Language and Localization: A Comparison of Left, Right, and Bilaterally Brain-Damaged Patients

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Many have looked at the relationship between the localization of brain damage and language deficits. This has generated intrahemispheric observations, (Goodglass and Kaplan, 1983; Kertesz, 1979), interhemispheric comparisons (Deal, Deal, Wertz, Kitselman and Dwyer, 1979; Myers, 1984) and comparisons between unilateral and bilateral brain damage (Deal, Wertz and Spring, 1981; Porch, 1981). Some (Halpern, Darley and Brown, 1973) suggest that localization of lesions translates into specific patterns of language impairment that typify different language disorders.

Relationships between where damage occurs in the brain and language behavior are not exact. For example, Halpern et al. (1973) listed specific language profiles for aphasia resulting from a focal left hemisphere lesion, and for the language of generalized intellectual impairment (GII) resulting from diffuse bilateral lesions. The Halpern et al. profiles were based on mean subtest performance in the Mayo Clinic Procedures for Language Evaluation, a modification of Schuell's Short Examination for Aphasia (1957). The profiles were derived by rank ordering performance for each group on ten measures--auditory retention, auditory comprehension, reading comprehension, naming, written dictation, arithmetic, syntax, adequacy, relevance, and fluency. Deal et al. (1981) attempted to cross-validate the Halpern et al. findings by comparing the profiles of a different sample of patients to those generated by the Halpern et al. study. A Q-factor analysis indicated that 80% of Deal et al.'s aphasic patients fit Halpern et al.'s aphasic profile, while only 55% of Deal et al.'s GII patients fit Halpern et al.'s GII profile. The result provided some support for the aphasic profile, but it seriously questioned the validity of the GII profile. Rank ordering is evidently not an adequate nor a reliable measure for group differentiation.

If one is interested in a test's ability to discriminate among groups, a more appropriate statistical procedure is discriminant function analysis. This has been used by Deal et al. (1979) to differentiate patients with left and right hemisphere lesions on the Porch Index of Communicative Ability (Porch, 1967) and by Porch, Friden, and Porec (1976) to differentiate PICA performance by aphasic patients from that by malingerers. The purpose of this paper is to present the results of a discriminant function analysis of performance on the Mayo Clinic Procedures for Language Evaluation (Mayo) by left, right, and bilaterally brain damaged patients. A discriminant function analysis would provide a test of the Mayo's ability to differentiate among three disorders--aphasia, GII, and right hemisphere communication deficit--resulting from left, bilateral, and right brain damage.

METHOD

We administered the Mayo to three groups of brain-damaged patients: 21 patients with single unilateral, focal left hemisphere lesions; 15 with diffuse, bilateral lesions; and 18 with single focal right hemisphere lesions. All

patients had been diagnosed previously with other measures. All with a left hemisphere lesion were aphasic, all with bilateral lesions displayed the language of generalized intellectual impairment, and all with a right hemisphere lesion displayed communication deficits consistent with right hemisphere brain damage.

Cause of brain damage was a single CVA in all left hemisphere and right hemisphere patients. Five bilateral patients had suffered multiple CVAs, six had diffuse cortical atrophy, and four had suffered a CVA and displayed cortical atrophy. Localization data were provided by clinical neurologic evaluation and neuroradiological results. Descriptive data on age, level of education and months postonset for each of the three groups is provided in Table 1. t-test analyses yielded no significant differences among groups on any of these measures.

Table 1. Descriptive data for each subject group.

VARIABLE	GROUPS					
	Left (n = 21)		Bilateral (n = 15)		Right (n = 18)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Age (in years)	57.33	9.43	63.87	8.36	59.28	9.78
Education (in years)	11.19	1.99	12.20	3.47	12.39	3.16
Months Postonset	23.48	29.21	36.53	62.06	14.11	33.88

The Mayo subtests were administered to all patients in each of the three groups, and each patient's percent of errors in auditory retention, auditory comprehension, reading comprehension, naming, written dictation, arithmetic, syntax, adequacy, relevance, fluency, as well as a total score were computed. These data were entered into a step-wise discriminant function analysis.

