. Thus, the developmental course of face recognition does not provide strong support for the uniqueness of this ability (Carey & Diamond, 1980).

The research reported in this paper is directly concerned with yet another argument used to support the uniqueness of face recognition: In particular, the argument that the right cerebral hemisphere is specifically involved in the recognition of faces, over and above any general involvement in processing complex visuospatial information. A review of the literature shows that numerous studies with normal subjects, unilaterally brain-damaged patients and commissurotomy patients provide consistent support for greater involvement of the right than the left hemisphere in the recognition of previously unfamiliar faces (e.g., Milner, 1960, 1968; Warrington & James, 1967; Levy, Trevarthan, & Sperry, 1972; Leehey, Carey, Diamond & Cahn, 1978; Young, Hay, & McWeeny, 1985). There is somewhat more controversy concerning hemispheric involvement in the recognition of known faces, (e.g., familiar colleagues' faces or famous

faces), some studies reporting a right hemisphere advantage (e.g., Leehey & Cahn, 1979; Levine & Koch-Weser, 1982; Young & Bion, 1981) and others reporting a left hemisphere advantage (e.g., Marzi & Berlucchi, 1977; Umiltá, Brizzolara, Tabossi, & Fairweather, 1978). The discrepancies among the results of these studies may stem from methodological differences, including variations in degree of familiarity of the face stimuli used, variations in the nature of the response required, etc. (Levine & Koch-Weser, 1982). These issues are not addressed in this paper as only previously unfamiliar faces are used as face stimuli.

It could be argued that the role of the right hemisphere in recognizing unfamiliar faces reflects its general superiority in a wide range of visuospatial tasks, (e.g., recognition of noncanonical views of objects, route finding, dot location, perception of line orientation, Gestalt-completion, complex shape recognition) (e.g., Warrington, 1982; DeRenzi, Faglioni, & Villa, 1977; DeRenzi & Spinnler, 1966; Warrington & Taylor, 1973; Fontenot, 1973; Robertshaw & Sheldon, 1976; Levy et al., 1972). However, Yin's (1970) results suggest that there may be an aspect of right hemisphere specialization that is face-specific. In particular, he reports that patients with damage to nonfrontal right hemisphere regions (parietal, temporal, and/or occipital lobes) are worse at recognizing upright faces but better at recognizing inverted faces than normal controls and other unilaterally brain-damaged patients (those with left hemisphere damage and those with right frontal damage). This dissociation between stimulus orientation and location of damage was not found for house stimuli. On the basis of these findings, Yin (1970) argues that "a general impairment in distinguishing and remembering visual objects does not account for the impairment shown by patients with right posterior lesions on tests of face recognition."

Additional evidence supporting orientation-sensitive right hemisphere involvement in face recognition comes from developmental studies. A left visual field (LVF)-right hemisphere advantage for recognizing previously unfamiliar faces has been reported to emerge at age 10, coincident with the attainment of the "adult level" face-inversion effect (Levine, 1984; Reynolds & Jeeves, 1978). Moreover, studies of normal adults in which upright and inverted faces were tachistoscopically presented to lateralized view reveal a significant LVF-right hemisphere advantage for upright faces but no visual field asymmetry for inverted faces (Leehey et al., 1978; Rapazynski & Ehrlichman, 1979; Young & Bion, 1981).¹

¹ Sergent (1983) presents an alternative explanation for Leehey et al.'s (1978) finding of differential right hemisphere involvement in the recognition of upright but not inverted faces. She suggests that the larger LVF advantage for upright than inverted faces is attributable to the different exposure durations used (120 msec for upright faces vs. 150 msec for inverted faces), rather than to the orientation difference per se. This argument is based on her notion that the right hemisphere is superior at extracting low spatial

Currently it is not known whether right hemisphere involvement in the recognition of stimulus classes other than faces is specific to the upright orientation. It is possible that the right hemisphere develops orientation-sensitive schemas for the recognition of members of familiar classes of stimuli, with faces merely being a prime example of such a class (Freedman & Haber, 1974; Wiseman & Neisser, 1974; Goldstein & Chance, 1980). Alternatively, greater right hemisphere involvement in the recognition of upright faces may reflect the operation of processes that are specific to faces.

The present study examines this question by presenting previously unfamiliar faces and another class of monooriented stimuli, previously unfamiliar houses, to lateralized tachistoscopic view in upright and inverted orientations. The finding of an orientation-sensitive component of right hemisphere involvement for face but not house recognition would support the uniqueness of the processes applied in recognizing upright faces. Of course, this finding would leave open the possibility that a stimulus class other than houses might show the same pattern as faces. The alternative finding of orientation-sensitive right hemisphere involvement in the recognition of houses as well as faces would suggest that "special" right hemisphere involvement in the recognition of upright faces actually reflects a more general capacity of the right hemisphere. This capacity can be characterized as an "orientation-sensitive schema formation capacity," which enhances the ability of the right hemisphere to differentiate members of familiar classes of stimuli in their canonical upright orientation and which may be particularly important in expert-level recognition abilities.

