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Impairment of Voice and Face Recognition in Patients with Hemispheric Damage

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Voice and face recognition were tested in 21 left- and 9 right-hemisphere-damaged patients. Test materials were photographs and recordings of famous political and entertainment personalities. Pathological face recognition (prosopagnosia) and voice recognition (phonagnosia) were both significantly more prevalent in the right-hemisphere group. Only one instance of prosopagnosia and one of phonagnosia were observed in the left-hemisphere group, all of whom were aphasic. Of the right-hemisphere cases, there were four instances of each agnosia, with three patients showing a dual impairment. These findings are discussed in relation to differential modes of processing by the two cerebral hemispheres.

There is a substantial body of scientific knowledge showing that certain neuropsychological processes are predominantly lateralized to one or the other of the cerebral hemispheres. It has been recognized for over a century that speech and language behavior is mediated primarily by the left hemisphere in the large majority of normal individuals. In recent years, certain specializations of the right hemisphere have come to light.

Prominent among the specialized functions of the right hemisphere is the ability to recognize faces. Pathological failure to recognize familiar faces is consistently associated with damage to the right hemisphere (Hecaen, Ajuriaguerra, Magis, & Angelergues, 1952; DeRenzi & Spinn-

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ler, 1966; Benton & Van Allen, 1968; Warrington & James, 1967; Yin, 1970). Moreover experimental studies have amply demonstrated that the right hemisphere in normal subjects (Hilliard, 1973; Leehey & Cahn, 1979) and in split-brain subjects (Sperry, 1974; Levy, Trevarthen & Sperry, 1972) is superior to the left in face recognition and discrimination.

That facial stimuli have a special status for human observers, rather than being merely a subclass of patterned visual stimuli in general, is suggested by the studies of Fantz (1958), where infants as young as 4 days old were shown to fixate on facial configurations in preference to other visual patterns. Another feature of facial recognition is that it appears to engage a holistic, or Gestalt, mode of perception. Both everyday experience and considerable laterality research suggest that one ordinarily tends to recognize a face *in toto,* without analysis of special details. Hence the holistic mode of processing utilized in facial recognition is generally believed to underlie the right hemisphere's special ability. This is indicated by laterality studies in visual processing by Cohen (1973), Beaton (1979), Martin (1979), Niederbuhl and Springer (1979), Patterson and Bradshaw (1975), Smith and Nielsen (1970), and Carmon and Nachshon (1971). This interpretation of right-hemisphere function is underscored by the studies of Yin (1968) and Leehey et al. (1978), in which persons viewing inverted faces did not show the expected right-hemisphere advantage. Presumably, the individual viewing an inverted face is forced to achieve recognition by an analysis of details rather than by grasping the total configuration, and the special processing capacities of the right hemisphere are thus not engaged. These findings are consistent with the body of research which suggests a dichotomy between left hemisphere/featural processing versus right hemisphere/holistic processing. [See, for example, Levi (1974) and Zaidel (1978.)]

Though most of the work which focuses on right-hemisphere dominance has utilized visual stimuli, certain auditory stimuli, such as environmental sounds (Curry, 1967, 1968; Carmon & Nachshon, 1973) and certain types of music (Kimura, 1967; Gordon, 1970, 1975; Cook, 1973), may also be processed predominantly by the right hemisphere. More importantly, despite the traditional association of speech with the left hemisphere, there is evidence that particular aspects of the speech signal are in fact processed mainly by the right hemisphere. These include overall intonational contour (Blumstein & Cooper, 1974) and emotional tone (Heilman, Scholes, & Watson, 1975; Searleman, 1977). Assal, Zander, Kremin, and Buttet (1976) reported that patients with right-hemisphere lesions were significantly more impaired than left-hemisphere cases in discriminating among foreign accents. Differences were not significant when the same patients discriminated among adult male, adult female, and children's voices, or among different female voices, though, on the average, the right-hemisphere patients made more errors.

