Writing Disturbances In Patients With Right Cerebral Hemisphere Lesions

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Since Broca (1865) described the dominance of the left hemisphere in the production of language, right hemisphere function in language has been considered of minor importance. McFie, Piercy and Zangwill (1950) described a visuo-spatial syndrome resulting from right hemisphere insult. Subsequent studies have confirmed their findings and have elaborated the role of the right hemisphere in visuo-spatial abilities. Presently, numerous other functions are ascribed to the non-dominant hemisphere as well, but researchers concur that while lesions of the right hemisphere produce visual, spatial and other dysfunctions, these disturbances are without linguistic aspects.

That is not to say that linguistic abilities are not present in the right hemisphere. The question has been raised recently by Gazzaniga, Bogen, and Sperry (1965) and others about the linguistic abilities of the non-dominant hemisphere. Despite the fact that some left hemisphere specialization for language appears to be present at birth, as evidenced by a study of neonatal brain specimens showing enlargement of the language areas (Whitelson and Pallie, 1973), it has been shown by several studies, including one by Gazzaniga and Hillyard (1971), that the right hemisphere has the potential for speech and language functions and has assumed these duties where left cerebral insult occurs at an early age. Pribram (1971) suggests that hemispheric specialization is due to an inhibitory suppressive mechanism exercised by the hemisphere which is dominant for a certain task. Levy, Nebes and Sperry (1971) express the view that at least some deficiencies of the right hemisphere are due to left hemisphere dominance over that function.

Placing these suppositions in perspective, acknowledgement must be made of studies which demonstrate the minor hemisphere's intrinsic linguistic limitations. Gazzaniga and Hillyard, for example, report that little or no syntactic ability exists in the right hemisphere. Levy, Nebes and Sperry found that graphic word retrieval ability was limited and that verbs were more difficult to retrieve than nouns in commisurotomized patients. Hines (1976) found that familiar and concrete nouns were recognized by both hemispheres.

Although writing is regarded as a complex linguistic task, consideration must be given to the probability that the act of writing may be coordinated by different areas of the cortex. Luria (1966) describes the stages of writing as initial acoustic analysis of the phonetic and sequential composition of speech, recoding of the phonetic elements into graphemes by a complex visuo-spatial analysis, and encoding into a system of motor acts which later becomes a highly automatized skill.

Studies of writing deficits in patients with unilateral right hemisphere lesions are rare and have generally looked at only visuo-spatial aspects. Some, however, have examined linguistic aspects as well. A study by Denny-Brown, Meyer, and Horenstein (1952) described a patient with a right parietal lesion whose written attempts demonstrated increasingly wide left margins and cramped right margins, uncrossed t's and undotted i's, but whose spelling was without error. Marcie, Hecaen, Dubois and Angelergues (1965) also looked at other parameters. Patients in their study performed a set of linguistic tests. Results showed faulty performance in both expression (writing) and reception (reading) of written language, accompanying verbal production difficulties (repetition of nonsense words and syllables), and problems in grammatical tests and sentence generating. A perseveration phenomenon was reported on many of these performances. A more recent study by Hecaen and Marcie (1974) compared written performances of patients with unilateral right hemisphere lesions, patients with unilateral left hemisphere lesions, and normal subjects. Writing on two tasks—a dictated text and a copied text—was compared along the following parameters: Reduplication (perseveration) of strokes of letters, syllables; insertion of blanks into words; size of left vs. right margins; slope of line of writing from the horizontal; and straightness of line. Only perseveration and enlargement of the left margin were correlated statistically with right hemisphere lesions. Left margin enlargement was highly correlated with left neglect. Both deficits were related to posterior lesions, especially occipital lobe lesions.

It is apparent that more research is needed in order to understand the role of the right hemisphere in writing. With the advent of computerized axial tomography the researcher is now better able to control for unilaterality and more specifically identify site of lesion which may assist in correlating areas of the right hemisphere with specific disturbances noted in writing.

