Differences Between Writing With the Dominant and Nondominant Hand By Normal Geriatric Subjects on a Spontaneous Writing Task: Twenty Perceptual and Computerized Measures

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INTRODUCTION

To date, the study of writing and the processes involved in writing have been confined largely to writing characteristics of neuropathological populations. Reports of writing disturbances associated with neuropathology first appeared in the literature in the mid-1800's. Since that time, several neurogenic dysgraphic syndromes have been identified (e.g., writing characteristics associated with aphasia, with right hemisphere lesion, etc.). However, the literature on the dysgraphias has been confined almost exclusively to the cataloging of various writing characteristics of the different neuropathological populations (e.g., Chedru and Geshwind, 1972; Leischner, 1969; Marcie and Hecaen, 1979; Rosenbek, McNeil, Teetson, Odell, and Collins, 1981). While these descriptions of motoric, linguistic, and visual-spatial graphic characteristics have provided useful information regarding the phenomenology and conditions under which dysgraphia arises, the data reported have been collected without systematic stimuli, tasks, and analysis procedures. The result is a series of heterogeneous findings without a referent for normal writing or for how writing disorders can be assessed and diagnosed.

Despite the absence of systematic measures for assessment and diagnosis of writing, clinical speech and language pathologists are continually confronted with the task of making judgments regarding the writing performance of individuals with various neuropathologies. Further confounding an already complicated clinical situation are the difficulties which arise when speech pathologists are confronted with assessing and diagnosing the writing of patients who are unable to write with their previously dominant hand due to hemiparesis. Data addressing the graphic characteristics of writing produced by normal individuals using their dominant or nondominant hand are unavailable. Differences in the motoric, linguistic, and visual spatial characteristics should exist in graphic output produced with the dominant and nondominant hand by normal geriatric subjects. Until these differences are systematically assessed and documented for normal writers, judgments regarding the writing of individuals with neuropathology are to be made with great caution, if at all. That is, the writing of a person with a lesion in one hemisphere and writing with the nondominant hand could be produced as it is because of the deficits associated with the lesion or simply because the person is writing with the nondomiant hand. These factors point to the need for 1) a replicable assessment protocol and 2) a reliable database that describes normal writing characteristics, as well as 3) an evaluation of differences which exist between graphic output produced with the dominant and nondominant hand. The present study provides the first reported data of this kind.

METHOD AND PROCEDURES

Fifty neurologically-normal individuals served as subjects. "Normal" was determined by a self-reported benign neurological history, and performance within normal limits on a vision and hearing screening, the Word Fluency Measure (Borkowski, Benton, and Spreen, 1967), the Revised Token Test (McNeil and Prescott, 1978), and the Raven's Coloured Progressive Matrices (Raven, 1967). Twenty-five male and 25 female individuals were selected. Forty-six were right-handed, and four were left-handed. Subjects had a mean education level of 4.4 years post high school. They were between 50 and 70 years of age, with a mean age of 59.5 years.

In response to the need for a test designed for clinicians to use in assessment and differential diagnosis of writing disorders, the tasks used and the characteristics reported in the literature to clinically define various neuropathological groups were compiled for use in a writing protocol. The tasks used to elicit writing consisted of a copying task which required subjects to copy five graphemes, twenty words, and five sentences; a dictation task in which the subjects wrote the same five graphemes, twenty words, and five sentences from dictation; an automatic task of writing their name and address; and a spontaneous task in which subjects wrote a description of the Cookie Theft Picture from the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1983). Word stimuli were selected based on their frequency of occurrence and their orthographic regularity. Sentence stimuli were selected from the Minnesota Test for Differential Diagnosis of Aphasia (Schuell, 1965).

Table 1. Perceptual and computer-assisted graphic features analyzed in the spontaneous writing productions of fifty normal geriatric subjects using their dominant and nondominant hands.