The hypothesis that "special" right hemisphere involvement in upright face recognition reflects a general schema formation capacity related to expert level visual-recognition abilities gains support from evidence suggesting that individuals who are expert at recognizing other classes of

frequencies which may be the only information available at brief exposure durations whereas the left hemisphere is superior at extracting higher spatial frequency information which only becomes available at longer exposure durations. Sergent's hypothesis predicts that the longer exposure duration used by Leehey et al. (1978) for inverted than upright faces should result in a decreased asymmetry score for inverted relative to upright faces, due to an increase in RVF performance. However, the absence of a significant visual field asymmetry for inverted faces in the Leehey et al. study was actually due to a significant decrease in LVF performance for inverted relative to upright faces as RVF performance was unchanged compared to upright faces. Under Sergent's hypothesis it is difficult to explain both why an increase in exposure duration would interfere with LVF performance as low spatial frequencies should be extractable at both short and longer exposure durations and also why an increased exposure duration would not increase RVF performance since higher spatial frequency information should have become more available. Moreover, the same pattern of results as reported by Leehey et al. (1978) has been reported when exposure durations for upright and inverted faces did not differ (Young & Bion, 1981; Rapazynski & Ehrlichman, 1979).

visuospatial stimuli may process them in a manner similar to faces. For example, a few case studies of prosopagnosic patients indicate that their deficits in recognizing highly familiar faces are accompanied by deficits in recognizing other stimulus classes that they had previously been expert at recognizing. One patient, who had been an ornithologist, not only had a face-recognition deficit, but was also unable to individuate birds following brain damage (Bornstein, 1963). Similarly, another patient was a farmer who in addition to his face-recognition deficit no longer was able to recognize his cows (Bornstein, Sroka, & Munitz, 1969). It is possible that prosopagnosic patients for whom the deficit appears to be confined to face recognition (e.g., DeRenzi, 1986) may not have developed expertise in recognizing any other class of visuospatial stimuli. Thus, the prosopagnosic deficit, like the inversion effect, may be expertise-level-, rather than stimulus-type-specific.

The present study also investigates whether individual variations in characteristic hemispheric arousal asymmetry among dextrals are related to individual variations in face processing. Levy, Heller, Banich, and Burton (1983a) hypothesize that subjects' perceptual asymmetries on standard laterality tasks (e.g., studies using lateralized tachistoscopic presentation or dichotic listening) reflect individual variations in characteristic pattern of hemispheric arousal as well as in pattern of hemispheric specialization. Thus, when the direction of a subject's characteristic arousal asymmetry is concordant with the hemisphere that is specialized for a particular task, his/her perceptual asymmetry on that task is increased. Conversely, when the direction of a subject's characteristic arousal asymmetry is discordant with the hemisphere that is specialized for a particular task, his/her perceptual asymmetry on that task is decreased and may even change its direction. Levy et al. (1983a) report that a strong leftward bias on the free-vision chimeric face task was associated with a small RVF advantage on a tachistoscopic CVC-syllable identification task whereas a weak leftward bias on the free-vision chimeric face task was associated with a large RVF advantage on the CVC task. Consistent with these findings, Levine, Banich, and Koch-Weser (1984) demonstrated that subjects with a left visual field advantage on a task that was nonlateralized for the group as a whole (mean asymmetry score did not significantly differ from zero) showed a greater LVF advantage on a face-recognition task than subjects with a right visual field (RVF) advantage on the nonlateralized task. In contrast, subjects with a RVF advantage on a nonlateralized task showed a greater RVF advantage on word recognition than subjects with a LVF advantage on the nonlateralized task. Furthermore, findings from studies using diverse measures (e.g., hemispheric blood flow, EEGS, eye movement asymmetries, and lateralized tachistoscopic presentation) suggest that individuals' hemispheric arousal asymmetries are related to a variety of stable cognitive and personality

measures (e.g., Gur & Reivich, 1980; Levine et al., 1984, Levy et al., 1983a).

In view of the evidence that the right hemisphere plays a more important role in the recognition of faces (e.g., Yin, 1970, Leehey et al., 1978; Young & Bion, 1981), it seems plausible that face stimuli may be processed differently by subjects with left vs. right hemisphere arousal asymmetry. A study by Ross and Turkewitz (1981) supports the hypothesis that variations in hemispheric asymmetry patterns are associated with variations in face recognition abilities. They found that inversion of faces was more disruptive to subjects with a LVF-right hemisphere advantage on a tachistoscopic face-recognition task than to subjects with a RVF-left hemisphere advantage. In contrast, omission of isolated facial features was more disruptive to subjects with a RVF-left hemisphere advantage than to those with a LVF-right hemisphere advantage (Ross & Turkewitz, 1981; Ross-Kossak & Turkewitz, 1986).

In the present study, characteristic hemispheric arousal asymmetry is indexed by two tasks: a tachistoscopic task on which mean asymmetry score across dextrals does not differ significantly from zero (Levine et al., 1984) and a free-vision chimeric face task (Levy, Heller, Banich, & Burton, 1983b). Subjects' arousal asymmetries as indexed by these tasks are then compared to their asymmetry scores for upright and inverted faces and houses. We hypothesize that subjects with arousal asymmetry in favor of the right hemisphere will show greater orientation-sensitive right hemisphere involvement in face recognition than those with arousal asymmetry in favor of the left hemisphere.

METHOD

Subjects. Sixteen male and 16 female subjects from the University of Chicago community were tested. Subjects ranged in age from 18 to 30 years, were right-handed, and reported that their parents were also right-handed. They also reported having normal or fully corrected vision. Subjects' handedness was assessed by a 12-item questionnaire. To be considered right-handed, a subject had to write with the right hand and habitually perform at least 9 of the 11 remaining items on the questionnaire with the right hand.