Population

The population for this study consisted of 20 persons with neurological diagnoses of right cerebral hemisphere lesions, patients of St. Jude Hospital and Rehabilitation Center in Fullerton, California. All were dextrals and native English speakers. None had a history of other neurological disease, alcoholism, or significant premorbid visual impairment. Each passed audiological evaluation of speech discrimination ability. All were more than two weeks post onset with embolic, thrombotic, or hemorrhagic infarcts; those patients with space occupying lesions or head trauma were excluded. Eighteen exhibited positive findings on computerized axial tomography (CAT) scans, seventeen showed single areas of infarct and one had multiple small areas of infarct in the right cerebral hemisphere. Fifty percent of the patients were of recent onset, being between two weeks and two months post-onset; the remaining fifty percent were between five and thirteen months post-onset.

The control group was matched to the experimental group with regard to sex, age, and educational level and met the following criteria: dextrals, native English speakers, no history of neurological disease or alcoholism, and no evidence of significant visual or auditory impairment. All were in good health at the time of testing. There were 14 males and 6 females in each group. The age range of the patients was between 47 and 72 years with a mean of 61.55 years. The age range of the controls was between 48 and 79 years with a mean of 61.70 years. The educational level of the patients ranged between 8th grade and six years of college with a mean of 13.45 years of education. The controls ranged between 8th grade and five years of college with a mean of 13.55 years of education.

Test Procedures

Six subtests were administered to each subject by the same examiner. Instructions were standardized and all subtests were timed. The subject was instructed to write his responses on paper placed on a clipboard squarely in front of him. The subjects were, however, allowed to change the position of the clipboard.

Subtest Descriptions

Subtest 1: The "quicksand" paragraph from the Minnesota Test for Differential Diagnosis of Aphasia was read to each subject (with mean reading time recorded by the examiner). The subject was then instructed to write down what he could recall.

Subtest 2: The subject was instructed to write a sentence describing the function of each of ten common objects. (Porch Index of Communicative Ability, graphic subtest A.)

Subtest 3: The subject was instructed to write the name of each of ten common objects (PICA graphic subtest B.)

Subtest 4: The subject was asked to write to dictation ten sentences describing the function of the ten objects, e.g., "I pick up food with a fork".

Subtest 5: The subject was asked to write the names of the ten objects to dictation (PICA graphic subtest C).

Subtest 6: The subject was instructed to copy the names of the ten common objects (PICA graphic subtest E).

Standard PICA graphic subtest forms were used for subtests 1-5 and PICA graphic form E was used for subtest 6. Standard PICA objects and placement were used.

All of the subtests were scored by a speech pathologist and the findings confirmed by a second blind analysis by one of five other speech pathologists.

Purpose Of The Study

In an attempt to identify writing differences between the right hemisphere damaged patients and normal controls, the results were analyzed along the following parameters: content, sentence structure, and quantity of subject-generated material; length of time required to complete each subtest; spelling errors; perseveration of strokes of a grapheme, graphemes, syllables, and words; omission of strokes of a grapheme, graphemes, syllabels, and words; undotted i's; uncrossed t's; punctuation; capitalization; left and right margin widths and horizontality of line of writing. A second purpose was to identify those significant variables which correlated highly with each other to delineate cluster deviations and relate them to site of lesion or time post onset.

A third purpose was to contrast the subjects' responses to self-generated vs. auditory vs. visual stimuli to note differences on the basis of input modality.

Results And Discussion

Table 1 presents the means and standard deviation for each subject group, the t values and probabilities for 34 variables. Figure 1 represents the incidence of each group that exhibited the behavior measured by the variable.

Content.

There were 27 specific facts or references and 7 general concepts in the "quicksand" paragraph which was read to each subject. Responses on subtest #1 were scored for 1) number of specific facts or references, 2) number of general concepts and 3) number of errors or irrelevancies. As the table indicates, there was no significant difference between the two groups retelling facts or concepts but the patient group exhibited more errors/irrelevancies, approaching significance at the .05 level (P=.052).