Perceptual Features	Computer-assisted Features
% Grapheme Formulation Errors	Left Margin Width
% Word Formulation Errors	Right Margin Width
% Graphemes Capitalized	Top Margin Distance
% Grapheme Errors Detected	Slope
% Word Omissions	% Graphemes Deviating From Slope
% Word Additions	Number of Graphemes per Deviation From Slope
% Illegible Words	Grapheme Height
% Word Substitutions	Intergraphemic Distance
Number Words Per Sentence	Interword Distance
Number Graphemes per Word	
% Grapheme Errors Corrected	

The test protocol was completed twice by each subject--once with the preferred hand, and once with the nonpreferred hand (in counterbalanced order). Subjects were allowed to print, use cursive, or a combination of the two. Subjects were instructed to write all responses within a 7-1/2 inch square drawn on each response sheet (identical to that used in the Porch

Index of Communicative Ability; Porch, 1967). The test protocol was always administered in the same sequence, with spontaneous writing first, automatic writing second, writing from dictation third, and copying last. Twenty features of the subjects' writing samples were coded for the purposes of these analyses (see Table 1). The features chosen for analysis were those features identified by previous investigators to be asociated with aphasia (Leischner, 1969; etc.), neuromotor speech disorders (Rosenbek et al., 1981), apraxia (Geschwind, 1973), nondominant hemisphere lesions (Hecaen and Marcie, 1974), and confusion (Chedru and Geschwind, 1972). The first eleven features were judged perceptually, and the last nine features were measured with a graphics tablet and a program written for the Harris Computer. All measures were reliably judged by the investigators. In addition, high interjudge reliability was obtained for all measures, with the exception of the presence and type of grapheme formulation errors produced.

RESULTS AND DISCUSSION

The descriptive data derived from this investigation, with 29 independent variables and the sixteen dependent variables, is massive. From these data the handedness, task, and stimulus length contrasts revealed several interesting findings. However, because of the massive amount of data generated from this study, the results and discussion to follow focus primarily on the differences detected between writing produced with the dominant and nondominant hand on the spontaneous writing task only. The clinical impact that these data have for assessing and diagnosing the writing of neuropathological individuals will be discussed.

Eleven perceptual measures were made on the data generated from the spontaneous task. The same measures were made on the samples produced with the dominant and nondominant hand. Means for each subject were used to compute a one way analysis of variance for each measure. Each one way ANOVA was tested at the .0025 alpha level. This was derived from dividing the predetermined .05 alpha level by the twenty comparisons. The perceptual measures and the results for the statistical analysis (Minitab, 1986) follow: 1) percentage of grapheme formulation errors (df=1,98; F=0.00; p>.0025), 2) percentage of word formulation errors (df=1,98; F=1.15; p>.0025), 3) percentage of graphemes capitalized (df=1,98; F=0.61; p>.0025), 4) percentage of errors detected (df=1,98; F=0.05; p>.0025), 5) percentage of word omissions (df=1,98; F=0.37; p>.0025), 6) percentage of word additions (df=1,98; F=1.00; p>.0025), 7) percentage of illegible words (df=1,98; F=0.01; p>.0025), 8) percentage of word substitutions (df=1,98; F=3.23; p>.0025), 9) number of graphemes per word (df=1,98; F=0.79; p>.0025), 10) number of words per sentence (df=1,98; F=8.79; p>.0025), 11) percentage of grapheme errors corrected was not computed as 100% were corrected for both hands. A large variability was noted between the means obtained from dominant and nondominant hand productions for each measure. However, this large variability was obliterated by the high intersubject variability reflected in the standard deviations (see Table 2). In addition to the test of mean differences provided with the ANOVA, Pearson product-moment correlation coefficients were computed to determine the degree of predictability for each measure from one hand to the other (Table 2).

Nine measures were derived from the computer analyses. As with the perceptual measures, a one way analysis of variance was computed for each of the measures derived. These computer measures and results of the statistical analysis follow: 1) left margin width (df=1,98; F=7.02; p>..0025), 2) right margin width ($df=1,98$; $F=5.50$; $p>,0025$), 3) top margin distance ($df=1,98$; $F=8.49$; $p>.0025$), 4) writing slope ($df=1,98$; $F=1.11$; $p>.0025$), 5) percentage of graphemes deviated from the slope ($df=1,98$; $F=7.32$; $p>.0025$), 6) number of graphemes per deviation from the slope (oscillations) ($df=1,98$; $F=0.52$; $p>.0025$), 7) grapheme height ($df=1,98$; $F=0.00$; $p>.0025$), 8) intergraphemic distance ($df=1,98$; $F=7.20$; $p>.0025$), 9) interword distance ($df=1,98$; $F=11.32$; $p>.0025$). Pearson product moment correlation coefficients were also computed (Table 2).

