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HEMISPHERIC SPECIALIZATION IN NONVERBAL COMMUNICATION

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INTRODUCTION

While verbal language is most frequently mediated by structures in the left cerebral hemisphere (Benson and Geschwind, 1975), several lines of evidence suggest that it may be the right side of the brain which dominates in processing paralinguistic aspects of communication. In the perception of facial expressions, normally the most salient channel of nonverbal communication (Buck, Savin, Miller and Caul, 1972; Izard, 1971; Ekman, Friesen and Ellsworth, 1972), a dominant role for the right cerebral hemisphere is indicated by results from tachistoscopic studies in normal subjects (Ley and Bryden, 1979; Suberi and McKeever, 1977), by observations in unilaterally brain-damaged patients (DeKosky, Heilman, Bowers and Valenstein, 1980; Cicone, Wapner and Gardner, 1980), and by localized brain stimulation (Ojemann, Fried, Mateer, Wohns and Fedio, 1980). Studies in both normal (Haggard and Parkinson, 1971; Carmon and Nachshon, 1973; Blumstein and Cooper, 1974) and brain-damaged subjects (Tucker, Watson and Heilman, 1977; Heilman, Scholes and Watson, 1974) likewise suggest a right hemisphere superiority in the interpretation of intonational qualities in the voice, although contrary findings have also been reported (Zurif, 1972; Schlanger, Schlanger and Gerstman, 1976). Finally, several studies indicate that the general capacity to assess the significance of life events, emotional stories or humorous material suffers more after right brain damage than left (Gainotti, 1972; Wechsler, 1973; Denny-Brown, Meyer and Horenstein, 1952; Gardner, Ling, Flaum and Silverman, 1975; Heilman, Schwartz and Watson, 1978).

We have studied cerebral localization of nonverbal communication in greater detail by giving unilaterally brain-damaged and "split-brain" subjects the Profile of Nonverbal Sensitivity (PONS), a test for the ability to evaluate facial expressions, body movements and intonational qualities of the voice. The PONS has been cross-validated as a measure of sensitivity to nonverbal communication, and has now been given to several thousand people, providing extensive normative data against which the performance of the neurological subjects could be evaluated. Our results indicate that general competence in nonverbal communication does indeed rely more on the integrity of the right cerebral hemisphere than the left, and that it is the evaluation of facial expressions in particular that is most strongly lateralized to the right hemisphere.

MATERIALS AND METHODS

The standard version of the PONS (Rosenthal, Hall, Archer, Di Matteo and Rogers, 1979a; Rosenthal, Hall, Di Matteo, Rogers and Archer, 1979b) is a film containing 220 2-second segments. These are taken from 20 different emotional scenes portrayed by a female graduate student, falling into four general emotional categories (positive-negative × dominant-submissive). Each scene is presented in the test in 11 different formats, three showing exclusively video information (facial expressions alone, FA; body movements alone, BO; or FA + BO combined), two presenting only audio information (content-filtered speech, CF, in which high-frequency components of the voice are removed, rendering the words incomprehensible but leaving temporal qualities of speech intact; and random-spliced speech, RS, in which the tape is cut into short segments and then randomly reassembled, destroying temporal aspects of speech but preserving tonal qualities); the other six modes mix various audio and video components. Items from different scenes and channels appear in random sequence on the test. For each item, the subject indicates which of two alternative descriptions best fits the scene that is portrayed. The full-scale test was administered individually to 10 subjects all having cortical damage that was radiologically lateralized (CT scan in nine subjects, angiography in one) to only one cerebral hemisphere. Normative data and percentile rankings were obtained from Rosenthal et al. (1979a, 1979b).

Five other subjects, four having complete resections of the cortical commissures (Sperry, Gazzaniga and Bogen, 1969; Levy Trevarthen and Sperry, 1972) and one with a radical right hemispherectomy, were given an abbreviated version of the PONS. This contains only the 40 video items in which the face or body is shown alone, plus the 40 audio items in which only CF or RS speech is presented. In one of the "split-brain" subjects an occlusive optical system was used[1] (Zaidel, 1977) which allowed us to present the video items to each cerebral hemisphere in isolation. For the other patients in this group, the test was presented freely, and verbal responses, presumed to reflect the choice of the left cerebral hemisphere (Sperry et al., 1969; Levy et al., 1972) were obtained. Informed consent was obtained from all subjects.