Stimuli and apparatus. Stimuli were presented to binocular view in a Gerbrands two-channel tachistoscope (Model T-2B1). The stimuli consisted of black and white front-view photographs of houses, chairs, and faces, with 24 examples from each category. The face stimuli were unfamiliar to subjects and consisted of photographs of young adults with neutral expressions. Hair was pulled back to make it difficult to discriminate the faces on the basis of hair length. A variety of wooden, straight-back chairs and wooden frame 19th-century houses constituted the other stimulus sets. Each stimulus card consisted of two photographs of the same type, one in the LVF and one in the RVF, symmetrically displaced from midline. On each stimulus card, the midpoint of each photograph was located $1^{\circ}43'$ from the central fixation point. Maximal horizontal visual angle of each stimuli was $3^{\circ}24'$ and maximal vertical visual angle was $4^{\circ}5'$. One of six symbols (+, =, ∞ , ∇ , *, o) appeared at the center of each stimulus card.

For each picture type two choice arrays of 12 pictures were formed. Subjects were presented with the appropriate array following each tachistoscopic stimulus presentation.

For houses and chairs an attempt was made to place items of similar brightness in the same array, i.e., lighter toned chairs in one array, darker toned in the other. For faces, one array contained all females, the other all males. Eighteen stimulus pairs were constructed for each picture type, nine from each array. Eight pictures were used twice, two once, and two never, in order to discourage a "process of elimination" strategy for trials shown late in the series. When a picture was repeated, it appeared with a different picture and in the opposite visual field than on the first presentation.

In addition to the tachistoscopic stimuli, each subject was presented with Levy et al.'s (1983b) free-vision chimeric face task. This task involves the presentation of 36 pairs of mirror-image chimeric faces, with each chimera consisting of one-half of an individual's face with a smiling pose and the other with a neutral pose. Thus, one member of each pair had the smiling half-face on the left and the neutral half-face on the right, and vice-versa for the other member of each pair.

Design. Five 18-trial test sets were tachistoscopically presented to each subject: (chairs (CH), upright faces (UF), upright houses (UH), inverted faces (IF), and inverted houses (IH)). Note that faces and houses were presented in both upright and inverted orientations, but that chairs were presented only in the upright orientation. Each test set was immediately preceded by a practice set consisting of 8 trials. The chair stimuli were always presented first. For the face and house stimuli, order of orientation and stimulus type conditions were counterbalanced across subjects. The same arrays and stimulus cards were used for both the upright and the inverted orientations, but the stimuli were presented in a different random order for each orientation. Items that appeared in a particular visual field in the upright condition also appeared in that visual field in the inverted condition. The chimeric face test was administered to each subject following the tachistoscopic tasks.

Procedure. For the tachistoscopic tasks, subjects began each trial by viewing a preexposure field consisting of the outline of a small black rectangle at the center of the visual field. The space defined by the rectangle was just large enough to be filled by the fixation-point symbol on each stimulus card. Subjects initiated each trial by depressing a telegraph key. The stimulus card appeared 500 msec after the key had been depressed, immediately after the offset of the preexposure field.

The center symbol provided positive control over fixation and the importance of identifying it correctly was stressed. Two trials with only a symbol in the center were shown to accustom subjects to the procedure and to emphasize the importance of central fixation. As a further precaution that central fixation was maintained, exposure duration was not allowed to exceed 200 msec, considered to be the latency to initiate an eye movement. On each trial, subjects first identified the center symbol, and then made a forced choice of two photographs from the array presented to them. When stimuli were presented in the upright orientation, the choice array was presented upright and when stimuli was presented in the inverted orientation, the choice array was also presented inverted.

Because degree of asymmetry is sensitive to overall accuracy, exposure duration was varied from trial to trial in an attempt to equate performance level across both subjects and stimulus types. The starting exposure duration on each block of test trials was chosen as the minimum time at which a subject could get one but not both items of a bilateral pair correct on the practice trials. During the test trials, we attempted to maintain performance level at 50% correct by varying exposure duration from trial to trial according to the following rules, established during pilot work. If a subject responded correctly to one item of a pair, the exposure duration remained the same. If a subject missed both items on a trial, exposure duration was increased by 10 msec, and if a subject

responded correctly to both items on a trial, exposure duration was decreased by 10 msec. In addition, if a subject made five consecutive single correct responses, exposure duration was decreased by 10 msec.

On the chimeric face test, Levy et al.'s (1983b) procedure was followed. The subject was asked which of the two mirror-image chimeras presented on each trial looked happier (the one with the smile to the left or the one with the smile to the right).

RESULTS

All Subjects

An analysis of variance on overall performance level for upright and inverted faces and houses revealed a significant Stimulus Type by Orientation interaction. Post hoc Scheffé tests showed that performance on Upright Faces (UF) (39% correct) was significantly better than performance on each of the other stimulus types (Inverted Faces (IF): 34%; Upright Houses (UH): 35%; Inverted Houses (IH): 35%) ($p < .001$). This higher performance level on upright faces emerged despite our efforts to equate performance level by varying exposure duration (mean exposure duration for faces was 90 msec, compared to 175, 158, and 188 msec for IF, UH, and IH, respectively). In fact, an analysis of variance on mean exposure duration for upright and inverted faces and houses revealed that exposure duration for upright faces was significantly shorter than for the other stimulus types ($p < .01$). In addition, exposure duration for upright houses was significantly shorter than for inverted faces or inverted houses ($p < .05$ in each case). Unlike faces, performance levels for upright and inverted houses were successfully equated by using a longer exposure duration for inverted than upright houses. The exposure duration findings for upright and inverted faces and houses are consistent with reports that the ability to recognize faces exceeds the ability to recognize exemplars in other classes of visuospatial stimuli, but that face recognition is more severely disrupted by inversion (Yin, 1969).

