J. FLUENCY DISORD.
11 (1986), 71–89

# HEMISPHERIC ALPHA ASYMMETRIES OF STUTTERERS AND NONSTUTTERERS FOR THE RECALL AND RECOGNITION OF WORDS AND CONNECTED READING PASSAGES: SOME RELATIONSHIPS TO SEVERITY OF STUTTERING

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This investigation studied hemispheric alpha asymmetries of stuttering men and nonstuttering men and women for high visual imagery words and connected reading passages under memory conditions of recall and recognition. The relationships between a measure of stuttering severity and hemispheric alpha ratios were studied. Stutterers were found to have greater right hemispheric alpha suppression under all memory and stimulus conditions as compared to nonstutterers who showed greater left hemispheric alpha suppression. Correlational procedures revealed a negative correlation between stuttering severity and alpha ratios, which indicated that as stuttering frequency increased ratios decreased (greater right hemispheric activation). Behavioral data showed stutterers to recall and recognize significantly less than the nonstuttering group. This latter finding is discussed in relation to the short- and long-term memory and the coding–retrieval strategy differences between the hemispheres. Results are discussed relative to nonsegmental, right-hemispheric information processing strategies in stutterers.

## INTRODUCTION

Morphologic asymmetries of the two cerebral hemispheres have been well documented and appear to be related to cognitive strategies used to process linguistic and nonlinguistic information. Differences of the upper surface of the left and right temporal lobes (Geschwind and Levitsky, 1968; Wada, Clarke, and Hamm, 1975; Witelson and Pallie, 1973; Hochberg and LeMay, 1975; Rubens, Mahowald, and Hutton, 1976; Ratcliff et al., 1980; Witelson, 1983) and asymmetries in the ventricular system

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0094-730X/86/$03.50

of the brain (McRae, Branch, and Milner, 1968; Strauss and Fitz, 1980) have been reported by several investigators. It is generally agreed that the left hemisphere is an analytic–segmental processor, whereas the right hemisphere is a holistic–gestalt processor (Kinsbourne, 1979; Segalowitz and Gruber, 1977; Zaidel, 1979). Both hemispheres are involved in language comprehension, although in different capacities, whereas only the left hemisphere seems involved in speech production in normal right-handers (Dennis, 1980a, 1980b; Hecaen and Sauget, 1971; Penfield and Roberts, 1959; Wada and Rasmussen, 1960; Zaidel, 1979). The right hemisphere's involvement in language is dependent upon such variables as syntactic complexity (Dennis, 1980a, 1980b) and imagery value of the stimuli (Day, 1977, 1979; Tallal and Piercy, 1974). Additionally, the right hemisphere is less able to analyze the constituent parts of a sentence but is able to process high imagery nouns and adjectives. The left hemisphere is able to analyze the constituent parts of sentences and process nouns and verbs regardless of imagery value (Dennis, 1980a, 1980b). The lexicon of the right hemisphere, compared to the left, has been described as connotative, associative, and imagined rather than precise, denotative, and phonologic (Bradshaw, 1980).

Considering the processing differences between the two hemispheres it could be hypothesized that greater dependency on one or the other modes of processing would result in cognitive–linguistic disruptions (see Dennis [1980a] for language differences in left and right hemidecorticates and Fromkin et al. [1974] for right hemispheric language processing in a child with experiential deprivation). In fact, Moore and Haynes (1980) suggested such a hypothesis with regard to stuttering:

> Stuttering may emerge when both hemispheric processing of incoming information and motor programming of segmental linguistic units is in the right hemisphere (a non-segmental processor). These processing differences may be related to an inability, under certain circumstances, to handle the segmentation aspects of language. (p. 243–244)