[1] A collimator mounted onto a contact lens moves with the eye. At the end of this tube is a lens which focuses the visual array onto the eye, and a hemifield occluder that restricts visual input to one half of the retina, and thus to only one hemisphere, when the other eye is kept closed.

RESULTS

In the first group of subjects, the most striking finding was an inability to evaluate facial expressions after right hemisphere lesions. As shown in Table 1, five out of six patients in this group scored 1.8 or more standard deviations below normal on items that relied on facial expressions alone, a result with a probability of occurring by chance in a group of six randomly selected individuals of $p = 0.0002$. In contrast, most of these same subjects preserved their ability to evaluate emotions presented through other visual or auditory channels. Four out of the five patients who had scored poorly on interpreting facial expressions scored within 0.8 S.D. of normal (1.6-3.1 S.D. above chance) on tasks that required evaluation of body movements. Conversely, the one right brain-damaged patient who did score well on interpreting facial expressions (R5) had one of the lowest scores on evaluating body movements. Most of these subjects also showed deficits in evaluating vocal items on the test, but again this disability may be dissociated from the impaired reading of facial emotions. One patient whose lesion was in the right temporal lobe (R6) was unable to interpret facial emotions, but scored extraordinarily well on both random-spliced and content-filtered speech (98° percentile for the two combined channels); the right parietal subject who was able to discriminate facial expressions had the lowest score for the two audio channels (2° percentile ranking for RS and CF combined).

Left brain-damaged subjects scored within the normal range overall on the PONS, and were within 1 standard deviation of the norm on all four "pure" channels. Even with the small number of patients tested, the superior performance of the left vs. right brain-damaged group attained statistical significance on the overall test score ($F = 3.84$; d.f. $= 1, 8$; p. $= 0.04$) and in judging facial expressions ($F = 5.84$; d.f. $= 1, 24$; p. $= 0.015$) relative to other channels.

In the one "split-brain" subject (S1) to whom the PONS video items were presented to each hemisphere separately, the right hemisphere, using finger signals on the left hand to indicate its choices, performed normally on facial expressions but at the 5° percentile level on body movements. SI's left hemisphere, in contrast, scored only in the 4° percentile for facial expressions but in the 26° percentile for body movements. Identification of binaurally presented audio items was normal. All three other "split-brain" subjects scored extremely poorly on the face channel when verbally identifying freely viewed test items. On body movements, one of these subjects scored normally while two others did poorly, and on intonational qualities of the voice scores ranged from + 0.8 to −0.9 S.D. around the mean. The right hemispherectomy case tested at Cal Tech, who might also be considered as R7, showed no ability whatsoever in evaluating facial

TABLE I

Subject	Age	Sex	Handed-ness	Extent of cortical damage	Cause	Time elapsed	WAIS IQ V	WAIS IQ P	Percentile rankings on PONS items Overall	FA	BO	RS	CE
Right hemisphere lesions													
R1	56	M	R	R Temporal inferior parietal	CVA, R MCA	6 mo	135	102	0.2	1	46	34	27
R2	41	M	L/R	R global; enlarged lat. ventricle	traumatic encephalopathy	8 yrs			1	1	5	1	57
R3	39	F	R	(similar to R2)	intracerebral hemorrhage, AVM	19 yrs			5	1	21	34	40
R4	24	M	R	(similar to R2 plus slowing of EEG over L hemisphere)	traumatic encephalopathy	8 yrs			12	4	46	2	65
R5	59	M	R	R parietal; dilated R lat. ventricle	CVA	5 yrs			12	86	14	2	5
R6	52	M	R	R temporal	AVM	?	110	93	42	4	79	96	92
Left-hemisphere lesions													
L1	27	M	R	General atrophy of L hemisphere	occluded L carotid	21 yrs	100	103	62	86	62	34	14
L2	48	F	R	L posterior frontal, parietal	CVA	8 mo			12	69	46	17	44
L3	61	F	R	L frontal insular; general cortical atrophy	CVA	1 yr			24	18	27	55	65
L4	49	M	R	infarct in distribution of L MCA	CVA	2 yrs	*	144	37	48	79	17	44
"Split-brain" subjects													
S1	25	M	R	Complete commissurotomy	surgery after long seizure history		110	100	*	50[a]	5[a]		
									*	4[b]	26[b]	75	97
S2	47	F	R	Commissurotomy; EEG abnormal over R temporal; calcification of R Rolandic fissure	(same as S1)		83	71	*	4	0.5	16	28
S3	54	M	R	(same as S1)	(same as S1)		99	79	*	1	48	73	68
S4	35	M	R	Commissurotomy; L frontoparietal; seizure focus in R hemisphere	(same as S1)		77	82	*	0.3	2	16	81
Right hemispherectomy subject													
U1	24	M	R	Complete removal of R cortical structure	surgery due to tumor		80	60	*	0.1	26	16	82

