Facial Recognition and Brain Asymmetries: Clues to Underlying Mechanisms

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A series of similar faces was presented to either the left or right visual field of three adults with brains surgically split along the corpus callosum. The left hemisphere displayed a marked and persistent deficit in performing a match-to-sample task, whereas the right hemisphere performed the task well. Additional test results suggest that the superiority is not specific to faces and is also not caused by specialized differences in sensory processes, but rather is related to differences in each hemisphere's ability to encode stimuli that cannot be adequately differentiated with a verbal description.

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Some neurological studies, as well as experimental studies on normal subjects, suggest that human facial recognition is a function predominantly served by the right hemisphere [1, 3, 4, 17, 21, 25]. At the same time, other reports suggest bilateral involvement [11, 13, 15]. A number of authors have dealt with this issue, and those accepting the claim for lateral specialization in the right hemisphere have proposed several possible explanations. These include such factors as the spatial frequency composition of the stimuli [10, 18], the familiarity of the stimuli [2], and the possible significance of the different cognitive styles of each hemisphere [14].

In the present study, evaluation of hemispheric asymmetries for facial recognition and follow-up studies of possible underlying mechanisms responsible for such asymmetries were carried out with patients who had undergone cerebral commissurotomy. To date, split-brain studies have been successful only in showing that the right hemisphere tends to dominate responses under conditions of bilateral competitive stimulus presentation [14]. Other studies have failed to demonstrate clear left hemisphere deficits for facial recognition under a variety of conditions [5, 7]. A confounding variable in all of these studies, however, was that they typically employed stimuli that had distinctive features such as glasses or baldness, that would permit recognition through verbal mnemonics. If subjects used a verbal strategy, any existing lateralized skill might be masked. In the present study, the separate hemispheres of three split-brain patients were examined using stimuli that were less readily distinguishable.

Case Histories

P.S. is a right-handed male, 21 years of age at the testing described here. He experienced a series of seizures at age 2, with a left temporal focus identified by electroencephalography. Subsequent development was normal until age 10, when seizures recurred and over the next five years proved intractable. At age 15, P.S. underwent complete surgical section of the corpus callosum. Since his operation, which was performed in January 1976, the patient has remained largely free of seizures.

J.W. is an alert, 30-year-old right-handed male with a history of staring spells, reportedly since grade school. After his first grand mal seizure, the frequency of attacks increased and remained intractable. Midline section of the corpus callosum was performed in two stages by Dr Donald Wilson of the Dartmouth Medical School. The posterior half of the corpus callosum, including the splenium, was sectioned first, with the remaining anterior portion sectioned in a second operation ten weeks later.

V.P., a right-handed 29-year-old female, experienced recurrent seizures at 9 years of age. Anticonvulsant drugs controlled the seizures until 1979, when she began experiencing grand mal, petit mal, and myoclonic episodes despite treatment with multiple anticonvulsants. She underwent partial anterior callosal section in early April 1979, followed by complete callosal resection in a second operation seven weeks later by Dr Mark Rayport of the Medical College of Ohio. Additional detailed information on the patients has been published elsewhere [8, 9, 19, 20, 22].

Observations

Group Studies

EXPERIMENT 1: FACIAL RECOGNITION TASK. In this study, 20 unfamiliar faces (10 female, 10 male; V.P.

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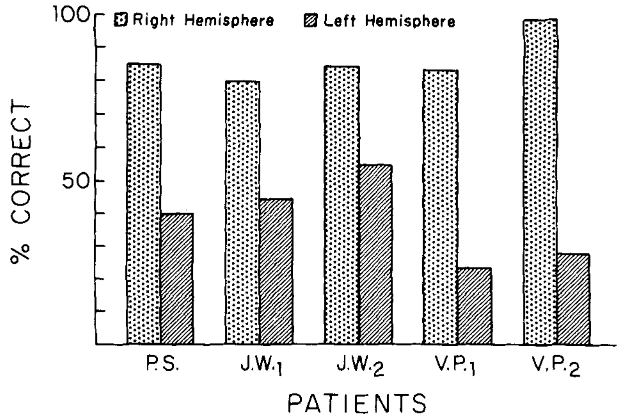

