

UPRIGHT AND INVERTED FACES: THE RIGHT HEMISPHERE KNOWS THE DIFFERENCE¹

Susan Leehey, Susan Carey, Rhea Diamond and Andrew Cahn

(Massachusetts Institute of Technology)

INTRODUCTION

Existing evidence suggests that the right hemisphere plays a critical role in face perception. Studies of patients with unilateral focal brain injuries suggest that loss of tissue in the posterior sector of the right hemisphere impairs the ability to recognize previously unfamiliar faces (Warrington and James, 1967a; Benton and Van Allen, 1968; De Renzi, Faglioni and Spinnler, 1968; Yin, 1970a, 1970b). Studies of commissurotomy patients have also implicated the right hemisphere in face perception (Levy, Trevarthen and Sperry, 1972). That the right hemisphere of normal adults is differentially involved in the processing of faces has been confirmed by tachistoscopic studies. A left visual field advantage for facial stimuli has been demonstrated both in studies using discriminative reaction time (Rizzolatti, Umiltà and Berlucchi, 1971; Geffen, Bradshaw and Wallace, 1971) and measures of recognition accuracy (Hilliard, 1973; Ellis and Shepherd, 1975; Klein, Moscovitch and Vigna, 1976).

Several studies suggest that the right hemisphere is differentially involved in the perception of complex non-facial patterns as well. For example, patients with right sided lesions have been shown to be impaired in the recognition of such complex visual patterns as meaningless figures (Kimura, 1963) and realistic figures presented as incomplete or overlapping drawings (De Renzi and Spinnler, 1966; Warrington and James, 1967b). In addition, tachistoscopic studies with normal adults have demonstrated left visual field advantages for the recognition of random Attneave patterns (Fontenot, 1973) and for the location of elements in a matrix (Kimura, 1969; Gross, 1972; Robertshaw and Sheldon, 1976).

Since faces are members of the class of complex visual stimuli, it is

¹ We would like to thank H.-L. Teuber for originally engaging our interest in face perception and for his continued encouragement of our work. Supported by NIH Grant No. 2R01 HD09179, and NIH graduate training grant No. NIH-5-T01-GM01064.

possible that the differential involvement of the right hemisphere in face recognition simply reflects this membership. One study (Yin, 1970a), however, has shown that the recognition of upright and inverted faces, equally complex as patterns, is differentially affected by lesions of the right hemisphere. Patients with loss of tissue in the right posterior sector of the brain did not differ from normals in recognizing inverted faces but were deficient in the recognition of upright faces. Yin concluded that it was a capacity specific to the encoding of *upright* faces which patients with these lesions had lost. Yin also demonstrated that the dissociation by orientation does not extend to houses, another class of mono-oriented objects. Patients with right posterior lesions performed like normals in the recognition of both upright and inverted houses. This pattern of results was interpreted by Yin as evidence for the existence of an orientation-specific processor for faces, vulnerable to injury in the posterior sector of the right hemisphere.

One implication of Yin's results appears to have been misunderstood, and is directly relevant to the question of whether the involvement of the right hemisphere in face recognition is specific to faces or reflects the involvement of the right hemisphere in complex pattern recognition. The fact that persons with right posterior injuries were not deficient in processing inverted faces or upright and inverted houses does not preclude differential right hemisphere involvement in processing these patterns. Areas of the right hemisphere which remained intact in these patients might have been critical to their normal performance on these materials. Yin's results are therefore consistent with the hypothesis that the right hemisphere of a normal adult is critically involved at a level of processing specific to upright faces as well as at a level common to upright and inverted faces as complex patterns.

This possibility might be examined by comparing the visual field advantages for the recognition of upright and inverted faces under lateralized tachistoscopic presentation. If the right hemisphere of a normal adult is involved in the perception of upright faces at both levels, there should be an interaction between lateral field of view and orientation of face stimuli. Whatever the degree of left visual field advantage for inverted faces (as patterns), the left visual field advantage for upright faces (as comparable patterns and additionally as upright faces) should be greater.

Recently, Ellis and Shepherd (1975) made this comparison and failed to find such an interaction. Instead, both upright and inverted faces were better recognized in the left visual field, but there was no difference in the degree of left visual field advantage for the two stimulus orientations. The authors interpreted this result as discrepant with the existence of a right hemisphere capacity specific to upright faces.