Greater right hemispheric involvement has been reported in stutterers for processing meaningful linguistic stimuli using a variety of procedures including dichotic listening (Curry and Gregory, 1969; Perrin and Eisenson, 1970; Quinn, 1972; Sommers, Brady and Moore, 1975; Davenport, 1979), tachistoscopic viewing (Moore, 1976; Plakosh, 1978; Hand and Haynes, 1983), hemispheric alpha asymmetries (Moore and Lang, 1977; Moore and Lorendo, 1980; Moore and Haynes, 1980; Moore, Craven, and Faber, 1983; Boberg et al., 1983), averaged evoked responses (Ponsford et al., 1975; Zimmerman and Knott, 1974), and cortical blood flow (Wood et al., 1980). Investigations using nonsense syllables under conditions of dichotic listening have not always reported similar findings as those using meaningful linguistic stimuli (Cerf and Prins, 1974; Sussman and MacNielage, 1975; Dorman and Porter, 1975; Brady and Berson, 1975; Pinsky and McAdam, 1980; Rosenfield and Goodglass, 1980; Liebetrau and Daly, 1981; Cimorell-Strong, Gilbert, and Frick, 1983). Several of these investigations have studied the proportions of stutterers and normals with left ear preferences or no ear preference for nonsense syllables and found many more stutterers, compared to normals, displaying left ear preferences (Brady and Berson, 1975; Strong, 1978; Rosenfield and Goodglass, 1980; Liebetrau and Daly, 1981; Cimorell-Strong et al., 1983).

By examining the language variables associated with increased stuttering we may gain insights into the predominant mode of information processing used. It has been shown that stuttering increases on the same words of initial segments of long sentences compared to short sentences (Tornick and Bloodstein, 1976); on low frequency words (usually of low imagery value) compared to high frequency words (Scheisinger, Melkam and Levy, 1966; Ronson, 1976; Palin and Peterson, 1982); from base structure sentences to transformations (Soderberg, 1967; Bloodstein and Gantwerk, 1967; Hannah and Gardner, 1968; Ronson, 1976; Palin and Peterson, 1982); at clause boundaries compared to internal (nonboundary) positions of clauses (Wall, Starkweather, and Cairns, 1981); and when voicing adjustments are required (Adams and Reis, 1971, 1974; Wall, Starkweather, and Harris, 1981). Stutterers' recall of verbal information compared to normals has been shown to be reduced (Daly, 1981; Moore et al., 1982). A recent review of language variables associated with stuttering by Homzie and Lindsay (1984) revealed that language deficits are a contributing factor and a continuing component of stuttering.

The linguistic variables associated with increased stuttering gain importance when language processing capabilities of the right hemisphere are considered. Due to the resources available to the right hemisphere (Friedman and Polson, 1981), it is less capable of analyzing the constituent parts of a sentence in the same manner as the left hemisphere. Consequently, it is less capable of interpreting passive and negative sentences as contrasted with active sentences (Dennis, 1980a, 1980b; Dennis and Whitaker, 1976; Zaidel, 1979). Additionally, the right hemisphere is not as efficient as the left in the recall of verbal information (Faber-Clark and Moore 1983; Zaidel, 1979) but is capable of verbal recognition using high visual imagery stimuli (Day, 1977, 1979; Faber-Clark and Moore, 1983). Perecman and Kellar (1981) and Molfese (1978a; 1978b) have shown that processing of voice in normal subjects can be carried out by the right hemisphere. Place of articulation, on the other hand, requires the resources of the left hemisphere.

The language variables associated with increased stuttering appear to be those that the right hemisphere is less capable of processing and provide support for a hypothesis of increased dependency on right hemispheric processing being associated with stuttering. Support for this position has been provided by Davenport (1979) who, using dichotic procedures, reported greater left ear preference scores as stuttering severity increased.

If stuttering is related to right hemispheric processing, then one might reasonably expect right hemispheric activation to increase with greater stuttering severity. The purpose of this investigation was to explore the hemispheric alpha asymmetries and behavioral performance data of a group of male stutterers, male nonstutterers, and female nonstutterers for tasks of nonoral memory recall and recognition for high visual imagery words and a connected reading passage. The investigation also sought to explore the relationship between hemispheric alpha asymmetries and a measure of stuttering severity.