Fig 1. Bar graph showing each subject's hemispheric ability to perform the upright facial recognition task. J.W. and V.P. were tested twice, and the same effect was noted.

was presented with 8 male faces) were flashed one at a time to either the left or right visual field for 120 msec. The faces were taken from a 1957 high school yearbook, and in each sex group any one face was similar to at least three or four others in head outline, hairstyle, coloring, and facial posture. No pictures showed readily distinguishable features such as glasses or facial hair. The subjects were seated in front of a rear projection screen and examined on the female faces (20 trials) and male faces (20 trials) separately. Each face subtended 4 × 8° of visual angle. The nearest edge was 3° from fixation. Under each condition, the appropriate array of 10 faces (each pasted on a 3- × 5-inch index card) was placed in full view on a table in front of the subject. The subjects were told that each face might be projected more than once. After each stimulus presentation the subject was to select the same face from the set of 10 cards placed on the table. The entire sequence was repeated twice for 2 of the 3 patients.

The results appear in Figure 1. It can be seen that for all three patients there was a striking superiority of the right hemisphere in the discrimination of unfamiliar faces. In addition to the high level of accuracy, the right hemisphere responses were noted to be faster and more decisive than the left hemisphere responses. A χ^2 analysis [23] revealed no significant difference between subjects ($\chi^2 = 1.18$, $df = 2$) or subject × field interaction ($\chi^2 = 1.96$, $df = 2$). There was, however, a highly significant effect of visual field ($\chi^2 = 22.35$, $df = 1$, $p < .001$).

EXPERIMENT 2: LINE ORIENTATION JUDGMENTS. In an earlier study, a line orientation discrimination task resulted in superior right hemisphere performance in one split-brain patient [8]. This result also has been noted with additional difficult-to-verbalize stimuli in other experimental contexts [6, 14]. Additional tasks using other modalities that make use of stimuli that are difficult to describe verbally also indicate a right hemisphere superiority in split-brain patients [16].

In this experiment a line orientation matching test was performed on J.W., P.S., and V.P. using a procedure comparable to that used to measure facial recognition. Thirteen different lines at different angular orientations in increments of 10°, symmetrical about the vertical meridian, each subtending approximately .25 × 8° of visual angle, were used. On each trial, a single line was presented tachistoscopically for 120 msec, and the subjects were asked to select the appropriate match from an array of 13 cards placed in front of them. A vertical line was presented four times to each hemisphere and all other angles were presented twice, for a total of 28 trials to each hemisphere.

Each trial was scored by taking the absolute value of the difference in degrees between the correct alternative and that selected by the subject. For each subject the three largest values for each visual field were omitted from the analysis. Omission of these trials did not alter the general pattern of results for any subject. It was found that, analogous to the discrimination of faces, there were fewer errors when the information was presented to the left field (mean errors, left visual field (LVF) = 9.6°, standard error (SE) = 1.9°; right visual field (RVF) = 16°, SE = 2.7°). A two-way analysis of variance (subjects × visual field) revealed no significant difference between subjects ($F_{1,144} = .62$, NS) or subject × visual field interaction ($F_{1,144} = .36$, NS). LVF performance was significantly better than RVF performance, however. ($F_{1,144} = 11.16$, $p < .001$).

Taken together, these results imply that the right hemisphere possesses some kind of supramodal encoding apparatus that allows it to perform in a superior way in response to stimuli that cannot be fully characterized by a verbal description. What is responsible for this striking asymmetry in hemispheric performance? Several follow-up observations on V.P., the patient showing the largest hemispheric difference, explore some possibilities.