An additional analysis of variance was performed on visual field difference scores (LVF-RVF) with Orientation (Upright, Inverted) and Stimulus Type (Faces, Houses) entered as factors. Although there was a larger asymmetry in favor of the LVF for upright stimuli than for inverted stimuli, the main effect of Orientation did not reach significance ($F(1, 30) = 1.90, p = .18$). Neither the main effect of Stimulus Type nor the Orientation by Stimulus Type interaction approached significance ($F < 1$ for both) (see Fig. 1).

Arousal Groups Defined by Median Split on Chairs

Subjects were divided by median split into two groups on the basis of their asymmetry scores on the chair task. As in a previous study (Levine et al., 1984), the chair task was found to be nonlateralized across

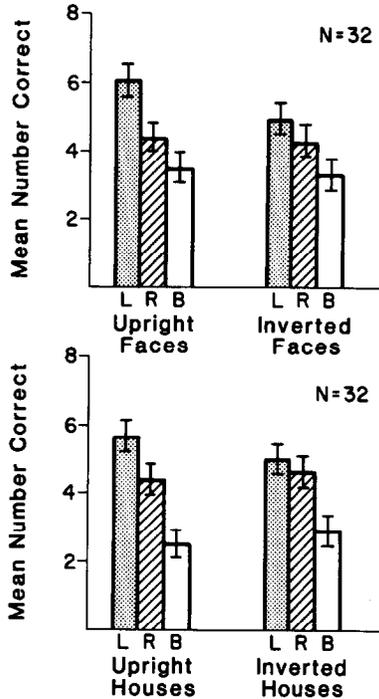


FIG. 1. Mean number of unilateral left correct responses (L), unilateral right correct responses (R), and bilateral correct responses (B) for upright and inverted faces and upright and inverted houses over all subjects tested ($N = 32$).

all subjects tested ($t = .04$, $df = 30$, $p = .97$). The left hemisphere arousal group ($N = 16$) consisted of all subjects with a RVF advantage on the chair task (Group RChair). Mean asymmetry (RVF-LVF) on the chair task for subjects in Group RChair was 3.68 ($SD = 3.26$). The right hemisphere arousal group ($N = 16$) consisted of 12 subjects with a LVF advantage and 4 subjects with no visual field asymmetry on the chair task (Group LChair). Mean asymmetry (RVF-LVF) on the chair task for subjects in Group LChair was -3.63 ($SD = 3.46$). (It should be noted that the pattern of results reported below is identical when the 4 subjects with no asymmetry on the chair task were excluded from Group LChair.) The distribution of males and females in the two arousal groups turned out to be completely equal (8 of each sex in each group).

An analysis of variance on overall performance level with the factors of Group (LChair, RChair), Stimulus Type (Faces, Houses), and Orientation (Upright, Inverted) revealed that the two arousal groups did not differ in overall performance level ($F(1, 30) = 1.25$, $p > .25$). This finding precludes the possibility that any differences between Group LChair and

Group RChair in pattern of visual field asymmetry are attributable to group differences in performance level.

An additional analysis of variance on visual field difference scores (LVF-RVF) was performed with Group (LChair, RChair), Orientation (Upright, Inverted), and Stimulus Type (Faces, Houses) as factors. A significant main effect of Group (LChair, RChair) ($F(1, 30) = 13.24, p < .001$) was found, as the visual field difference score in favor of the LVF was significantly larger for Group LChair than Group RChair. The Group \times Orientation interaction also was significant ($F(1, 30) = 4.15, p = .05$) (See Fig. 2). Tests of simple effects showed a significant Orientation effect for Group LChair ($F(1, 30) = 5.84, p < .025$), but not for Group RChair ($F < 1$). For Group LChair, t tests showed that the LVF advantage was significantly greater than zero for upright stimuli ($t = 4.62, df = 15, p < .01$), but not for inverted stimuli ($t = 1.63, n.s.$). For Group

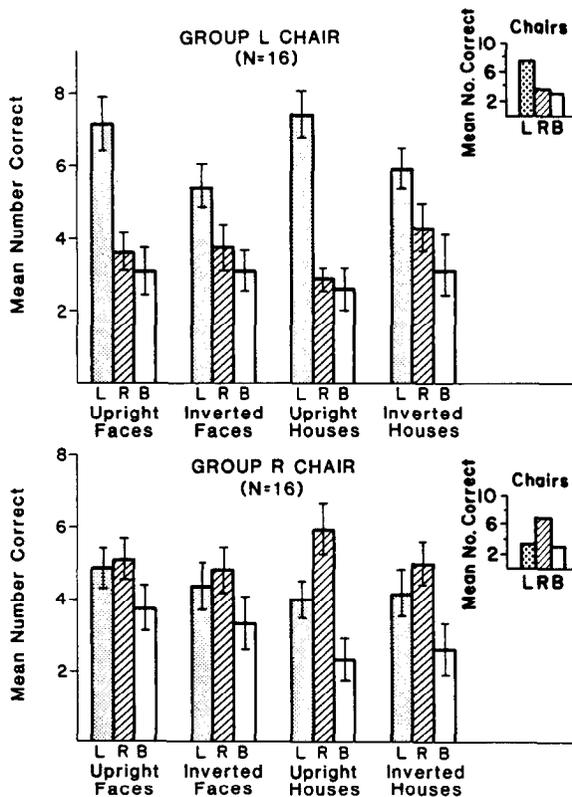


FIG. 2. Mean number of unilateral left correct responses (L), unilateral right correct responses (R), and bilateral correct responses (B) for upright and inverted faces and houses for Group LChair ($N = 16$) and Group RChair ($N = 16$). Mean visual field scores (L, R, and B) for chairs in upper right-hand corner of each graph.