## METHOD

### Subjects

The 36 subjects included 12 nonstuttering males, 12 nonstuttering females, and 12 stuttering males. The groups of nonstuttering males, nonstuttering females, and stuttering males had mean ages of 25.54 (18.8–30.4), 26.4 (20.0–43.7), and 26.88 (12.07–44.50), respectively. The nonstuttering subjects were screened for speech, language, and fluency disorders, and any subject with a communication impairment was excluded from the study. All subjects reported a negative history of cerebral pathology when asked if they had ever suffered any brain damage, concussions, epilepsy, or had been under the care of a neurologist. All subjects were familial (parents and siblings) right-handers and indicated that they used their right hand in 8 out of 10 activities on a modification of the Neurosensory Center Handedness Questionnaire (Benton, Meyers, and Polder, 1962). Hearing for pure tones was within normal limits as determined by passing a 15 dB HTL (ANSI: 1969) screening test for the octave frequencies of 500 through 4000 Hz.

The men who stuttered were volunteers from the present and past population of clients at the Speech, Language and Hearing Clinic at California State University, Long Beach. All stutterers had histories of fluency management. A measure of stuttering was obtained for each of the stutterers during a 5-min dialogue. Stuttering was defined as part-word repetitions, whole word repetitions, and prolongations. The stuttering rate per minute was obtained by averaging the five 1-min stuttering frequencies. Table 1 presents the measure of stuttering and other subject information for the stuttering subjects.

**Table 1.** Mean Stutterings (per minute) in 5-min of Dialogue, Type of Fluency Management and Hemispheric Alpha Ratios

| Subject | Mean Stutterings | Management | Ratios | | | |
|---|---|---|---|---|---|---|
| | | | RW | RGW | RRd | RGRd |
| 1 | 5.8 | Mont & EMG | .42 | .47 | .51 | .47 |
| 2 | 6.6 | Mont | .42 | .42 | .41 | .40 |
| 3 | 1.8 | Mont | .54 | .45 | .54 | .45 |
| 4 | 4.0 | Mont & DAF | .52 | .59 | .57 | .54 |
| 5 | 8.6 | Mont | .47 | .50 | .49 | .51 |
| 6 | 15.0 | Mont | .45 | .43 | .47 | .43 |
| 7 | 7.6 | Mont | .53 | .55 | .50 | .49 |
| 8 | 10.8 | Mont | .47 | .50 | .48 | .50 |
| 9 | 5.4 | Mont | .44 | .47 | .46 | .48 |
| 10 | 7.2 | Mont | .45 | .44 | .47 | .46 |
| 11 | 10.4 | Mont | .34 | .40 | .46 | .46 |
| 12 | 4.2 | Mont | .54 | .52 | .48 | .47 |

Mont = Monterey; EMG = EMG biofeedback; DAF = Delayed auditory feedback; R = Recall; RG = Recognition; W = Words; Rd = Connected reading.

## Stimuli

Four stimulus audiotapes were prepared. The stimuli were spoken by a male voice with general American dialect having no obvious articulatory or phonatory disorders. A 5-sec interval occurred between offset of a word and the next stimulus item. Two tapes contained 15 high-imagery nouns. All words had two syllables. The 15 words in the first list had a mean imagery value of 5.71 and those in list two of 5.82 using a 7-point scale reported by Paivio (1978). These stimuli were recorded using a cassette tape deck (Sony, Model TCK-5) and a condensor microphone (Sony, Model ECM-955).

Two additional tapes were prepared that contained a 3-min and 45-sec reading passage from *The Hardy Boys Series* (Dixon, 1959). This particular material was chosen because of the high imagery value of the words and the concrete nature of the story. Both passages were read by a male voice with a general American dialect having no obvious articulatory or phonatory disorders. Passage 1 contained a total of 772 words and passage 2 a total of 807 words. The test stimuli were presented at 65 dB, SPL through a speaker located in front of the subject at eye level 90 cm from the nasion.