Sentence Structure.

Each sentence on subtest #2 was analyzed and scored with a modified PICA scoring system. A response was described as "elaborate" if multiple functions were given, as "complete" if it was grammatically and syntactically accurate, as "incomplete" if it was syntactically incomplete (only 2 grammatical errors were observed in the entire sample), or as an "error" if it was vague or inaccurate. The results are presented below as percentage of sentences in each classification:

	elaborate	complete	incomplete	error
patients	7%	44.5%	39.5%	9%
controls	6%	57%	32%	5%

Using a chi square heterogeneity test the difference between the two groups did not achieve significance (X^2_3=7.09, P=.075).

Quantity.

The number of words each subject produced on subtests #1 and #2 was recorded. There was no significant difference between the patients and controls on this parameter.

Length of Time.

The time required by each subject to complete each subtest was recorded. t tests indicate significant difference between the two groups on five of the six subtests and on the total time required.

Spelling Errors.

Spelling errors made by each patient in the entire battery were recorded and expressed in frequency of occurrence per hundred words. This difference between the groups was significant, the patient group making more errors. When spelling errors due to perseverated or omitted graphemes were excluded for a "modified" spelling error count, the patient group still made more errors but this was not statistically significant. Ninety-five percent of the patient group and one hundred percent of the control group made these errors. Metatheses, noted in forty percent of the patient group and in ten percent of the controls, accounted for nineteen percent of the patients "modified" spelling error count and only two percent of the controls "modified" spelling error count. The difference in frequency of metatheses between the groups approached significance (P=.072).

Perseveration.

The duplication of strokes, graphemes, syllables and words were recorded and expressed in frequency of occurrence per hundred words. More patients than controls exhibited perseverations of each type. The frequency of occurrence was statistically significant for strokes and syllables (P=.018, P=.043 respectively) and approached significance for graphemes (P=.053). Perseveration of strokes and graphemes correlated highly (.89) in the patient group but did not correlate with other types of perseveration or with other variables in this study.

Omissions.

The omission of strokes, graphemes, syllables and words were similarly expressed in frequency of occurrence per hundred words. Omissions of each type were exhibited by more patients than controls, and omissions of each type occurred more frequently in the patient group. The differences were significant for omission of strokes and words at the .05 level (P=.003, P=.043). There were not high correlations between the different types of omissions or with perseverations.

Undotted i's.

Undotted i's were computed per frequency of total occurrence of the grapheme i. Failure to dot i's occurred in more patients than controls and with significantly higher frequency (P=.005). This did not correlate highly with omissions of any type.

Uncrossed t's.

Uncrossed t's were noted and expressed in frequency of total occurrence of the grapheme t. Failure to cross t's was a significant difference between the patients and controls (P=.01) but this did not correlate with undotted i's or omissions.

Punctuation.

The omission of periods in subtests #1, #2 and #4 was noted and expressed in percentage of occurrence per total number of sentences. Ninety-five percent of each group exhibited this behavior and this did not significantly differentiate the two groups using a t test.

Capitalization.

The use of extra capitals was expressed in frequency of occurrence per hundred words and was observed in more patients than controls. Similarly, the omission of a capitalized grapheme at the beginning of a sentence was observed in more patients than controls but neither extra nor omitted capitals were statistically significant in discriminating the two groups. Consistency of capitalization of single word responses on subtests #3 and #5 was noted. One hundred percent of the patient group was inconsistent and 47 percent of the control group was inconsistent but this was not statistically significant. (Subtest #6 was excluded from this analysis because most subjects used block capitals for the entire word responses, not allowing a basis for comparison.)

Margin Widths.

The maximum and minimum left and right margin widths were measured in centimeters for each subject on subtest #1. No statistically significant differences were found.