RChair, t tests showed that visual field asymmetries did not differ from zero for either upright ($t = -1.23$, n.s.) or inverted stimuli ($t = -.85$, n.s.). Additional tests of simple effects revealed a significant difference between Groups LChair and RChair in visual field asymmetry for upright stimuli ($F(1, 57) = 17.21$, $p < .0001$) but not for inverted stimuli ($F(1, 57) = 3.21$, $p > .05$).

Although visual field asymmetry scores of the two arousal groups did not differ significantly for inverted stimuli, it should be noted that the direction of subjects' asymmetry scores for these stimuli was the same as the direction of their arousal asymmetries. That is, there was a non-significant LVF advantage for Group LChair and a nonsignificant RVF advantage for Group RChair (see Fig. 2). This is reflected by the significant correlation of chair asymmetry (LVF–RVF) and asymmetry for inverted face and house stimuli (LVF–RVF) ($r = .43$, $df = 30$, $p < .02$). The magnitude of this correlation did not differ significantly from the magnitude of the correlation between chair asymmetry and the asymmetry for upright face and house stimuli ($r = .58$, $df = 30$, $p < .005$).

Within each group the pattern of visual field asymmetry was similar for faces and houses, reflected by the nonsignificant Stimulus Type by Group ($F(1, 30) = 1.29$, $p > .25$) and Stimulus Type by Orientation by Group interactions ($F(1, 30) = 1.60$, $p > .20$). That is, Group LChair showed a LVF advantage for recognizing both upright faces and houses but not for either stimulus type in the inverted orientation. In contrast, Group RChair did not show a significant visual field asymmetry for faces or houses in either the upright or inverted orientation.

Arousal Groups Defined by Median Split on Chimeric Face Task

Subjects' asymmetry scores on the chimeric face task were calculated as

$$N_L - N_R/36,$$

where N_L is the number of trials on which the chimeric face with the smile on the right was chosen as "happier," N_R is the number of trials on which the chimeric face with the smile on the left was chosen as "happier," and 36 is the total number of trials.

When subjects were divided into two arousal groups on the basis of a median split on chimeric face scores (Strong Bias Group: Mean Asymmetry = $-.670$, $SD = .189$; Weak Bias Group: Mean Asymmetry = $.080$, $SD = .404$), the pattern of results was identical to that obtained by the median split on the basis of the chair task. In particular, the groups did not differ in overall performance level on the tachistoscopic face and house recognition tasks. However, they did differ in visual field difference scores ($F(1, 30) = 7.45$, $p < .025$) such that the Strong Bias Group had a significantly larger LVF advantage than the Weak Bias Group on the tachistoscopic tasks. Again, the Group by Orientation

interaction was significant ($F(1, 30) = 6.28, p < .025$). As expected, tests of simple effects showed a significant effect of Orientation for the Strong Bias Group ($F(1, 30) = 7.71, p < .01$) but not for the Weak Bias Group ($F < 1$). For the Strong Bias Group, t tests showed that the LVF advantage for upright faces and houses differed significantly from zero ($t = 4.03, df = 15, p < .01$) whereas that for inverted stimuli did not ($t = 1.04, n.s.$). For the Weak Bias Group visual field asymmetries did not differ significantly from zero for either upright ($t = -.98, df = 15, n.s.$) or inverted stimuli ($t = -.18, df = 15, n.s.$). Further tests of simple effects revealed that the two groups differed significantly in visual field asymmetry for upright stimuli ($F(1, 54) = 26.80, p < .001$) but not for inverted stimuli ($F < 1$). As in the analyses that used asymmetry on the chair task as the grouping criterion, there was no Stimulus Type by Group interaction ($F < 1$) and no Stimulus Type by Orientation by Group interaction ($F < 1$).

Arousal Groups Defined by Median Split on Chair Task and Chimeric Face Task

In an attempt to further differentiate arousal groups, subjects were classified on the basis of asymmetry scores on both the chair and chimeric facebook tasks. It should be noted that the correlation of facebook asymmetry score and chair asymmetry score was significant though small, accounting for only 14.4% of the variance in subjects' asymmetry scores ($r = .38, df = 30, p < .025$). Twelve subjects showed a RVF advantage on the chair task and a rightward bias on the facebook task: they formed the Left Hemisphere Arousal Group. Another group of 12 subjects showed a LVF advantage on the chair task and a leftward bias on the facebook task: they formed the Right Hemisphere Arousal Group. The remaining 8 subjects showed lateral advantages in different directions on the chair and facebook tasks (4 in each of the discordant cells). These subjects were combined to form a third group (Discordant Group). An analysis of variance on face and house performance again showed no main effect of group so that differences in patterns of visual field asymmetry cannot be attributed to differences in overall performance level. An additional analysis of variance on visual field difference scores with the between-subjects factor of Arousal Group (Right, Left, Discordant) and the within-subjects factors of Orientation and Stimulus Type revealed a main effect of Group ($F(2, 29) = 7.24, p < .005$) and a Group by Orientation interaction ($F(2, 29) = 4.12, p < .05$). Post hoc Scheffé tests on the main effect of Group revealed that the asymmetry score for the Right Hemisphere Arousal Group differed significantly from the Left Hemisphere Arousal Group ($p < .05$). The asymmetry score for the Discordant Group was intermediate but did not differ significantly from either of the other groups. Tests of simple effects revealed that visual field asymmetry scores for

upright vs. inverted stimuli differed significantly for the Right Hemisphere Group ($F(2, 29) = 8.43, p < .001$) but not for either of the other groups ($F_s < 1$, See Fig. 3). As before, there were no significant main effects or interaction effects involving Stimulus Type.