## Apparatus

All electroencephalographic data were recorded in an electrically shielded, acoustically treated experimental chamber (Tracoustics, Model

RE-242). Separate recording systems were used for the right and left hemispheres. An AC preamplifier (Grass, 7P3) recorded the raw EEG signal for each hemisphere. The raw signal was interfaced with an 8- to 13-Hz Med Associates, Model EEG 500, 10-pole (rolloff -30 dB/octave) filter. The filtered alpha signal was fed into a Grass, 7P10, cumulative integrator using full rectification. Raw, filtered, and integrator channels were displayed on an ink-writing oscillograph (Grass, 74C-21 PAO) using Grass, 7DA, drivers (see Moore and Haynes [1980] for a more complete description of the EEG system).

## Procedure

Electrodes were attached over the left and right temporoparietal areas using electrode cream (Grass, EC2) for common reference recording at sites 30% of the intermeatal perimeter down from the vertex and 10% of the nasion–inion distance posterior from the intermeatal perimeter using Robbins and McAdam's (1974) measurement procedure. A reference electrode was attached to the vertex (CZ) and a ground electrode was located on the forehead at midline. The impedence of recording electrodes was measured using a Grass (Model EZM-1E) electrode impedence meter and was below 10k ohms whereas impedence between electrodes did not exceed 2k ohms.

Each recording system was calibrated using an external 10.5 Hz (1.73 volt, RMS) sine wave with the preamplifier amplitude calibrator set at 50 mv to allow adjustment of the cumulative integrator to reset at 40 mm within a 1-sec time epoch that equaled 1.05 mv/sec. Once this adjustment was made the integrator model was set to integrator amplitude and calibrated to reset at 40 mm. During recording the calibrated integrator amplitude mode was used (see Moore and Haynes [1980] for a complete description of the calibration procedures). Postcalibration measures revealed minimal or no fluctuations in precalibration adjustments between and within recording systems.

Following electrode placement and calibration procedures, each subject was seated in a comfortable chair in the dimly lit experimental chamber. Once the electrodes were connected to the electrode cable, the experimenter monitored the raw EEG to insure an adequate signal that was free of 60 Hz artifact. Following this, the subject was exposed to one of the stimulus conditions (words or connected reading) for one of the response tasks (recall or recognition) which was determined in accordance with a counterbalancing procedure. Prior to data gathering the subject was instructed to relax, keep his or her head immobile, keep his or her eyes closed, and try not to move. Before each tape presentation the subject was informed that at the end of the presentation he or she would be asked to write down information from memory about the material (recall) or asked to circle information about the material (recognition). Instructions were read to each subject by a research assistant. For the recall task of the word condition, subjects were required to write down as many words as they could recall. The connected reading condition required subjects to answer 10 questions in single descriptive words about the passage. The recognition task for the word condition required subjects to circle, from a list of 25, the words they recognized. The connected reading condition required subjects to answer 10 multiple choice questions about the material. Subjects were informed of task requirements prior to each presentation, and task requirements were performed by the unattended subjects, after being given response forms, in the experimental chamber. When the subject indicated that the recall or recognition task was completed the response forms were taken by an assistant. Conditions were separated by at least 3 min.

EEG data were gathered during the time of each stimulus presentation and a voice activated relay triggered the polygraph event marker to indicate the onset and offset of stimulus material for data reduction and analysis. Stuttering data were gathered prior to gathering EEG data in a dialogue speaking situation during a 5-min interval.

## Measurements

Measurements of integrated alpha amplitude obtained from the cumulative integrator channels constituted the primary data for analysis. The total and fractional number of 40-mm integrator resets were determined for each hemisphere for the time of stimulus presentation. A ratio score was computed to determine the relative amount of hemispheric participation for each subject for the various tasks and conditions. Reset data for the right (R) and left (L) hemispheres were used in the following formula: $R/(R + L)$. A score of 0.50 indicated an equal amount of alpha in each hemisphere. A score above 0.50 indicated more right-hemisphere alpha whereas a score less than 0.50 indicated more left-hemisphere alpha. Other measurements included the correct percentage for the word and connected reading conditions on the recall and recognition tasks. Measures of stuttering were obtained in a 5-min dialogue, averaged over the five 1-min intervals, and were defined as whole- and part-word repetitions and prolongations.