The Assal et al. study points to some of the information encoded into the speech signal along with linguistic meaning. Age, sex, size, emotional state, geographical and sociological background—all these attributes contribute to the specification of the acoustic signal to produce the individual's unique speech pattern (Garvin & Ladefoged, 1963; Scherer, 1972; Davitz & Davitz, 1974; Dittman, 1972; Tartter, 1980; Lambert, 1967; Giles & Powesland, 1975). [For review, see Hecker (1971) and Bricker & Pruzanski (1976).] As a result, the speech signal conveys ample information for the easy identification of a speaker. Though voice recognition is perhaps not so prodigious a human faculty as familiar-face recognition (Bahrick, Bahrick, & Wittlinger, 1978), the repertory of individuals whom one can recognize from even a brief speech sample must be immense. Moreover, like face recognition, identification of a voice seems to be accomplished almost instantaneously. The mere greeting "Hello," even when degraded by low-fidelity telephone systems, commonly suffices to cue the identity of the speaker with little or no benefit from context. Correct identification of voices (from a closed set) can even be accomplished when the stimulus is limited to 1/40th of a second of a sustained vowel (Compton, 1963).

These observations suggest that familiar-voice recognition might well depend on a right-hemispheric Gestalt perception, much like recognition of familiar faces. Another parallel between face and voice recognition is seen when we consider early perceptual preferences. An ability to distinguish mother's from strangers' voices in 3-month-old infants has been observed (Roe, 1978; Turnure, 1971). Even more striking, DeCasper and Fifer (1978) have reported that 3-day-old infants respond significantly more often to their own mother's voices than to other female voices. This is somewhat reminiscent of the previously mentioned infant preference for human facial patterns over other visual patterns (Fantz, 1958). Further data suggesting a special facility for recognizing familiar voices come from Bartholomeus (1973), who reported that nursery school children were almost as accurate in recognizing classmates' voices as were their teachers. In contrast, the ability to discriminate between unfamiliar voices follows a much slower maturational schedule (Mann, Diamond, & Carey, 1979). This early-emerging capacity for recognition of familiar voices thus contrasts with the later-developing ability for discrimination of unfamiliar voices. Here again, one sees a parallel between voices and faces in that similar differences in children's discrimination of familiar versus unfamiliar faces have also been shown (Carey, Diamond, & Woods, in press). Consideration of these diverse research findings suggests that right-hemisphere function may be best elicited by recognition (as opposed to discrimination) of familiar (rather than unfamiliar) patterned stimuli. This guided us in the design of the present investigation.

METHODS

We set out to study the idea that the identification of speakers from their vocal characteristics might constitute an auditory analog to face recognition. We studied a group of adult patients with right and left brain damage. We wished to compare the relative frequencies of occurrence of prosopagnosia (pathological face recognition) and phonagnosia (pathological voice recognition).[1] Our hypothesis was that phonagnosia would be associated primarily with right-hemisphere lesions, as the literature indicates is the case with prosopagnosia. We were also interested in whether the two disturbances are neuropsychologically linked or occur independent of one another.

Development of Test Materials

The visual materials were photographs of famous persons. The auditory materials were tape recordings of the speech of other famous persons. All were white males, well known either in politics or in show business. To ensure that these stimuli were in fact easily identifiable, we pretested them on a group of normal adults, all educated in the United States. These subjects covered a range of educational levels from elementary to graduate school and were engaged in a variety of occupations, including clerks, homemakers, salespersons, and teachers.

To develop the set of famous faces, a large pool of photographs taken from *Current Biography* (New York: H. W. Wilson Co., various annual editions) were shown to 44 subjects, aged 21–75, who were asked to select the name corresponding to each face from five written choices. From this set of stimuli we ultimately selected seven which were recognized correctly by virtually all our normal subjects. None of the seven selected photographs was misidentified by more than a single subject; in addition, no subject misidentified more than a single face. These materials were the basis for the Face Recognition Test. For utilization by our clinical subjects, the test consisted of photographs of seven famous persons, for each of which four possible choices were provided.[2]