RESULTS

A comparison of group performance on the ten Mayo measures can be seen in Table 2. Left hemisphere patients made more errors on all measures than both the bilateral and right hemisphere patients. Bilateral patients made more errors than right hemisphere patients on all measures

Scheffé post hoc comparisons among groups are shown in Table 3. The left hemisphere group made significantly more total errors than the other two groups, and the bilateral group made significantly more total errors than the right hemisphere group. Left hemisphere patients made significantly more errors than bilateral patients on four of the ten measures: auditory retention, naming, syntax, and fluency. Left hemisphere patients made significantly more errors than right hemisphere patients on all ten measures. Comparison of the bilateral and right hemisphere groups indicated that bilateral patients made significantly more errors on four of the ten subtests: auditory retention, reading comprehension, arithmetic, and adequacy.

The first stage in a stepwise discriminant function analysis is to select those measures which best discriminate among groups. Our analysis of the Mayo selected six measures: auditory retention, reading comprehension, naming, adequacy, relevance, and fluency. Thus, these six subtests, taken together,

Table 2. Group percent error performance on the Mayo measures.

MEASURE	GROUP					
	Left		Bilateral		Right	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Auditory Retention	69.81	23.69	49.40	21.20	26.89	10.67
Auditory Comprehension	46.38	35.14	27.13	21.82	7.06	7.08
Reading Comprehension	45.24	36.01	39.80	35.23	6.28	10.96
Naming	43.05	39.35	14.53	18.61	1.72	3.22
Written Dictation	62.67	39.32	46.60	42.30	12.94	14.52
Arithmetic	71.19	27.43	55.13	30.54	25.33	17.75
Syntax	47.76	37.57	14.87	24.07	7.72	16.48
Adequacy	77.24	23.60	57.93	26.78	24.89	14.35
Relevance	33.86	42.25	7.67	24.07	1.33	3.07
Fluency	63.14	37.28	7.73	12.62	5.56	15.08
Total	56.95	26.62	32.60	21.06	11.06	5.74

Table 3. Group mean percent error comparisons and results of Scheffé post hoc comparisons.

MEASURE	GROUP MEAN DIFFERENCES		
	Left-Bilateral	Left-Right	Bilateral-Right
Auditory Retention	20.41*	42.92*	22.51*
Auditory Comprehension	19.25	39.33*	20.08
Reading Comprehension	5.44	38.96*	33.52*
Naming	28.51*	41.33*	12.81
Written Dictation	16.07	49.72*	33.66
Arithmetic	16.06	45.86*	29.80*
Syntax	32.90*	40.04*	7.14
Adequacy	19.30	52.35*	33.04*
Relevance	26.19	32.52*	6.33
Fluency	55.41*	57.59*	2.18
Total	24.35*	45.90*	21.54*

*significant at $p < .05/3 = .017$

provided enough information about group performance to permit the second stage of the analysis, the classification of patients.

Results of the discriminant function analysis classification are shown in Table 4. Forty-one of the 54 patients (76%) were classified correctly. Classification was most accurate for right hemisphere patients (89%), followed by left hemisphere patients (76%), and bilateral patients (60%). Two right hemisphere patients were classified incorrectly, one as left hemisphere and one as bilateral. Five left hemisphere patients were classified incorrectly, four as bilateral and one as right hemisphere, and six bilateral patients were classified incorrectly, all as right hemisphere

Table 4. Discriminant function analysis classification.

ACTUAL GROUP	PREDICTED GROUP MEMBERSHIP		
	Left	Bilateral	Right
Left (n = 21)			
number of cases	16	4	1
percent of cases	76.2	19.0	4.8
Bilateral (n = 15)			
number of cases	0	9	6
percent of cases	0.00	60.0	40.0
Right (n = 18)			
number of cases	1	1	16
percent of cases	5.6	5.6	88.9

Percent of all cases classified correctly = 75.93

DISCUSSION

Results of this analysis indicate that the Mayo Clinic Procedure for Language Evaluation is able to differentiate patients with different localization of lesions who demonstrate different language disorders with 76% accuracy.. It appears to distinguish patients who demonstrate communication deficits subsequent to a right hemisphere lesion best(with 89% accuracy). Its ability to differentiate aphasic patients who suffered a unilateral left hemisphere lesion is 76% accurate. Misclassified aphasic patients are more likely to be labeled GII than they are right hemisphere. The Mayo's ability to differentiate patients who display the language of generalized intellectual impairment subsequent to bilateral brain damage is relatively poor, only 60% accurate. All of the misclassified GII patients were labeled right hemisphere.