## Statistical Analyses

Hemisphere alpha asymmetry ratios were analyzed with a mixed effects analysis of variance (ANOVA) comprised of the between-subject variable of groups (stuttering males, nonstuttering males, nonstuttering females) and the within-subject variables of stimulus (words and connected reading) and memory task (recall and recognition). Means associated with significant F ratios were analyzed with the Newman-Keuls procedure (Winer, 1971). Subjects' recall and recognition correct score percentages for the stimulus and task conditions were also evaluated with a three-way mixed effects ANOVA and the Newman-Keuls test where appropriate.

Pearson correlational procedures (Glass and Stanley, 1970) were used to analyze the relationships between the hemispheric alpha ratios and measure of stuttering severity.

## RESULTS

### Analysis of Hemispheric Alpha Ratio Data

Table 2 presents the mean alpha ratio scores and standard deviations associated with the three main effects of groups, stimulus, and tasks. Although there are overlaps in the distribution of ratio scores from the three groups, the results of the ANOVA and Newman-Keuls tests (Winer, 1971) indicate that these scores were obtained from two statistically distinct subject populations.

Mean ratio scores for the three groups across stimulus and task conditions are shown in Figure 1. Because the group main effect was significant ($F = 3.81$, $df = 2/33$, $p < .033$) means comparisons tests, using the Newman-Keuls procedure, were computed. These tests revealed the mean of the stuttering males ($\overline{X} = 0.47$) to be significantly ($p < .05$) less than that for the males ($\overline{X} = 0.52$) and the females ($\overline{X} = 0.51$). The difference between the men's and the women's mean ratio scores was not found to be significant when tested at the $p = .05$ level. Thus, the stuttering males demonstrated, as a group, significantly greater right hem-

**Table 2.** Ratio Means ($\bar{X}$) and Standard Deviations (SD) for the Males, Females, and Stuttering Males for Recall and Recognition of Words and Information From Connected Reading Passages

| | | | Groups | | |
|---|---|---|---|---|---|
| Stimulus | Task | | Males | Females | Stutterers |
| Words | Recall | $\bar{X}$ | 0.52 | 0.51 | 0.45 |
| | | SD | 0.08 | 0.05 | 0.06 |
| Words | Recognition | $\bar{X}$ | 0.52 | 0.51 | 0.47 |
| | | SD | 0.10 | 0.03 | 0.05 |
| Connected reading | Recall | $\bar{X}$ | 0.52 | 0.51 | 0.47 |
| | | SD | 0.06 | 0.03 | 0.03 |
| Connected reading | Recognition | $\bar{X}$ | 0.52 | 0.51 | 0.48 |
| | | SD | 0.07 | 0.02 | 0.03 |