The voice recognition materials were developed from a large pool of recorded samples obtained from broadcasts and commercial recordings. The tapes were edited to eliminate revealing content words and phrases. After the editing, we selected 17 of these recorded samples, each from 10 to 15 sec in duration, to play to a second group of 24 subjects, aged 22–67. The subject was required to select the correct name from a set of five written choices. On the majority of items, identifications were typically made in less than 2 sec, indicating to us that the listeners had experienced a genuine recognition rather than arriving at a correct answer by a process of elimination and reasoning. To ensure that the items had not been answerable on the basis of content, we had a separate group of 20 normal adult subjects read written transcripts of the recorded materials and try to identify the source from the same multiple-choice array used with the listeners. No voice sample which was correctly identified at a level above chance (20% accuracy) by transcript alone was included. We were left with seven items for the voice recognition test after these refining

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[1] The clinical term *prosopagnosia* is derived from the Greek προσ–ωπον (*prosōpon*), meaning face, and αγνωσια (agnōsia), meaning a not knowing. In the absence of an accepted term for pathological voice recognition, we have coined the parallel term *phonagnosia*, from the Greek φωνη (phonē), meaning voice, and *agnosia*.

[2] The shift from five choices in pretesting with normal subjects to four choices for use in testing clinical patients was made to avoid possible errors arising from visual confusion. The test was thus made even easier for the clinical subjects.

procedures. The pretest data on the final seven selected items were identical to the data on our face recognition materials: no item was misidentified by more than a single listener, and none of the normal listeners erred on more than a single item. These materials became the Voice Recognition Test. Each test item was a recorded speech sample from a famous person, presented with a response array of four possible choices.[3]

Clinical Subjects

The subjects were 30 consecutive right-handed patients, all of whom had been diagnosed as having unilateral cerebral lesions from CVAs or traumatic accidents, on the basis of neurological examination and, in several instances, CAT scans. Twenty-one had left-hemisphere damage,[4] and the remaining nine had right-hemisphere lesions. The left-hemisphere group had a mean age of 52.4 years (SD = 15.3), and the right-hemisphere group mean was 61.7 years (SD = 16.2). Mean time since onset was 8.9 months (SD = 13.4) for the left-hemisphere patients and 2.0 months (SD = 1.2) for the right-hemisphere patients. The difference in time since onset between groups is due primarily to different courses of clinical treatment for left- and right-brain-damaged patients. Left-hemisphere-damaged aphasic patients are commonly seen in rehabilitation settings as outpatients long after they have been released from the hospital. Right-hemisphere cases, on the other hand, are seen for prolonged therapy less frequently.

All patients had been educated in the United States. Like the normal subjects we had pretested, the patients were quite variable with regard to occupation and level of education. No patient was included who had a hearing loss sufficient to impair speech perception significantly. Similarly, patients with poor visual acuity despite correction and patients showing mental confusion or poor attention spans were not included.

Test Protocol

All testing was carried out in a quiet room, with the patient seated next to the examiner. All visual materials, clearly printed on white paper, were placed directly before the patient. Recorded materials were played at a preset, comfortable listening level. Face recognition was tested first for all subjects, followed by voice recognition.

Prior to each test, simple practice items were administered to ensure that the subject was able to make unequivocal responses. Once the examiner was assured that the patient understood the task and could respond appropriately, the test proper was started.

For each test item, a separate sheet containing a photograph and four printed names was presented. The examiner pointed to the photograph and asked "Who is this? Is it ______(pointing to the name)? It is ______(pointing again)? etc." The subject could respond to pointing to the written name, by saying the name, or by indicating "yes" when the examiner pointed to and said the judged correct name. These response options were

[3] Photographs (selected from *Current Biography*) were added to the names provided on the response sheets previously used for normal pretesting. This was done to maximize response options for patients. In addition, the number of choices was reduced from five to four, as was the case for the test materials for face recognition in clinical subjects.

[4] All of the left-hemisphere patients were aphasic. The group included seven Broca's aphasics, three mixed anteriors, two Wernicke's, one amnesic, and five global aphasics. Three patients had mixed symptomatologies and were not clinically classifiable.

included to reduce the possibility that a patient might fail an item, despite correct recognition, because of a particular modality deficit (speaking, reading, listening).