We are led to reopen this question by the following consideration. Ellis and Shepherd found no overall advantage for recognition of upright faces. This is in striking disagreement with results obtained using a variety of non-

tachistoscopic paradigms. Performance on upright faces has been shown to be better than that on inverted faces in tasks requiring recognition of familiar faces (Goldstein, 1975; Rock, 1974) as well as encoding and subsequent recognition of unfamiliar faces (Hochberg and Galper, 1967; Scapianello and Yarmey, 1970; Yarmey, 1971). The absence of an inversion effect in the Ellis and Shepherd (1975) study suggests, therefore, that their stimuli were not being processed as faces. Perhaps their use of a stimulus duration of only 15 msec. precluded the engagement of whatever special capacity to encode upright faces the right hemisphere might possess. Consistent with this suggestion is Yin's demonstration (1970b) that recognition of faces was more vulnerable to tachistoscopic presentation than was recognition of items from the other classes of objects he studied.

In the present study we attempted to provide maximum opportunity for upright faces to engage processes which differentiate them from inverted faces. Upright faces were shown for 120 msec. and inverted faces for 150 msec. These values represent the longest durations at which eye movements can be precluded. A slightly longer duration was used for inverted faces than upright faces in an attempt to equate overall performance levels for the two orientations.

Faces were presented upright to one group of subjects and inverted to another group. Both groups were also presented words under lateralized tachistoscopic presentation in order to test for the normal RVF advantage. This permitted independent assessment of the comparability of the two groups of subjects. Bilateral presentation of word and face stimuli was used, as it appears to yield more sensitive measures of lateralization than does unilateral presentation (McKeever and Huling, 1971; MacKavey, Curcio and Rosen, 1975).

MATERIAL AND METHOD

Subjects

Seventy-one right-handed adults with right-handed parents served as subjects. All had vision correctable to 20/20. For 32 subjects (16 males and 16 females) the face stimuli were presented upright (Group I). For 39 subjects (20 males and 19 females) the face stimuli were inverted (Group II).

Stimuli and Apparatus

Following the design of McKeever and Huling (1971), pairs of words and pairs of faces were bilaterally presented to binocular view. A Gerbrands 2-channel tachistoscope (Model T-2B1) was used to present stimuli. The words were high frequency four-letter nouns taken from Kucera and Francis (1967), shown upright

with the letters aligned vertically.² The faces were black and white photographs of persons unknown to the subjects, half male faces and half female faces. Each face item consisted of a pair of faces of the same sex. There were 8 practice pairs and 18 test pairs for both words and faces.

The near point of each word was located $1^{\circ}36'$ to the left or right of fixation and each word subtended $1^{\circ}32'$ of vertical visual angle. The near point of each face was located $56.5'$ to the left or right of fixation and each face subtended $3^{\circ}33'$ of horizontal visual angle. A digit chosen at random appeared upright at the fixation point of each stimulus card.

Procedure and Design

Each trial began with *S* viewing a pre-exposure field consisting of 6 lines radiating from an open space in the center of the field. This space was just large enough to be filled by the digit on each stimulus card. Two trials with cards having only a digit at the fixation point were shown to accustom *S* to the procedure. Both the word recognition and face recognition portions of the experiment began with 8 practice trials. Prior to a trial, *E* said "focus" to alert *S* to fixate the center space. The stimulus card was then flashed, followed immediately by the return of the pre-exposure field. Only data from trials on which the digit was correctly reported were used, assuring positive control over fixation. As a further precaution, all stimuli were presented at durations below eye movement latency; upright faces at 120 msec., inverted faces at 150 msec., and words at 80, 100, or 120 msec. A variable exposure duration in the word recognition task was used to reduce intersubject variability in ability to recognize words. The exposure duration for word pairs was established for each subject on the basis of his performance during the 8 practice trials.

On the word recognition task, after reporting the digit, *S* reported the words or any part of the words which he had seen. On the face recognition task, after reporting the digit, *S* made a forced choice of two faces from an array of 12 which included the two which had been shown. The arrays were presented upright to Group I and inverted to Group II, i.e., in the same orientation as the flashed faces. There was a single array of male faces and a single array of female faces. Within each array, 8 faces were presented twice each, 2 were presented once each, and 2 were never presented. In order to discourage use of a "process of elimination" strategy for targets shown late in the series, *Ss* were informed beforehand that not all the faces in the array would be shown and that some would be repeated. When a face was in fact repeated, it was shown in the visual half-field opposite to that of its first presentation and paired with a different face than on the first presentation.

Materials were blocked so that half the subjects in each group were presented words before faces and half were presented faces before words. Eight random presentation orders, balanced across conditions, were used throughout the experiment. Each word pair and face pair was shown to each subject only once. Side of presentation of the two members of each pair was counterbalanced across *Ss*.

² Words were oriented vertically rather than horizontally to avoid the possible interaction of differential informativeness of beginning vs. end of a word with distance from the fixation point.