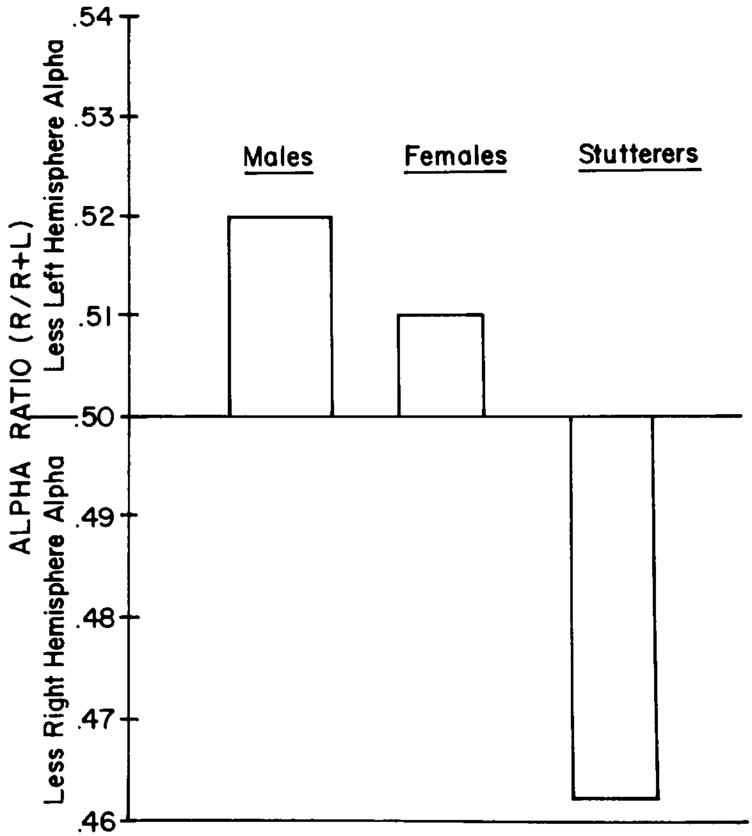


**Figure 1.** Mean alpha ratios for the three groups.

ispheric alpha suppression whereas the nonstuttering males and females showed greater relative left hemispheric alpha suppression.

The two main effects of stimulus ($F = 1.02$, $df = 1/33$, $p > .30$) and task ($F = 1.02$, $df = 1/33$, $p > .31$) were not found to be significant, nor were the two-way interactions of stimulus × group ($F = 1.26$, $df = 2/33$, $p > .29$), task × group ($F = 0.81$, $df = 2/33$, $p > .45$), and stimulus × task ($F = 0.08$, $df = 1/33$, $p > .77$) or the three-way interaction of group × stimulus × task ($F = 0.23$, $df = 2/33$, $p > .79$). These findings indicated that the stutterers had greater right alpha suppression across all combinations of stimulus and task conditions as compared to both male and female nonstutterers who demonstrated consistent left hemispheric alpha suppression ratios (Table 1).

## Analysis of Recall and Recognition Tests Scores for the Word List and Connected Reading Passage

Table 3 presents the mean percentage correct scores and standard deviations for the three main effects of group, stimulus, task, and the group grand means.

The group main effect was found to be significant ($F = 4.32$, $df = 2/33$, $p < .002$) and, therefore, means comparison tests with the Newman-Keuls procedure were undertaken. These tests revealed the stutterers' mean score of 64.44 to be significantly less than the men's ($\bar{X} = 77.67$) and women's ($\bar{X} = 80.69$) mean scores. The difference between the men's and women's mean scores were not found to be significant.

The mean percentage correct for the word stimulus condition ($\bar{X} = 67.42$), when collapsed across groups and tasks, was found to be significantly less ($F = 20.18$, $df = 1/33$, $p < .001$) than the percentage correct score for the connected reading passage ($\bar{X} = 81.11$). The mean percentage correct for the recall task ($\bar{X} = 63.07$), collapsed over groups and stimuli, was also found to be significantly less ($F = 85.63$, $df = 1/33$, $p < .0001$) than the percentage correct score for the recognition task ($\bar{X}$ 85.46). The two-way interaction between these two factors (stimulus $\times$ task) was also found to be significant ($F = 43.71$, $df = 1/33$, $p < .0001$). Means comparison tests indicated that the mean for recall of words ($\bar{X} = 49.47$) was significantly less ($p < .01$) than the mean for recall of information from the connected reading passage ($\bar{X} = 76.67$), recognition of words ($\bar{X} = 85.36$), and recognition of information from the connected reading passage ($\bar{X} = 85.56$). Recall of information from the connected reading passage was also found to be significantly less than recognition of words ($p < .01$) and recognition of information from the connected reading passage ($p < .05$). No significant differences were found for the

**Table 3.** Percent Correct Means ($\bar{X}$) and Standard Deviations (SD) for the Males, Females, and Stuttering Males for Recall and Recognition of Words and Information From Connected Reading Passages

| | | | Groups | | |
|---|---|---|---|---|---|
| Stimulus | Task | | Males | Females | Stutterers |
| Words | Recall | $\bar{X}$ | 52.750 | 53.916 | 41.750 |
| | | SD | 19.932 | 18.382 | 15.106 |
| Words | Recognition | $\bar{X}$ | 88.750 | 92.166 | 75.166 |
| | | SD | 11.450 | 7.371 | 24.844 |
| Connected reading | Recall | $\bar{X}$ | 79.166 | 83.333 | 67.500 |
| | | SD | 21.087 | 18.748 | 30.488 |
| Connected reading | Recognition | $\bar{X}$ | 90.000 | 93.333 | 73.333 |
| | | SD | 12.792 | 6.513 | 29.644 |
| Grand means | | | 77.666 | 80.687 | 64.437 |