Of all these perceptual and computer assisted measures, no significant differences were found between writing produced with the dominant hand and writing produced with the nondominant hand on this spontaneous writing task. The correlation coefficients indicate that (with one exception) no correlation coefficient was high enough to predict more than 50% of the variance in the two sets of data (Table 2). This exception, percentage of graphemes capitalized, predicted 91% of the graphemes capitalized from one hand's production. The low correlation coefficients derived from the other measures suggests that individuals are not consistent from one hand's production to the other. Further, the direction of these interhand differences are not predictable, save for the percentage of graphemes capitalized. In other words, individuals who, for example, write small or large with one hand do not write predictably small or large with the other hand.

The results obtained from this study are surprising and unexpected. Subjective observations of writing produced with the domiannt and nondominant hands suggest that differences exist in writing productions, as is evident in the writing samples produced by the same subject with the dominant and nondominant hand (see Figure 1). In order to evaluate these subjective differences, five speech pathologists were instructed to sort the spontaneous writing samples from each of the fifty subjects according to dominant and nondominant productions. An average of 93% of the 100 samples were sorted accurately by these judges, with a range of 83% to 100%.

Despite the subjective differences noted between dominant and nondominant hand productions, the computer and perceptual features identified in the literature to define "dysgraphia" were not significantly different for dominant and nondominant hand productions. Contrary to our predictions, these data lend support to the assumptions that differences between normal and various neuropathological populations are not likely to be attributable to differences in the hand used to produce the writing.

In addition to the handedness differences presented, the data were combined to provide the first reference data collected on a standard set of tasks, with responses analyzed with a standard and reliable set of procedures from which pathological writing can be judged. Means, standard deviations, and quartile ranges are provided in Table 2. The scores from each subject for both the dominant and nondominant hand have been combined, since no significant differences were found between hands. These data suggest that normal writing is not characterized by "error free" production, as is observed, for example, in the presence of grapheme and word formulation errors. Therefore, the standard for comparison of writing produced by individuals with neuropathology should not be "perfect written English." The present data are not intended to be used clinically in differentiating normal from disordered writing. Further studies which describe the performance of neurologically-impaired adults on the same protocol, with the same analysis procedures, are mandatory in order to provide data useful in differentiating normal variation in writing from a writing disorder, or one which has neuropathologically predictable substrates.

Table 2. Correlation Coefficients, Quartile Ranges and Standard Deviations for each of eleven perceptually judged and nine computer measured characteristics of writing from a spontaneous writing task for fifty normal geriatric subjects with dominant and nondominant hand scores combined (N=100).

MEASURE	Correlations Dom.-Nondom. Hands	1st %ile	25th %ile	50th %ile	75th %ile	100th %ile	S.D.
PERCEPTUAL							
% Grapheme Formulation Errors	0.09	0.00	0.83	3.52	5.20	18.00	3.91
% Word Formulation Errors	0.49	0.00	0.00	6.05	5.90	46.30	11.68
% Graphemes Capitalized	0.95	0.00	1.72	4.97	4.25	92.90	12.58
% Grapheme Errors Detected	0.12	0.00	0.00	0.43	0.00	9.00	1.31
% Word Omissions	0.20	0.00	0.00	28.60	91.92	100.00	44.35
% Word Additions	---*	0.00	0.00	0.09	0.00	9.10	0.91
% Illegible Words	-0.01	0.00	0.00	2.40	0.00	100.00	14.18
% Word Substitutions	0.22	0.00	0.00	8.91	0.00	100.00	27.66
Number Words per Sentence	---**	2.00	6.50	10.41	13.50	36.00	5.31
Number Graphemes per Word	0.44	3.10	3.80	4.12	4.30	6.50	0.49
% Grapheme Errors Corrected	1.00	100.00	100.0	100.0	100.0	100.00	0.00
COMPUTER							
Left Margin Width (MM)	0.51	0.89	8.46	12.71	17.14	30.01	6.38
Right Margin Width (MM)	0.56	0.83	11.25	17.38	21.86	56.63	9.58
Top Margin Distance (MM)	0.39	0.00	2.79	5.48	7.52	20.85	4.04
Slope (MM)	0.14	0.00	0.01	0.03	0.04	0.12	0.02
% Graphemes Deviating From Slope	0.12	0.00	0.10	0.31	0.46	1.00	0.25
Number of Graphemes per Deviation From Slope	0.07	0.00	1.00	3.62	3.68	49.00	5.84
Grapheme Height (MM)	0.37	1.40	1.99	2.76	3.20	6.03	0.98
Intergraphemic Distance (MM)	0.41	1.11	1.54	2.01	2.37	3.42	0.56
Interword Distance (MM)							
Nondominant Hand (N=50)	0.62	0.35	3.29	4.44	5.62	9.05	1.73
Dominant Hand (N=50)	----	0.57	2.33	3.34	4.30	7.44	1.54