RESULTS

The results are shown in Figure 1. Analysis of variance revealed a significant materials (words, faces) by visual field (left, right) interaction

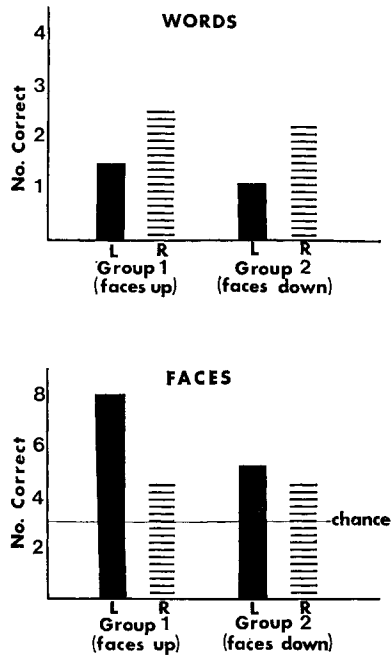


Fig. 1 — Performance Levels in Left Visual Field (L) and Right Visual Field (R) on Words and Faces.

for both Group I ($F = 30.38$, $d.f. = 1, 31$, $p < .001$) and Group II ($F = 9.54$, $d.f. = 1, 38$, $p < .005$). There were no effects, in either group, of sex of the subject or of order of presentation of words and faces.

The number of words recognized in each visual field was above chance level for both groups ($p < .005$ for all four cases). The analysis of word scores revealed a significant main effect for visual field ($F = 11.72$, $d.f. = 1, 69$, $p < .001$) and no significant interaction of visual field with Group ($F = 0.71$, $d.f. = 1, 69$, $p > .05$). In both groups words were recognized more often in the RVF than in the LVF (Group I: $t = 2.14$, $d.f. = 31$, $p < .025$, one-tailed correlated means; Group II: $t = 2.68$; $d.f. = 38$, $p < .01$, one-tailed correlated means), and the groups did not differ in degree of lateralization for words ($t = .23$, $d.f. = 69$, $p > .05$, two-tailed uncorrelated means).

All analyses of the results on faces were performed on scores corrected

for guessing.³ After the guessing correction was applied, both upright and inverted faces were recognized at better than chance level in each visual field ($p < .001$ in all four cases). Analysis of variance showed a main effect for orientation ($F = 11.08$, $d.f. = 1, 69$, $p < .002$). Upright faces were recognized better than inverted faces ($t = 3.33$, $d.f. = 69$, $p < .01$, two-tailed uncorrelated means). There was also a main effect for visual field ($F = 21.55$, $d.f. = 1, 69$, $p < .001$). Faces were recognized better in the LVF than in the RVF ($t = 4.35$, $d.f. = 70$, $p < .005$, one-tailed correlated means). In addition there was a significant interaction of orientation by visual field ($F = 10.62$, $d.f. = 1, 69$, $p < .002$).⁴ Subsequent t -tests showed, as predicted, that this interaction was due to the greater degree of lateralization of upright than inverted faces. While upright faces were recognized significantly better in the LVF than in the RVF ($t = 4.95$, $d.f. = 31$, $p < .001$, one-tailed correlated means), the LVF advantage for inverted faces failed to reach significance ($t = 1.40$, $d.f. = 38$, $.1 > p > .05$, one-tailed correlated means).

In the LVF, Group I (faces upright) performed significantly better than Group II (faces inverted) ($t = 4.17$, $d.f. = 69$, $p < .001$, one-tailed uncorrelated means), while in the RVF the two groups did not differ ($t = 0.07$, $d.f. = 69$, $p > .4$, one-tailed uncorrelated means). The absence of a significant difference in the RVF should not be interpreted as meaning that orientation made no difference when faces were presented in that field. Inverted faces were always presented for 30 msec. longer than were upright faces. This extra time was apparently sufficient to compensate for the advantage in encoding upright faces in the RVF while it did not approach full compensation for the additional advantage in encoding upright faces which obtained in the LVF.

The absence of a significant LVF advantage for inverted faces might be thought to be due to the lower level of performance on the inverted stimuli overall. However, the greater lateralization of upright than inverted faces cannot be attributed to a floor effect on inverted faces as inverted faces were recognized at better than chance level in both visual fields. Moreover, inverted

³ The probability on any given trial that a random guesser would correctly identify the face presented to one visual field is one-sixth (two guesses, each with a one-twelfth chance). Over 18 test trials, random guessing would have produced an average of 3 correct responses in each visual field; therefore, this amount was subtracted from individual accuracy scores for each visual field prior to any further analysis.