Slope.

The maximum slant of a line of writing in subtest #1 was noted in centimeters for each subject. There was no significant difference between the two groups.

Summary of Results of t Tests.

A summary of the t test performance scores of the patient group is found in Table 2. Those variables which identified significant differences ($P<.05$) between the right hemisphere damaged patients and normal controls included length of time required to complete the subtests, total spelling errors, perseveration of stroke and syllable, omission of stroke and word, undotted i's and uncrossed t's. Less important discriminators ($.05 \leq P<.10$) included errors in retelling a paragraph, perseveration and omission of grapheme and metatheses. Some of these findings support the studies cited earlier in this paper.

The commonalities of the two groups include retention of facts and concepts of the paragraph, quantity of words generated, punctuation, capitalization, margin widths, slope of line of writing and sentence structure. Clinical observation of patients with unilateral right cerebral hemisphere lesions, as confirmed by computerized axial tomography, supports the findings of Denny-Brown et al. (1952) and others of markedly exaggerated left margins and sloping of the line of writing. This was not exhibited by the patients in this study, however.

A correlation coefficient matrix of the variables yielded few appreciable correlations. Thus, cluster deviations were not identified. (perseveration of stroke and grapheme, as previously noted, were positively correlated and some of the times required on subtests were highly correlated.) The significance of individual correlations was not tested.

Discriminant Function Analysis.

In an attempt to divide the patients and controls into discrete groups based on their performance on this battery of graphic tasks, a subset of variables was sought which would effectively separate subjects, with a low probability of misclassification. A discriminant function analysis was performed on the eighteen variables contained in Table 2 to determine the linear combination of variables which best divided the forty subjects into patients and controls. Discriminant function coefficients were used to assign each subject an overall score in the following way:

Score = .0354 (errors in paragraph) + .0009 (time subtest #1)
.0004 (time subtest #2) +...+ .0016 (uncrossed t's)

The scores were arranged in descending order for each group and the degree of overlap, patients with controls, was noted. In this scheme, (Table 3) one patient[1] (*) appeared as a typical control and one control (**) was located in the gap between the clusters of patient scores and control scores. A measure of the divergence between the two groups of scores, Mahalanobis D^2, was 14.44 which was significant at the .01 level. Nonsystematic trial identified several sets of twelve variables which discriminated almost as effectively as the original eighteen and a set of fifteen (the original eighteen less time subtest #2, perseveration of word, and omission of syllable) variables which discriminated appreciably better. These observations suggest the feasibility of using a relatively short, economical, and uniformly scored writing test as a diagnostic tool in identifying right cerebral hemisphere lesions given additional research in this area of writing disturbances.

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[1] Patient 14 had a small right internal capsule lesion and was 10 months post-onset.

Comparison of Input Modalities.

The results of subtests #3, #5, and #6 were compared to determine differences between the same ten word responses to self-generated (recalling and writing object names), auditory (writing to dictation), and visual (copying) stimuli. Responses were analyzed for spelling errors (excluding perseverated and omitted graphemes), perseverations and omissions.

Both the patient and control group exhibited the largest number of spelling errors when writing the names independently and the smallest number when copying. This was true for 95 percent of the individual subjects who had errors on these subtests.

In the patient group, perseverations of stroke and grapheme occurred with approximately the same frequency when the subject wrote the name independently and when he wrote to dictation, but less frequently when he copied the word. (There was only one perseveration of syllable and no words perseverated on these three subtests.) Omissions of strokes and graphemes followed the same pattern. There were not enough perseverations or omissions in the control group to afford similar comparisons.

On the basis of fewer spelling errors for both groups and fewer perseverations and omissions in the patient group, the copying task appeared easiest. Acknowledgement of a learning factor must be made, however, as this was always the final subtest.

Discussion.