Case Studies

EXPERIMENT 1: NAME ASSOCIATION TASK. The female faces were divided into two groups of three faces, one group consisting of highly similar faces and the other of highly dissimilar faces, and the ability of each half-brain to learn a name for each face was assessed. In the similar group all three women were facing to the left and had similar smiles and short, straight brown hair. In the dissimilar group one woman had short blonde hair, faced left, and had no smile; one had shoulder-length, straight brown hair, faced left, and had a large smile; and the third had short, curly brown hair, faced right, and had no smile. Initially, a hemisphere was exposed 3

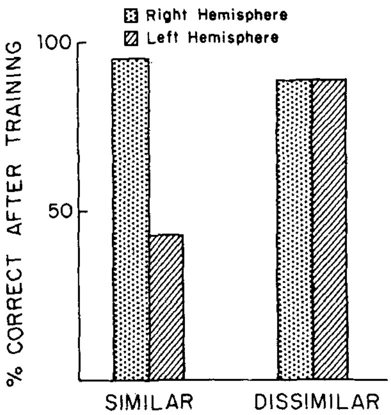

Fig 2. Bar graph showing V.P.'s performance on the name association task. V.P. was able to learn the dissimilar faces with either hemisphere. The left hemisphere found it difficult to learn names for the similar faces. When the similar faces were tested, the right hemisphere was trained first; with the dissimilar faces the left was trained first. In both cases, before the second hemisphere was trained, transfer tests were run; performance was at chance level.

times to the face and name to be learned. Before and after each exposure the examiner stated the name to be learned. Subsequently, 15 trials of the faces were randomly presented, and the subject was required to name each face.

The results for V.P. are seen in Figure 2. It can be seen that the right hemisphere had little difficulty learning the names for both the similar and dissimilar faces. (V.P. can speak from each hemisphere.) The left hemisphere, however, was able to learn names only for the dissimilar faces. Thus, the left hemisphere can differentiate distinctive faces, but becomes incapacitated when the faces are similar. Such a deficit could arise from a sensory, perceptual-encoding or experiential limitation, or both.

EXPERIMENT 2: PERCEPTUAL MATCHING. In a further examination of the sensory hypothesis, the left hemisphere, the one showing the discrimination deficit, was required to distinguish each face with a "same-different" judgment. In this test, same or different face pairs from both sets of similar and dissimilar faces were presented to the right visual field with an interval of approximately 1 to 3 seconds between each stimulus presentation. The subject indicated with a spoken response whether the faces were the "same" or "different." The left hemisphere performed at 90% (18 correct responses of 20 presentations), suggesting that the subtlety of the pattern perception did register in the left hemisphere.

EXPERIMENT 3: TESTS FOR LOW SPATIAL FREQUENCY INFORMATION. Other current views concerning the underlying mechanism responsible for so-called cerebral specializations such as face perception include the claim that the right hemisphere is particularly sensitive to visual stimuli of low spatial frequency. Patients with right posterior lesions recently have been reported to show a deficit in perceiving such stimuli [12]. This finding, combined with the observation that most complex forms are difficult to differentiate with the low spatial frequency components removed, could suggest that a more fundamental perceptual mechanism is responsible for a right hemisphere superiority for facial recognition.

In V.P., we first attempted to assess the role of the low spatial frequency components by repeating the match-to-sample procedure for facial recognition (20 trials to each hemisphere) with the stimuli reduced in size (from $4 \times 8°$ of visual angle to $2 \times 4°$ with the nearest edge at least 3° from fixation), a procedure that increases the high spatial frequency components of the stimuli and decreases the low spatial frequency components [10]. Twenty additional trials were also administered to each hemisphere with the pictures defocused, a procedure that increases the low spatial frequency components. Thus, these manipulations should have contrasting effects on a hemispheric asymmetry due to different contrast sensitivity functions for the two hemispheres. Both manipulations failed to alter significantly the left hemisphere's performance, and neither manipulation disrupted the right hemisphere's high level of performance: specifically, following defocusing the scores were LVF 85% correct, RVF 30% correct. When the stimuli were decreased to half size, the scores were LVF 85% correct, RVF 25% correct. The results of the intrafield same-different studies as well as those just described suggest that the left hemisphere is capable of carrying out the critical discrimination, and theoretically rule out the possibility of a structural, perceptual asymmetry.