⁴ The analyses of variance reported in this paper are within-subjects. In the case of the interaction between visual field and orientation of faces, the central result of this paper, a significant result would be obtained if only a few faces were consistently recognized more often by most of the subjects in Group I (faces upright) than by most of the subjects in Group II (faces inverted). A within-item analysis of variance was also performed, asking whether, for each face, averaged across subjects, the interaction obtained. The item analysis confirmed the orientation by visual field interaction ($F = 10.73$, $d.f. = 1, 17$, $p < .005$). Min F' was then calculated, controlling for the error variance which remains in both F_1 , analysis by subjects, and F_2 , analysis by items (see Clark, 1973, for a discussion of Min F'). The interaction reached significance by this highly conservative statistic (Min $F' = 5.3$, $d.f. = 1, 55$, $p < .05$.)

faces were recognized as well as upright faces in the RVF and less well only in the LVF.

DISCUSSION

The principal finding of the present study is the significant orientation by visual field interaction for face stimuli. We found a highly significant left visual field advantage only for upright faces. Although we did not find an effect of visual field on inverted faces, the small difference in favor of the left visual field (Figure 1) was quite consistent, approaching significance ($p < .09$). This pattern of results supports the existence of a right hemisphere specialization for upright faces *in addition* to a right hemisphere specialization for visuo-spatial patterns.

The significant orientation by visual field interaction obtained in the present study contrasts with the absence of such an interaction in the Ellis and Shepherd study. Our results differ from those of Ellis and Shepherd in another respect as well. Whereas Ellis and Shepherd failed to find an effect of orientation (upright and inverted faces were recognized equally well) we found a large effect of orientation, especially in the left visual field. Both of these differences are probably related to the differences in exposure duration in the two studies. It appears likely that the stimuli in Ellis and Shepherd's study were not being fully encoded as faces. Chi (1977) measured the threshold for recognition of a centrally presented photograph of a highly familiar face. The subjects in her experiment had had ample experience with the restricted set of eight photographs all of which depicted colleagues known for several years. The threshold for recognition under these circumstances was 42 msec. This is well beyond the 15 msec. allotted in the Ellis and Shepherd study for unfamiliar faces, presented off center unpredictably to the left or right.

If stimuli are not fully encoded as faces, the usual decremental effect of inversion might not obtain. This is what Ellis and Shepherd found. We suggest that the very short exposure duration used by Ellis and Shepherd was insufficient to allow enough depth of processing (Craik and Lockhart, 1972) to engage the orientation-specific component of face processing for which the right hemisphere is specialized.

The results of the present experiment are relevant to the issue of the "specialness" of faces. There has been, in our opinion, considerable confusion as to the meaning of the claim that faces are special. It should be clear, for example, that evidence that the right hemisphere is critically involved in processing upright faces does not imply that the right hemisphere is not also critically involved in tasks that do not involve faces.

The present experiment provides evidence for a component of right hemisphere involvement special in the sense that it operates in the encoding

of upright but not inverted unfamiliar faces. Evidence for such an orientation-specific component of face processing was, of course, originally provided by Yin's studies on patients with right posterior lesions. The present experiment confirms that for normal adults the right hemisphere's engagement with faces is special in this sense.

Yin's work also provided tentative evidence that faces are special in another sense; the possibility that for few or even for no other class of natural objects is there an orientation-specific component of right hemisphere involvement. Yin's patients were impaired on upright faces but were impaired neither on inverted faces nor on upright or inverted houses. However, since only faces and houses were used, this experiment provides only tenuous evidence that faces are special in this stronger sense. The claim would be strengthened by a comparable result with stimulus classes other than houses. In addition, if faces are special in this stronger sense, for no other class of items besides faces should there be an interaction between stimulus orientation and lateral field advantage.

SUMMARY

The existence of a right hemisphere capacity, specific to upright faces was investigated. Upright and inverted faces, equally complex as patterns, were presented under lateralized tachistoscopic conditions to two groups of normal adult subjects. A significant orientation by visual field advantage was found. While there was a highly significant left visual field advantage for upright faces, the visual field difference for inverted faces failed to reach significance. This pattern of results supports the hypothesis that the right hemisphere is specialized for the perception of faces in particular, in addition to its specialization for the perception of visuo-spatial patterns in general.