Arousal Groups and Mean Stimulus Exposure Durations

The absence of any stimulus type effects may have resulted from our attempt to equate performance level by varying exposure duration which resulted in nearly equal accuracy levels for the different stimulus types. This contrasts with the situation in free vision, where recognition accuracy of the different stimulus types clearly varies (Yin, 1969). In the present study, exposure duration for each stimulus type was determined by the speed at which a subject could achieve a given performance level. Thus, it provides a measure of subjects' recognition proficiency for each stimulus type. It is possible that effects of stimulus type may emerge when exposure duration, rather than accuracy, is the dependent variable.

In fact, an analysis of variance on mean exposure duration for Group LChair and Group RChair as defined by a median split on the chair task revealed main effects of Stimulus Type (Mean exposure duration Faces: 133 msec, Houses: 173 msec; $F(1, 30) = 69.94, p < .0001$) and Orientation (Mean exposure duration Upright Stimuli: 124 msec, Inverted Stimuli: 181 msec; $F(1, 30) = 51.74, p < .0001$). Although both faces and houses could be recognized at shorter exposure durations in the upright than the inverted orientation, a highly significant Stimulus Type by Orientation interaction emerged ($F(1, 30) = 32.78, p < .0001$). Post hoc Scheffé tests showed that the magnitude of the exposure duration inversion effect was significantly greater for faces ($IF_{\text{exp dur}} - UF_{\text{exp dur}}$) than for houses ($IH_{\text{exp dur}} - UH_{\text{exp dur}}$) ($p < .01$).

A significant Group by Stimulus Type by Orientation interaction ($F(1, 30) = 4.00, p = .05$) was also found. Post hoc Scheffé tests comparing the magnitude of the exposure duration inversion effects for faces and houses ($[IF_{\text{exp dur}} - UF_{\text{exp dur}}] - [IH_{\text{exp dur}} - UH_{\text{exp dur}}]$) for Group LChair and Group RChair revealed a larger difference for Group LChair ($.05 < p < .10$) (See Fig. 4). Examination of the data suggests that this effect was mainly due to group differences in exposure duration for upright and inverted faces. Whereas Group LChair had a shorter mean exposure duration for upright faces than Group RChair (84 msec vs. 97 msec), they had a longer mean exposure duration for inverted faces (187 msec vs. 163 msec). For Group LChair the difference in exposure duration for upright and inverted faces (84 msec vs. 187 msec) represents a 123% increase, whereas the comparable contrast for Group RChair (97 msec vs. 163 msec) represents only a 68% increase. A different pattern emerged for houses, as mean exposure durations for upright and inverted houses were practically identical for Groups LChair and RChair (159 msec vs.

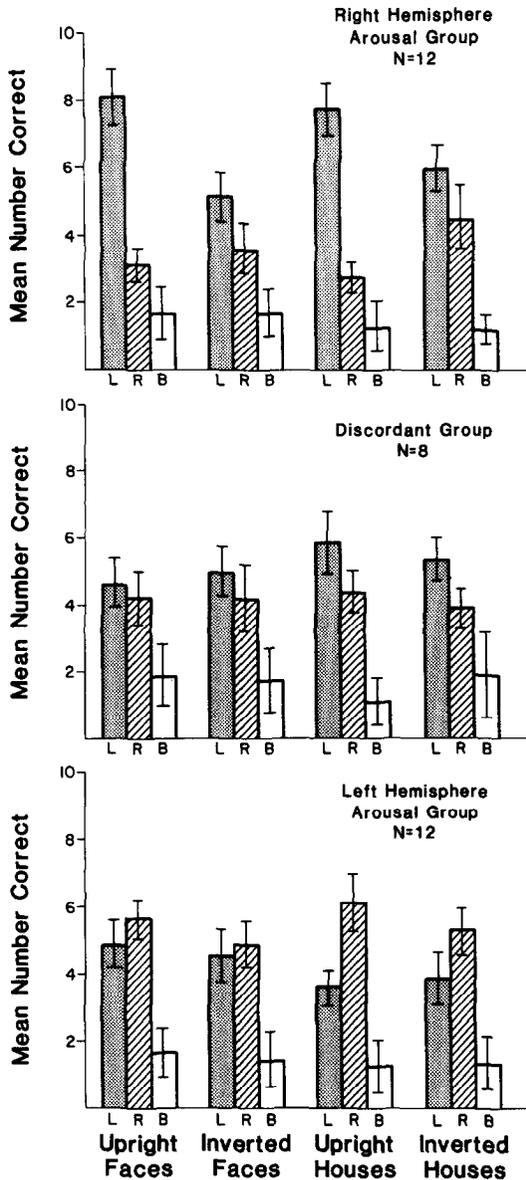


FIG. 3. Mean number of unilateral left correct responses (L), unilateral right correct responses (R), and bilateral correct responses (B) for upright and inverted faces and houses for the Right Hemisphere Arousal Group ($N = 12$), the Discordant Group ($N = 8$), and the Left Hemisphere Arousal group ($N = 12$).