A short break was followed by administration of the voice recognition test. The response sheet for each item in this test contained four printed names coupled with matching photographs. A recorded speech sample was played, and the examiner said "Who was that? Was it——(pointing to the written name, saying the name, and pointing to the photograph)? Was it——(pointing again similarly to the next possible response)? etc." The patient once again was allowed wide latitude in responding. He or she could name the speaker, or indicate "yes" on hearing the name spoken or seeing it pointed to. In addition, the patient could point to the photograph in the array corresponding to the voice.

The entire procedure, including practice items, was typically accomplished in less than 10 min. Most patients understood the tasks readily and seemed to enjoy the activity. The materials and test procedures thus seemed to lend themselves well to clinical application.

RESULTS

Because both sets of test materials had been so easy for our normal subjects (no more than one subject erring on any single item in either test, and no subject scoring lower than six correct out of seven on either test), we considered that any marked deviation from a perfect score could be taken as evidence for pathological recognition. We selected a conservative criterion for identifying abnormal function: three or more errors on either task.

Table 1 gives the frequency distributions of the right- and left-brain-damaged patients on the face and voice recognition tasks. It is apparent from these data that the right-hemisphere patients, as a group, experienced more difficulty in these tasks than did the left-hemisphere group. Out of a possible total seven correct, mean scores for the right-hemisphere group were 5.33 (SD = 1.58) for face recognition and 4.89 (SD = 2.21) for voice recognition. In contrast, the left-hemisphere group had

TABLE 1

FREQUENCY DISTRIBUTIONS OF FACE AND VOICE RECOGNITION SCORES

	Frequency			
	Left hemisphere (N = 21)		Right hemisphere (N = 9)	
Score	Face	Voice	Face	Voice
7	12	10	3	4
6	8	8	2	—
5	—	2	—	1
4[a]	1	1	3	1
3	—	—	1	1
2	—	—	—	2
1	—	—	—	—
0	—	—	—	—

[a] Scores of 4 and below were considered to indicate pathology.

a mean correct score of 6.48 (SD = .75) on the face recognition task and 6.29 (SD = .85) on voice recognition. Though these means show suggestive group trends, our primary interest was in the occurrence of frank pathology in individual patients. Therefore we cast our data into two contingency tables—one for face recognition and one for voice recognition—in which each patient was classified by laterality of lesion and presence or absence of agnosia.

Table 2 presents the classification data for patients on both tasks. On the face recognition task, whereas only 4.8% (1 out of 21) of the left-hemisphere-damaged patients were defective, 44.4% (4 out of 9) of the right-hemisphere-damaged cases were. Using the Fisher exact probability procedure to test the null hypothesis that presence of agnosia for faces is independent of lesion laterality, the obtained probability was .019. This leads us to reject the hypothesis of independence and to assert that there is a significant association between right-hemisphere damage and prosopagnosia. This finding agrees with the clinical literature cited earlier.

Parallel data on phonagnosia are also presented in Table 2. Although the cell totals for voice recognition were coincidentally identical to those for face recognition, the patients who contributed to the corresponding cells in each table were not the same in all cases. The statistical results, of course, are the same: Voice recognition impairment was observed in 44.4% of the right-hemisphere group and in only 4.8% of the left-hemisphere group, with p = .019. Thus, like defects of face recognition, defects of voice recognition—the main object of this research—are seen to be associated significantly with right-hemisphere lesions.

It was of interest to determine whether the occurrence of prosopagnosia in a patient might be linked to the presence of a phonagnosic defect. In the left-hemisphere cases, no such relationship was observed. The single incidences of prosopagnosia and phonagnosia occurred in two

TABLE 2

PASS/FAIL CONTINGENCY TABLES FOR FACE AND VOICE RECOGNITION IN LEFT- AND RIGHT-BRAIN-DAMAGED PATIENTS

	Face recognition		Voice recognition	
	Left (N = 21)	Right (N = 9)	Left (N = 21)	Right (N = 9)
Pass (5–7 correct)	20	5	20	5
Fail (0–4 correct)	1	4	1	4
	p = .019		p = .019	

different patients.[5] In the right-hemisphere patients, on the other hand, there was an apparent linkage. Of the four right-hemisphere cases with face recognition abnormalities, three were abnormal in voice recognition (and conversely, three of the four patients with voice recognition distrubances were also impaired in face recognition).