The degree to which visuo-spatial dysfunction is responsible for the writing disturbances noted in this study has not been thoroughly determined. Disturbed visual feedback has been cited as responsible for perseveration and omission of strokes and graphemes by Lebrun and Rubio (1972) who restricted visual feedback in normal subjects, and as responsible for undotted i's and uncrossed t's in the study by Denny-Brown et al., cited earlier. Visuo-spatial dysfunction may be responsible for slowing down the writing process. Metatheses may be due to impaired visual sequencing of graphemes and spelling errors due to failure to couple the correct visual symbol with the phonetic element. (Luria identifies omissions and metatheses in writing as secondary to faulty acoustic analysis or synthesis in those patients with left hemisphere dysfunction.)

Perseveration in writing, as explained by Luria, is due to "pathological inertia" resulting from pre-motor area dysfunction and the motoric aspect of writing must also be examined as it relates to these disturbances.

One should also consider some of these writing disturbances may reflect a disturbance of higher mental function, a possible explanation for the higher number of errors/irrelevancies in retelling a paragraph or for the greater amount of time required by the patients to generate the same quantity of writing as the controls.

Of the 18 patients who had infarcts identified on CAT scans, four had single lobe lesions (three parietal and one temporal), four had lesions in two lobes (one fronto-temporal, one fronto-parietal, one temporo-parietal, and one temporo-occipital) and ten had infarcts involving three or four lobes. There were 16 patients with areas of parietal infarction, 15 with areas of temporal infarction, 13 with areas of frontal infarction and four with areas of occipital infarction.

In an attempt to relate site of lesion to the writing disturbances identified, the rank order of patients on the following variables was examined: total length of time required to complete the battery, errors/irrelevancies in retelling the paragraph, spelling errors, metatheses, perseverations, omissions, undotted i's and uncrossed t's. Each of the cerebral lobes and the combinations of involvement was randomly represented in the rank order of each variable. Thus it was not possible to confirm or deny a relationship between the cerebral lobes and the identified disturbances. It was noted, however, that those six patients who took the longest time to complete the testing all had three or four lobes with areas of infarct, suggesting a relationship between the rate of writing and diffuseness of damage.

Length of time post onset did not significantly correlate with test performances. However, earlier writing samples of eight of the ten patients who were more than four months post onset were examined carefully. Clinical observation indicated more spelling errors, perseverations, omissions and more exaggerated left margins in most of the earlier writing performances, suggesting these disturbances may diminish with time.

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Table 1. Means, Standard Deviations, t Values (Controls-Patients) And Probabilities For Patients And Controls.