The most frequent misclassifications were labeling aphasic patients as GII and GII patients as right hemisphere. Examination of performance by these misclassified aphasic patients indicated that they made fewer total errors and fewer fluency errors than aphasic patients who were classified aphasic. Examination of performance by misclassified GII patients indicated that they made fewer total errors and more auditory retention errors than

adequacy errors when compared with GII patients who were correctly classified. Therefore, patients who were only mildly aphasic were classified as GII, and mildly GII patients were classified as right hemisphere.

Classification of patients by discriminant function analysis differs from classification using Halpern et al.'s profiles. For example, our discriminant function analysis classified six of 15 GII patients as right hemisphere and none as aphasic. Had we used Halpern et al.'s profiles, seven of our 15 GII patients would have been classified as aphasic. This questions the clinical application of the Halpern et al. profiles, and it also implies the need for profiles on additional neurogenic communication disorders.

Again, we believe the problem with the Halpern et al. profiles is that they were derived from rank orderings. If we compare our own rank orderings of percent error performance for our three groups (Table 5), we find little variation in the order of the variables, with the exception of fluency. Yet with the discriminant function analysis we conducted, six measures were found to be the minimum required for adequate discrimination among groups, with fluency making the smallest contribution. The reason for this is that discriminant function analysis is an exhaustive and comprehensive statistical procedure that computes which combination of variables will be the best discriminators.

Table 5. Rank order of percent error performance on the 10 Mayo measures for each study group.

	GROUP		
RANK ORDER	Left	Bilateral	Right
01	Adequacy	Adequacy	Auditory Retention
02	Arithmetic	Arithmetic	Arithmetic
03	Auditory Retention	Auditory Retention	Adequacy
04	Fluency	Written Dictation	Written Dictation
05	Written Dictation	Reading Comprehension	Syntax
06	Syntax	Auditory Comprehension	Auditory Comprehension
07	Auditory Comprehension	Syntax	Reading Comprehension
08	Reading Comprehension	Naming	Fluency
09	Naming	Fluency	Naming
10	Relevance	Relevance	Relevance

As Darley (1979) observed, we do not have a single measure that differentiates among patients who display different neuropathologies of speech and language. Nor, as we have shown, is the Mayo a likely candidate. So, as we continue to look for a single measure that differentiates among patients who display different neuropathologies, we may want to indicate, "Hold the Mayo."

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REFERENCES

Darley, F.L. The differential diagnosis of aphasia. In R.H. Brookshire (Ed.), Clinical Aphasiology: Conference Proceedings, 1979. Minneapolis, MN: BRK Publishers, 1979.

Deal, J.L., Deal, L.A., Wertz, R.T., Kitselman, K., and Dwyer, C. Right hemisphere PICA percentiles: Some speculations about aphasia. In R.H. Brookshire (Ed.), Clinical Aphasiology: Conference Proceedings, 1979. Minneapolis, MN: BRK Publishers, 1979.

Deal, J.L., Wertz, R.T. and Spring, C. Differentiating aphasia and the language of generalized intellectual impairment. In R.H. Brookshire (Ed.), Clinical Aphasiology: Conference Proceedings, 1981. Minneapolis, MN: BRK Publishers, 1981.

Goodglass, H. and Kaplan, E. The Assessment of Aphasia and Related Disorders, Second Edition. Philadelphia: Lea and Febiger, 1983.

Halpern, H., Darley, F.L., and Brown, J. Differential language and neurological characteristics in cerebral involvement. Journal of Speech and Hearing Disorders, 38, 162-173, 1973.

Kertesz, A. Aphasia and Associated Disorders. New York: Grune and Stratton, 1979.

Myers, P.S. Right hemisphere impairment. In A.L. Holland (Ed.), Language Disorders in Adults. San Diego: College-Hill Press, 1984.

Porch, B.E. Porch Index of Communicative Ability, Volume 2, Third Edition. Palo Alto: Consulting Psychologists Press, 1981.

Porch, B.E. Porch Index of Communicative Ability. Palo Alto: Consulting Psychologists Press, 1967.

Porch, B.E., Friden, T., and Porec, J. Objective differentiation of aphasic versus nonorganic patients. Paper presented to the International Neuropsychological Society, Santa Fe, New Mexico, 1976.

Schuell, H. A short examination for aphasia. Neurology, 7, 625-634, 1957.

DISCUSSION

Q: What will you use instead of the Mayo battery?

A: We are trying discriminant function analysis on different batteries. For example, we are going to try the PICA next to see how it discriminates among groups. But, we are not sure we will find one test that discriminates among all groups. One reason for this may be our use of localization data to classify behavioral disorders. While localization information is important, we may need to focus more on the behavior we see and whether patients who exhibit similar behavior can be diagnosed and treated in the same manner.