*Correlation coefficients were not computed because of the number of zero entries (99)

**Correlation coefficients were not computed because of missing data (unequal numbers)

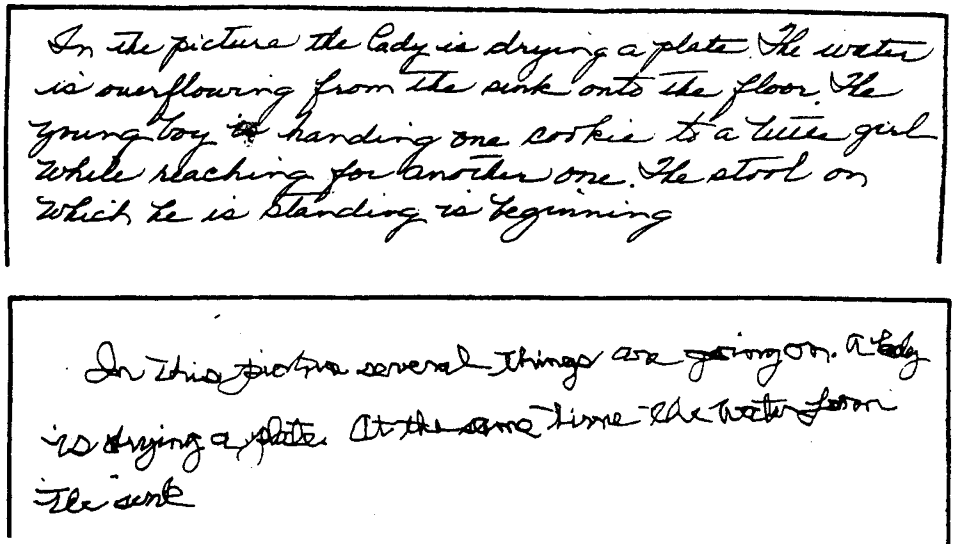

Figure 1. Spontaneous writing samples produced with the dominant (upper sample) and nondominant (lower sample) hands by a single geriatric subject.

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DISCUSSION

C: I think that very often we threaten our science by assuming even tacitly that everything stroke patients do results from their strokes, and that aphasia is what aphasic people do. I'm really glad to have these normative data.

Q: Your sample appeared to be a pretty highly educated group. Did you select them for any particular reason for years beyond high school? Do you think they're representative of the geriatric population?

A: No, they were not selected based on their education, or lack of it. A very highly educated group was tested. That's something that we will follow through with; testing people with different education levels.

C: The Mayo Clinic group, when they did that normative data on the PICA, did normal people doing the PICA with the dominant and nondominant hands. They looked at the graphic test and found a difference, and published that with their normative data. You might look at that just to have it in your literature. They found that people do less well with their nondominant hand, but it affected the overall score on the PICA by .42 and the graphics score by 1.62. The assumption that an aphasic person using their nondominant hand is like us using our nondominant hand doesn't hold true. There's a lot of crosstalk between the cortices and if you have one damaged your nondominant hand isn't as efficient in the damaged brain as in the nondamaged brain. I'm sure you'll find a difference between the damaged-brain data with the nondominant hand and your normal people.

Q: In your selection of patients you said you controlled for health status based on a health questionnaire. Did you exclude people based on hypertension or heart disease, or did you allow those people to stay in?

A: They were not excluded. It was not reported by any of the subjects, although it was not an exclusion factor.

C: I think it's important that when any of us select control patients when we're looking at aphasic patients that we be careful in not excluding hypertensive individuals and people with coronary disease, because those factors will be found in all your aphasic subjects. By excluding them you may find some striking behavioral differences.