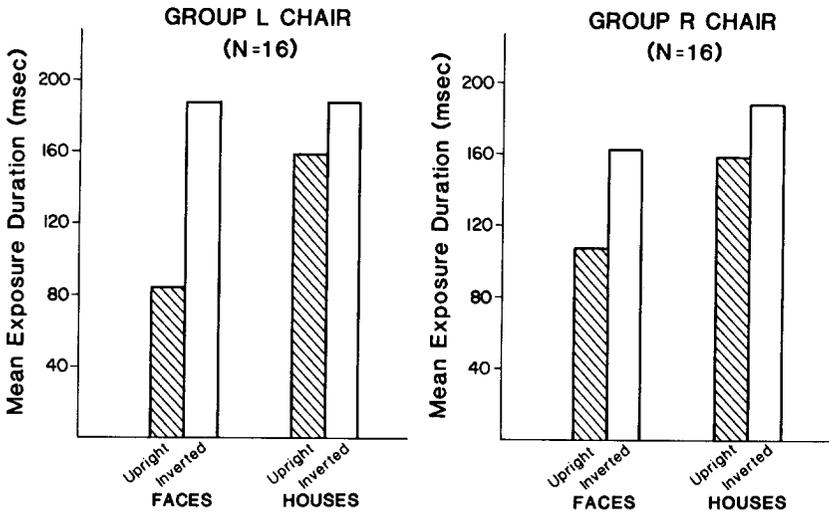


FIG. 4. Mean exposure durations for upright and inverted faces and houses for the Right Hemisphere Arousal Group (Group LChair) and the Left Hemisphere Arousal Group (Group RChair).

158 msec for upright houses; 187 msec vs. 188 msec for inverted houses, for Groups LChair and RChair, respectively). (See Fig. 4.) It is important to note that there was no main effect of Group, showing that across the different stimulus types (upright and inverted faces and houses), mean exposure time did not significantly differ for Groups LChair and RChair ($F < 1$). Thus, any significant effects involving Group cannot be attributed to generally longer exposure durations for one group than the other. The same pattern of results was found when the arousal groups were defined by a median split on the chimeric facebook task rather than on the chair task.

DISCUSSION

Results of the present study clarify the role of the right hemisphere in face processing (Leehey et al., 1978; Young & Bion, 1981). It has been suggested that the right hemisphere is specifically involved in the processing of upright faces, over and above any general involvement in the processing of other complex visuospatial patterns. The finding of a greater LVF advantage for the recognition of upright than inverted faces is frequently cited as support for this hypothesis (Leehey et al., 1978; Young & Bion, 1981). However, in the present study, we find this orientation-sensitive pattern of right hemisphere involvement for another class of visuospatial stimuli, houses, as well as for faces. These results suggest that orientation-sensitive right hemisphere involvement in face recognition is a by-product of a general schema formation capacity of

the right hemisphere that is applied to faces as well as to other classes of stimuli in the canonical upright orientation. It should be noted that the results of the present study detract from only one of the arguments that face recognition is a special ability, i.e., the argument that the right hemisphere is specifically involved in the recognition of upright faces, over and above any general involvement in processing complex visuospatial information. However, several recent studies suggest that face recognition shares a variety of properties with other object-recognition tasks. In particular, faces and words are processed similarly in search tasks (Bruce, 1979); faces, words, and object pictures are subject to similar priming effects (Bruce & Valentine, 1985), and face-name interference effects are similar to object-word interference effects (Young, Ellis, Flude, McWeeny, & Hay, 1986).

In addition to suggesting certain commonalities between the role of the right hemisphere in face recognition and the recognition of other classes of visuospatial stimuli, the present study identifies a factor that accounts for some of the variation among dextrals in hemispheric involvement in the recognition of visuospatial stimuli. Greater right hemisphere involvement in the recognition of upright faces and houses than in the recognition of their inverted counterparts is found only for dextrals who show evidence of arousal asymmetry in favor of the right hemisphere. These subjects show a significant LVF advantage for the recognition of both faces and houses in the upright orientation, but not for either class of stimuli in the inverted orientation. In contrast, dextrals who show evidence of arousal asymmetry in favor of the left hemisphere show no visual field asymmetry for either upright or inverted stimuli, and this pattern holds for both faces and houses. Whereas the two arousal groups significantly differ in their asymmetry scores for upright stimuli, they do not differ in their asymmetry patterns for inverted stimuli. The group of subjects with inconsistent hemispheric arousal asymmetries (Discordant Group) showed an intermediate degree of orientation specificity which did not differ from either the right or left hemisphere arousal groups. These results suggest that the arousal asymmetries of dextrals are continuous rather than dichotomous, ranging from strong right to strong left hemisphere patterns. The finding of individual differences in orientation-sensitive right hemisphere processing of familiar classes of stimuli such as faces and houses is consistent with Ross and Turkewitz's (1981) finding that the magnitude of the face-inversion effect is associated with visual field asymmetry scores for faces.

The absence of a significant Orientation by Visual Field interaction across the entire group of subjects tested in the present study contrasts with previous findings (Leehey et al. 1978; Young & Bion, 1981). This may be explained by the arousal factor. In particular, the relative number of dextrals with characteristic arousal asymmetries in favor of the right

hemisphere may have been smaller in this study than in previous studies due to chance sampling (Leehey et al., 1978; Young & Bion, 1981). In the present study, only 12/32 subjects showed arousal asymmetries in favor of the right hemisphere whereas 4/32 showed no asymmetry and 16/32 showed arousal asymmetries in favor of the left hemisphere (as indexed by visual field asymmetry scores on the chair task). Prior studies that report significant effects of stimulus orientation on visual field asymmetry for faces may have included a greater proportion of dextrals with arousal asymmetries in favor of the right hemisphere.