Q: I think too, that we ought to wait for some of the more objective, linguistic methodologies like the ones that have been alluded to, [e.g., discourse analysis] to tell us more. To a certain extent, a test designed to test aphasia is not an objective way to study language per se, so I'm not sure that the question is which of our current tests we should use to differentially diagnose. We have just begun to study dementia and its

language characteristics, and I think we need to get more information before we decide on how we are going to assess.

A: I agree that there is a lot of other information we need to collect. For instance, in patients with Alzheimer type dementia, memory deficits are a hallmark of the early stages of the disease, and that's something that one would, of course, want to look at if one is looking to differentiate between Alzheimer's disease, for example, and aphasia. There are also visual-spatial deficits that are seen in Alzheimer patients that are not seen in aphasic patients. Clearly other tests and other behaviors should be recorded and examined when assessing a patient. But standardized tests could be giving us a lot more information than we are getting, if we use better statistical procedures. What we have shown here, and what we will probably show with the PICA as well, is that there is much more information about patient and group profiles to be gained from these tests than we are getting from them now.

Q: I wonder if you gave discriminant analysis a fair shake. Most statisticians don't like to talk to you unless you've got at least twenty cases per factor. You have six factors and 54 subjects. You really should have 120 subjects, and most statisticians would like to see you with 30 cases per factor. So, when you find nondiscrimination with a factor analysis or discriminant function analysis, and you haven't satisfied the requirements for number of cases, you're really not entitled to say much about that because you really haven't given the technique a fair shake.

A: My understanding is that you need to have at least one subject per variable per group in order for discriminant function analysis to have some validity. We had slightly more than that, though I do agree that the larger number of subjects you have in a group, the more information you will get about that group.

Q: I didn't understand clearly how you decided whether they were left, right, or bilaterally brain-damaged.

A: That was based on neurologic examination and neuroradiological results.

Q: I'd like to suggest that that's not the <u>definitive</u> way of deciding that issue. In some of your patients, the neurologic exam might have been wrong. Your patients might have really been bilateral when the neurologic exam said he was right and so on, and the way to do it is to look at the brains, and do histologic examinations on them. What you should do is save all those patients that you did the study on and some day look at them and see if the Mayo might have been right or not. We've run into this before, where the neurologic exam, even with CT scans, will say that the patient has a right hemisphere lesion, when in fact he had lesions on both sides that were demonstrated later. I'm just adding another complication besides the statistical one; the methodologic problem of really verifying that it's a single lesion, or that it's a double lesion. Then there's another complication, and that is that bilateral patients will vary in their symptomatology depending on which side they had the lesion on first and the sequence of the lesions. So maybe we have to look at that separately, too.

A: Your question really presenta a dilemma. I have heard that approximately 30% of the brains that come to autopsy show an additional lesion. Because we cannot do an autopsy and then test, we feel that neurologists and the neuroradiological tools may be the best resource we have to localize lesions. Yet, we are probably going to miss some.

Q: The term "GII" must be a speech pathology term. I'm not familiar with it anywhere else in the literature. How many of your patients were demented?

A: Darley, I believe, introduced the term the "language of generalized intellectual impairment." Speech pathologists tend to make language and speech diagnoses rather than neurologic or psychologic diagnoses, so we use that term. All of the bilateral patients displayed that kind of language impairment, and all were demented.

Q: Looking at your groups, it looks as if you have at least two, three, or possibly four different types of dementias in your bilateral groups, though some of those people may not really be demented at all. If you have bilateral infarcts, it's a very different type of syndrome than Alzheimer's disease or multi-infarct dementia. I personally have a lot of trouble with your label of "GII" because it seems to be a potpourri of a lot of things, judging by the way you've described them.

A: I would agree with that, but as I pointed out, "GII" is really a description of a language behavior rather than an etiology or a localization. We had some Alzheimer's patients, or suspected Alzheimer's. Again, they hadn't come to autopsy yet, but the neurologic diagnosis was Alzheimer's disease. And, we had some multi-infarct dementia patients as well.

C: Localizing brain lesions at this point in time is really becoming a major hassle. Our imaging techniques are improving so much that as we move into the area of MRI, we're finding a large number of lesions that even at post-mortem you can't find. Who knows what those represent. Plus, structural lesions that you see on CAT scan may or may not be causing problems. It may be irrelevant whether you find other lesions, as long as you identify the clinically significant ones.