REFERENCES

- BENTON, A., and VAN ALLEN, M. W. (1968) *Impairment in facial recognition in patients with cerebral disease*, "Cortex," 4, 344-358.
- CHI, M. T. H. (1977), *Age differences in memory span*. "J. Exp. Child Psych." 23, 266-281.
- CLARK, H. (1973) *The language-as-fixed-effect fallacy: a critique of language statistics in psychological research*, "J. Verb. Learn. Verb. Behav.," 12, 335-359.
- CRAIK, F. I. M., and LOCKHART, R. S. (1972) *Levels of processing: a framework for memory research*, "J. Verb. Learn. Verb. Behav.," 11, 671-684.
- DE RENZI, E., FAGLIONI, P., and SPINNLER, H. (1968) *Performance of patients with unilateral brain damage on face recognition tasks*, "Cortex," 4, 17-34.
- , and SPINNLER, H. (1966) *Visual recognition in patients with unilateral cerebral disease*, "J. Nerv. Ment. Dis.," 142, 515-525.
- ELLIS, H. D., and SHEPHERD, J. W. (1975) *Recognition of upright and inverted faces presented in the left and right visual fields*, "Cortex," 11, 3-7.
- FONTENOT, D. J. (1973) *Visual field differences in the recognition of verbal and nonverbal stimuli in man*, "J. Comp. Physiol. Psychol.," 85, 564-569.
- GEFFEN, G., BRADSHAW, J. L., and WALLACE, G. (1971) *Interhemispheric effects on reaction times to verbal and non-verbal stimuli*, "J. Exp. Psychol.," 87, 415-422.

- GOLDSTEIN, A. G. (1975) *Recognition of inverted photographs of faces by children and adults*, "J. Genetic Psych.," 127, 109-123.
- GROSS, M. M. (1972) *Hemispheric specialization for processing of visually presented verbal and spatial stimuli*, "Percep. and Psychophys.," 12, 357-363.
- HILLIARD, R. D. (1973) *Hemispheric laterality effects on a facial recognition task in normal subjects*, "Cortex," 9, 246-258.
- HOCHBERG, J., and GALPER, R. E. (1967) *Recognition of faces: an exploratory study*, "Psychonom. Sci.," 9, 619-620.
- KIMURA, D. (1963) *Right temporal lobe damage*, "Arch. Neurol.," 8, 264-271.
- (1969) *Spatial localization in left and right visual fields*, "Canad. J. Psychol.," 23, 445-458.
- KLEIN, D., MOSCOVITCH, M., and VIGNA, C. (1976) *Perceptual asymmetries and attentional mechanisms in tachistoscopic recognition of words and faces*, "Neuropsychologia," 14, 44-66.
- KUCERA, H. and FRANCIS, W. N. (1967) *Computational Analysis of Present Day American English*, Rhode Island: Brown University Press.
- LEVY, J., TREVARTHEN, C., and SPERRY, R. (1972) *Perception of bilateral chimeric figures following hemisphere deconnexion*, "Brain," 95, 61-68.
- MACKAVEY, W., CURCIO, F., and ROSEN, J. (1975) *Tachistoscopic word recognition performance under conditions of simultaneous bilateral presentation*, "Neuropsychologia," 13, 27-33.
- McKEEVER, W. F., and HULING, M. D. (1971) *Bilateral tachistoscopic word recognition as a function of hemisphere stimulated and interhemispheric transfer time*, "Neuropsychologia," 9, 281-288.
- RIZZOLATTI, G., UMLTÀ, C., and BERLUCCHI, G. (1971) *Opposite superiorities of the right and left cerebral hemispheres in discriminative reaction time to physiognomic and alphabetical material*, "Brain," 94, 431-442.
- ROBERTSHAW, S., and SHELDON, M. (1976) *Laterality effects in judgment of the identity and position of letters: a signal detection analysis*, "Quart. J. of Exp. Psych.," 28, 115-121.
- ROCK, I. (1974) *The perception of disoriented figures*, "Sci. Amer.," 230, 78-85.
- SCAPIANELLO, K. F., and YARMEY, A. D. (1970) *The role of familiarity and orientation in immediate and delayed recognition of pictorial stimuli*, "Psychon. Sci.," 2, 329-331.
- WARRINGTON, E. K., and JAMES, M. (1967a) *An experimental investigation of facial recognition in patients with unilateral cerebral lesions*, "Cortex," 3, 317-326.
- , — (1967b) *Disorders of visual perception in patients with localized cerebral lesions*, "Neuropsychologia," 5, 253-266.
- YARMEY, A. D. (1971) *Recognition memory for familiar "public" faces: effects of orientation and delay*, "Psychonom. Sci.," 24, 286-288.
- YIN, R. (1970a) *Face recognition by brain injured patients: a dissociable ability?*, "Neuropsychologia," 8, 395-402.
- (1970b) *Face recognition: a special process?*, unpublished doctoral dissertation, M.I.T. Psychology Department.