The finding of equivalent patterns of visual field asymmetry for faces and houses within each of the arousal groups is consistent with the view that any special right hemisphere involvement in the recognition of upright faces derives from our greater expertise in recognizing faces than other stimulus classes (see Diamond & Carey, 1986; Davidoff, 1986, for similar viewpoints). Importantly, in the present study we artificially equated performance level for recognizing faces and houses by varying exposure duration for faces and houses. In effect this equated subjects' level of expertise at recognizing faces and houses in the experimental situation. Under these conditions, the expertise hypothesis would predict that the Orientation by Visual Field interaction would not interact with Stimulus Type. That is, the Orientation by Visual Field effect for faces and houses should be equivalent. In contrast, the hypothesis of a right hemisphere specialized face processor would predict a Stimulus Type by Orientation by Visual Field interaction such that upright and inverted faces would be more differentiated with respect to right hemisphere involvement than upright and inverted houses. In fact, our results support the expertise hypothesis as the magnitude of the Orientation by Visual Field interaction did not differ for faces vs. houses.

We hypothesize that the extent to which the schema formation capacities of the right hemisphere are applied to recognizing members of a stimulus class is related to one's level of expertise in individuating members of that stimulus class. Typically, the ability to recognize faces is highly developed compared to the ability to recognize other stimulus classes, providing a possible explanation for reports of greater right hemisphere involvement in face recognition than in the recognition of other stimulus classes. However, the finding of processing differences between faces and other stimuli when accuracy level is not equated cannot be regarded as support for a face-specific capacity (Davidoff, 1986). In principle, these right hemisphere processes could be applied to other classes of visuospatial stimuli for which we become expert recognizers. Even the finding that patients with damage to the posterior sector of the right hemisphere are more impaired in the recognition of upright faces than other classes of stimuli (i.e., inverted faces and upright and inverted houses) (Yin, 1970) can be explained in terms of our greater expertise

at recognizing faces. That is, damage to this region of the brain may be particularly disruptive to the capacity of the right hemisphere to process visuospatial stimuli in relation to a schema. Because the schema for faces is typically more highly developed than schemas for other stimulus classes, injury to posterior regions of the right hemisphere may be more disruptive to face recognition. Thus, the greater deficit in recognizing faces than other stimulus types may be expertise-level-specific, rather than stimulus-type-specific.

On the basis of these considerations, it should be the case that a significant Stimulus Type by Orientation by Visual Field advantage would emerge if subjects were presented with upright and inverted faces and houses at a constant exposure duration. Under these conditions, subjects' greater expertise at recognizing upright faces than upright houses should result in differentially greater right hemisphere involvement in the recognition of upright faces than upright houses, whereas inverted faces and houses should show a similar pattern of hemispheric involvement. Thus, we favor the hypothesis that orientation-sensitive right hemisphere involvement for a particular class of visuospatial stimuli reflects subjects' expertise at recognizing members of that class. In fact, differences in expertise have been found to affect perceptual asymmetries, and by inference, hemispheric involvement, in another domain, the perception of melody. Bever and Chiarello (1974) report a right ear advantage on a dichotic melodies task among amateur musicians but a left ear advantage on the same task among nonmusicians.

Although the present study does not allow us to directly test the hypothesis that orientation-sensitive right hemisphere involvement reflects subjects' degree of expertise, the exposure duration data provide some relevant information. Recall that approximately equivalent accuracy levels for face and house recognition were achieved using a much shorter exposure duration for faces. Thus, the exposure duration results might provide evidence as to whether right hemisphere involvement in the recognition of visuospatial stimuli is related to expertise. Unfortunately, because stimuli were presented bilaterally, we do not have separate exposure durations for the two visual fields. However, we did find that subjects with arousal asymmetry in favor of the right hemisphere had shorter exposure durations for upright faces but longer exposure durations for inverted faces than those with arousal asymmetry in favor of the left hemisphere. In contrast, the two arousal groups had equivalent exposure durations for upright and inverted houses. Yin (1969) found a related pattern of results using a two-alternative forced-choice recognition memory task. In particular, for faces, subjects who made fewer errors in recognizing inverted exemplars made more errors in recognizing upright exemplars. In contrast, for nonface stimuli (houses, airplanes, stick figures of men in motion), subjects who made fewer errors in recognizing inverted ex-

emplars also made fewer errors in recognizing upright exemplars. The exposure duration results suggest that expertise at upright face recognition is greater for subjects with an arousal asymmetry in favor of the right hemisphere. The findings that subjects with an arousal asymmetry in favor of the right hemisphere require shorter exposure durations for the recognition of upright faces, but not upright houses, suggest that arousal asymmetry in favor of the right hemisphere may be particularly advantageous to expert-level visual recognition abilities, such as are commonly developed for faces.

In summary, our findings support the hypothesis that right hemisphere processes applied to the task of recognizing upright unfamiliar faces are not unique to faces, but rather reflect our expertise at recognizing this stimulus class. Although these processes do not appear to be restricted to faces, they may derive from environmental pressures to develop highly proficient face-recognition skills. Evolutionarily, the right hemisphere's visuospatial schema formation capacity may or may not have developed specifically to handle the face-recognition task. In any case, the present results suggest that this capacity is sufficiently flexible that it can be applied to other classes of visuospatial stimuli.

Our findings also suggest that there are individual differences in the utilization of right hemisphere processes in the recognition of familiar classes of stimuli such as upright faces and houses. In particular, those dextrals with an arousal asymmetry in favor of the right hemisphere make greater use of the specialized processes of the right hemisphere in recognizing complex visuospatial stimuli such as faces than do those with an arousal asymmetry in favor of the left hemisphere. The exposure duration results suggest that at least for faces, this greater utilization of right hemisphere processes leads to a processing advantage. If this is true, a subject with a right hemisphere arousal asymmetry may be the type of person who never forgets a face, whereas a subject with a left hemisphere arousal asymmetry may be the type of person who is embarrassed by difficulty in recognizing previously encountered individuals.

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