EXPERIMENT 4: VERBAL DESCRIPTION OF LATERALIZED STIMULI. V.P., who can speak from each hemisphere, was asked to describe each face. In this test, each hemisphere received the 10 pictures of women's faces, and each was able to describe each picture verbally. V.P. spontaneously selected approximately four attributes to characterize each picture (LVF: mean = 4.2, standard deviation (SD) = .79; RVF: mean = 3.6, SD = .52), typically, gender, hair color, hair length, and facial posture. There was virtually no difference in the accuracy of her descriptions for left and right visual field stimuli (LVF 93% correct, RVF 97% correct; $\chi^2 = .76$, $df = 1$, NS) In general, however, such crude identification would not be sufficient to distinguish among several possible choices for the similar faces, emphasizing the verbal system's limited ability to describe such stimuli and further suggesting that the right hemisphere uses nonverbal strategies to solve the problem.

Discussion

The foregoing data are consistent with the view that facial recognition involves information processing mechanisms that elicit differences in the two cerebral hemispheres' ability to encode perceptual information for subsequent responses. The superior right hemisphere performance seen on tests of facial recognition was also observed in a discrimination of line orientation task. This finding suggests that the lateral specialization responsible for the superior facial recognition scores might well be related to a more general perceptual encoding skill present in the right half-brain and not based on differences at highly integrated levels of form perception per se. Although these experiments were carried out on patients with varying neurological histories of epilepsy and thus on abnormal brains, the data are entirely consistent with data from earlier studies on adult brain-damaged patients as well as studies on normal subjects [17].

In follow-up studies on V.P., who showed the largest functional asymmetry, the left hemisphere, which was unable to discriminate faces, was able to carry out a simple, same-different judgment of facial stimuli when these discriminations involved simple matches made at the same point in the visual field. Additionally, manipulation of the spatial frequency of the stimuli did not alter the performance of either hemisphere. As a consequence, it is unlikely that the cerebral asymmetry observed is strictly sensory in nature. The asymmetries appear when encoding of the stimuli is required, a requirement that is implicit in a recognition choice task as used in the present context. Placing the asymmetrical skill in the context of information encoding or memory mechanisms relieves one of the task of explaining such asymmetries in terms of structural properties of the central nervous system, such as possible different hemispheric distributions of "x" and "y" cells within the visual system.

It would appear that there are learned aspects of form perception and that these processes reside in the right hemisphere. Because this skill is established late in development and after language has been firmly established [3], it may be that the right hemisphere becomes specialized for this kind of memory because it has uncommitted cortical space available for the function [6]. This specialized skill is not dependent on language. The two hemispheres in V.P. could describe the features of the stimuli equally well, but only the right could encode the information usefully. The data argue against the view that language specializations and perceptual specializations cannot reside in the same half-brain [24].

The present results also suggest that dimensions of our mental life such as visual aesthetic judgments are tied to the lateralized skill just reported. In a preliminary examination of this issue, V.P. was asked to give judgments of "attractiveness" of the 10 females. V.P. gave accurate judgments (as compared with judgments by normal subjects) with the right hemisphere; the left gave only neutral ratings. This finding suggests that some of the less tangible qualities of mind, such as aesthetics, have their bases in such skills as form-encoding processes.

A more general implication of these findings of the existence of specialized processing centers in the brain is that the normal cognitive system is a composite of such special centers. Put differently, the data support the view that not all cognitive decisions are mediated by verbal analysis. The cognitive system is not a single, unified processing mechanism but rather a system composed of many preverbal processes that are continually active in carrying out computations and announcing the products of these computations to the conscious mechanism.

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