Though we have interpreted our findings on agnosic disturbances with emphasis on laterality of lesion, the variable of time since onset requires consideration. The reader will recall that the right-hemisphere patients were tested following a shorter period since onset on the average, than the left-hemisphere group. More to the point, all five of the right-hemisphere cases who performed abnormally on one or both of the recognition tests were no more than 3 months post-onset. We wondered whether these failures might have been associated with previously undetected mental confusion and attentional disturbances often found in acute cases. To address this question, we looked at the left-hemisphere cases whose damage was of 3 months' duration or less. This group comprised a full one-third (seven cases) of our total left-hemisphere sample. None of these individuals failed either test. (The two left-hemisphere patients who were classified as agnosic on the basis of poor test performance were 4 and 5 months post-onset when they were tested.)

We also sought to determine how stable the recognition performance of our right-hemisphere agnosics might be. We were able to reexamine two of these individuals approximately 1 month after the initial testing. One of these patients was classified as prosopagnosic (3/7 correct responses) but as having normal voice recognition (5/7 correct) on the basis of initial testing. His performance was virtually identical on retest (4/7 for face recognition; 5/7 for voice recognition). The second patient had been considered agnosic for both faces (4/7) and voices (2/7). On retest, his performance on face recognition improved to a normal level (6/7); however, his performance on voice recognition on second testing was identical to his initial score, again indicating gross impairment (2/7 correct). Thus two out of three of the agnosias observed in the two retested patients persisted. Still, we are not able to state with certainty whether such agnosias as we have observed will become part of the patients' chronic symptomatology or if the recognition problems might gradually resolve over time. Further study of agnosic patients with longer-standing right-hemisphere lesions is necessary to resolve this uncertainty.

DISCUSSION

Voices and faces constitute two markedly contrasting varieties of stimuli, processed by different modalities. The finding that recognition of

[5] The prosopagnosic left-hemisphere patient was a global aphasic, and the phonagnosic left-hemisphere patient was a Wernicke's aphasic.

both is frequently impaired in persons with right-brain damage, and that, within our admittedly small sample, these impairments tend to co-occur, suggests that both agnosias might derive from a single underlying dysfunction. Given the theory that the right hemisphere is specialized for holistic pattern recognition, the results of this study might be interpreted to indicate that voice and face stimuli both tend to engage the holistic mode of processing attributed to the right hemisphere. The interpretation that it is the mode of processing which determines hemispheric lateralization rather than the stimulus per se seems all the more compelling when we consider that the voice stimuli were speech signals. Simplistically, one might expect a left-hemispheric superiority here. That we observed normal voice recognition in 20 of the 21 aphasic patients (including 5 severe global aphasics with virtually no functional expressive or receptive language) shows clearly that voice recognition is an ability dissociable from left-hemisphere language function. Moreover, voice recognition also seems to be dissociable from recognition of nonspeech environmental sounds. Two of our left-hemisphere patients had been found to be grossly deficient in environmental-sound recognition as tested by the clinical audiologist. In one of these cases, the defect was so profound that the family was advised not to allow the patient to go outside alone. Yet both of these patients performed normally in familiar voice recognition.

We consider this investigation as a preliminary study. Sufficient neuropathological data on individual subjects were not available in many cases, so that we could not examine precisely clinicopathological correlations. Thorough follow-up retesting of all patients showing deficits is desirable. We are particularly interested in specifying the intrahemispheric sites of lesion in patients with voice recognition defects. It would also be of interest to determine if different sites of lesion are involved when phonagnosia and prosopagnosia coexist than when one or the other defect occurs alone. The present data show that defective recognition of familiar voices is related to right-hemisphere damage; study of other populations is required to demonstrate that normal recognition is a function of the intact right hemisphere. And comparison of familiar voice recognition abilities with abilities for discriminating unfamiliar voices on both kinds of populations would be of interest, in view of the findings for familiar versus unfamiliar faces referred to earlier in this paper.

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