Variable	Patients mean (S.D.)	Controls mean (S.D.)	t	P
Facts	13.7 (3.1)	13.9 (5.8)	.14	.892
Concepts	4.2 (1.2)	4.1 (1.7)	-.22	.828
Errors	1.5 (1.5)	.7 (.7)	-2.03	.052 *
Number of Words #1	54.7 (17.2)	53.2 (16.5)	-.28	.780
Number of Words #2	71.4 (36.9)	70.8 (27.5)	-.06	.954
Time Subtest #1	4:19 (:53)	3:08 (:50)	-4.32	.000 *
Time Subtest #2	4:55 (2:52)	3:47 (1:58)	-1.51	.140
Time Subtest #3	1:38 (:50)	:50 (:17)	-3.99	.001 *
Time Subtest #4	3:19 (1:15)	2:23 (:43)	-2.87	.007 *
Time Subtest #5	1:14 (:37)	:41 (:08)	-3.84	.001 *
Time Subtest #6	1:33 (:40)	:44 (:10)	-5.19	.000 *
Time (Total)	16:55 (5:19)	11:35 (3:06)	-3.79	.001 *
Spelling Errors	7.6 (8.1)	2.5 (1.6)	-2.76	.005 *
Spelling Errors (excluding perseverated and omitted graphemes)	2.3 (2.1)	1.7 (1.1)	-1.23	.230
Metatheses	1.3 (2.1)	.3 (1.1)	-1.87	.072 *
Perseveration				
of stroke	3.8 (5.5)	.6 (.8)	-2.58	.018 *
of grapheme	4.0 (7.9)	.3 (.4)	-2.07	.053 *
of syllable	.3 (.7)	0	-2.18	.043 *
of word	.3 (.7)	.03(.1)	-1.63	.119
Omission				
of stroke	4.1 (3.6)	1.1 (2.1)	-3.23	.003 *
of grapheme	1.5 (2.5)	.5 (.6)	-1.76	.093 *
of syllable	.2 (.5)	0	-1.48	.156
of word	1.6 (2.3)	.4 (.6)	-2.16	.043 *
Undotted i's	3.1 (3.1)	.8 (1.2)	-3.11	.005 *
Uncrossed t's	.5 (.6)	.1 (.1)	-2.84	.010 *
Punctuation	.4 (.3)	.5 (.3)	.17	.864
Extra Capitals	2.3 (3.0)	1.6 (2.8)	-.78	.438
Omitted Capitals	.2 (.3)	.2 (.2)	.38	.705
Consistency of Capitalization	.4 (.3)	.5 (.4)	.79	.435
Least Left Margin	4.5 (4.5)	6.9 (5.6)	.93	.358
Greatest Left Margin	12.3 (9.3)	13.0 (6.7)	.29	.772
Least Right Margin	3.3 (4.7)	2.8 (3.5)	-.34	.733
Greatest Right Margin	21.0 (10.2)	18.3 (6.8)	-.97	.339
Slope	.5 (.9)	.5 (.5)	.16	.876

* = < .10

Table 2. Summary Of t Test Performance Scores Of The Patient Group.

Variable	$P \leq .05$	$.05 < P \leq .10$	$.10 < P \leq .20$	$.20 < P \leq 1.00$
Time Subtest #1 +	*			
Time Subtest #2 +			*	
Time Subtest #3 +	*			
Time Subtest #4 +	*			
Time Subtest #5 +	*			
Time Subtest #6 +	*			
Time (Total)	*			
Spelling Errors (Total)	*			
Metatheses +		*		
Perseveration				
of stroke +	*			
of grapheme +		*		
of syllable +	*			
of word +			*	
Omission				
of stroke +	*			
of grapheme +		*		
of syllable			*	
of word +	*			
Undotted i's +	*			
Uncrossed t's +	*			
Errors (in paragraph) +		*		
Facts				*
Concepts				*
Number of Words #1				*
Number of Words #2				
Spelling Errors (excluding perseverated and omitted graphemes)				*
Punctuation				*
Extra Capitals				*
Omitted Capitals				*
Consistency of Capitalization				*
Least Left Margin				*
Greatest Left Margin				*
Least Right Margin				*
Greatest Right Margin				*
Slope				*

[+] variable used in discriminant function analysis (Table 3)

[*] probability associated with t test difference between patients and controls.

Table 3. Discriminant Function Analysis

Rank Order	Patient Group Values	Control Group Values	Individual Patient Number	Individual Control Number
1	.90384		8	
2	.88578		15	
3	.85858		3	
4	.85326		7	
5	.81256		6	
6	.80070		20	
7	.80025		2	
8	.79601		4	
9	.79322		1	
10	.76159		11	
11	.75807		17	
12	.75472		12	
13	.74082		16	
14	.73337		9	
15	.70911		10	
16	.68769		5	
17	.68663		18	
18	.66979		19	
19	.66733		13	
20		.59091		9**
21		.48849		14
22		.48020		3
23		.47577		8
24		.45293		17
25		.44519		6
26		.42421		13
27	.41830		14*	
28		.39106		10
29		.39052		5
30		.38971		16
3o		.37040		11
32		.32560		19
33		.32379		18
34		.31083		7
35		.28567		1
36		.28477		20
37		.27814		4
38		.27790		15
39		.26659		12
40		23815		2

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