* Full scale test not given
[a] Video items presented to right hemisphere alone, left finger signals used to indicate choices
[b] Video items presented to left hemisphere alone, used right finger signals
Abbreviations: CV, cardiovascular accident; MCA, middle cerebral artery; AVM, arteriovenous malformation.

expressions, but was within the normal range on all other channels.

Pooling together all 11 cases where only a normal left hemisphere was involved in making the response (i.e., the six cases of right hemisphere damage, the four "split-brain" cases from whom verbal responses were elicited, and the right hemispherectomy case), 10 scored in the 4° percentile or lower on facial expressions, a result with a probability of occurring by chance in an unselected population of about 1 in 10^{12}. This deficit was not positively correlated with impairments in evaluating body movements ($r = -0.28$), or vocal intonational patterns ($r = -0.27$ and -0.65 for RS and CF, respectively). These results suggest that the latter capacities either require different structures in the right hemisphere than does reading the face, or that they have a more bilateral representation, or perhaps that they are more variable in their localization pattern between individuals.

DISCUSSION

The foregoing results point to a critical role of the right hemisphere in evaluating the significance of social interactions through nonverbal cues, particularly via facial expressions. While a dominant role of the right hemisphere in recognizing facial expressions has recently been noted by others (Ley and Bryden, 1979; Suberi and McKeever, 1977; DeKosky et al., 1980; Cicone et al., 1980), the present study is the first to use standardized tests to assess quantitatively the significance of this deficit in the overall context of nonverbal communication, while also showing it to be separable from the ability to evaluate emotional situations through other channels. The neurological dissociation between reading the face and evaluating body movements demonstrates that the former disability cannot be explained simply as a deficit in visuospatial processing, or even in processing all visually presented emotional information. Other studies have suggested that evaluating facial expressions may even be dissociated from the ability to recognize individual faces (Ley and Bryden, 1979; Suberi and McKeever, 1977; DeKosky et al., 1980; Cicone et al., 1980), and our own informal observations would seem to support this. The one right brain-damaged patient who could discriminate facial expressions does not remember the faces of people with whom he has recently had prolonged contact, whereas all of the other patients in this group, with the exception of R1, had no apparent facial recognition deficits (i.e., were not prosopagnosic) when tested using familiar faces.

Our results would suggest, then, that the recognition of facial emotions may be a specialized function relying upon a circumscribed area of the right hemisphere. A review of the CT scans of our patients would suggest that it may be portions of the right temporal cortex that are most significant in supporting facial emotional recognition, a conclusion consistent with observations from a recent local brain stimulation study (Ojemann et al., 1980). Left-sided damage in this area would probably result in Wernicke's aphasia (Benson and Geschwind, 1975), with verbal comprehension deficits which would make it difficult for us to contrast patients with equivalent right- vs. left-sided lesions. However, our studies did include one subject whose excellent performance on facial expressions after global left brain damage early in life contrasted sharply with the inability of the subject with a right brain hemispherectomy on this task. Moreover, the one split-brain subject who was tested with each hemisphere separately provides an explicit right-left control.

Given the significance of facial expressions for the social communication of affect, for mother-infant interactions, and for regulating social relations, it perhaps is not surprising that competence in this domain may be specified by our neurology, an hypothesis which was first proposed by Darwin in 1872.

Abstract

Subjects sustaining right hemisphere damage were impaired in the ability to evaluate emotional situations presented through nonverbal means, particularly through facial expressions. Left brain damage, even of considerable extent, led to significantly milder deficits. In agreement with these findings, a study in split-brain patients showed the isolated right hemisphere to be competent in evaluating facial expressions but less sensitive to body movements, while the left hemisphere showed the opposite pattern.

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