**Table 4.** Correlation Matrix for the Measure of Stuttering Severity and the Four Hemispheric Alpha Asymmetry Ratios

| Variable | Mean Stutterings | Ratios | | | |
|---|---|---|---|---|---|
| | | RW | RGW | RRd | RGRd |
| *Mean stutterings* | | | | | |
| RW | −0.59[a] | | | | |
| RGW | −0.23 | 0.71[b] | | | |
| RRd | −0.48[a] | 0.59[a] | 0.66[b] | | |
| RGRd | −0.01 | 0.47 | 0.77[b] | 0.70[b] | |

[a] $p = .05$
[b] $p = .01$
R = Recall; RG = Recogntion; W = Words; Rd = Connected Reading

two recognition tasks. These analyses revealed the recall scores to be significantly lower than the recognition scores for both stimulus conditions with words being significantly lower than information from the connected reading passage.

The 2 two-way interactions of stimulus × group ($F = 0.10$, $df = 2/33$, $p > .90$) and task × group ($F = 0.33$, $df = 2/33$, $p > .71$) and the three-way interaction of group × stimulus × task ($F = 0.05$, $df = 2/33$, $p > .94$) were not found to be significant. These findings revealed the stutterers to be consistently lower than the nonstuttering groups for the various stimulus and task combinations (Table 2).

## Correlational Analyzes

The average number of stutterings for the 5-min dialogue interval and the hemispheric alpha asymmetry ratios were analyzed with Pearson correlational procedures. Results from this procedure are reported in Table 4.

Two correlations between stuttering frequency and hemispheric alpha ratios were found to be significant when tested at the $p = .05$ level: stuttering frequency and the ratio for the word recall condition ($r = -0.58$) and stuttering frequency and the reading passage recall condition ($r = -0.48$). Table 4 also presents significant positive correlations between the ratios for the various conditions, all of which were significant with the exception of the correlation between the recall of words and recognition for the connected reading task.

## DISCUSSION

In this investigation the hemispheric alpha ratios of a group of 12 male stutterers were compared to those of 12 nonstuttering males and 12 nonstuttering females for word lists and connected reading passages requiring memory tasks of recall and recognition. Although no main or interaction effects were found to be significant involving the stimulus or task conditions, a significant group main effect was found. This significant group main effect indicated that the stuttering males, as compared to both the nonstuttering males and females, had greater right hemispheric alpha suppression across stimulus and task conditions. These results, given the rationale upon which the hemispheric alpha asymmetry procedure is based, indicate that the stuttering males were more dependent upon right hemispheric information processing strategies when compared with their fluent male and female counterparts. These observations support the notion of many more stuttering individuals in contrast to nonstuttering individuals employing right hemispheric strategies for the processing of meaningful auditory and visual linguistic stimuli (Curry and Gregory, 1969; Perrin and Eisenson, 1970; Zimmermann and Knott, 1974; Sommers, Brady, and Moore, 1975; Ponsford et al., 1975; Moore, 1976; Moore and Lang, 1977; Plakosh, 1978; Wood et al., 1980; Moore and Haynes, 1980; Moore and Lorendo, 1980; Moore, Craven, and Faber, 1982; Hand and Haynes, 1983; Boberg et al., 1983).

An important finding of this investigation was two negative correlations that involved the recall tasks and the stuttering frequency. Research findings have shown that the right hemisphere is capable of processing information in a recognition mode and is less capable of verbal recall (Faber-Clark and Moore, 1983). Haynes and Moore (1981) have suggested that this difference between memory tasks may reflect the short- and long-term memory and coding–retrieval strategy differences between the hemispheres. This finding has important implications for the interpretation of results from investigations that seek to understand the relationship between hemispheric processing and stuttering. If severity is left uncontrolled we may expect to find apparently inconsistent results across studies that have used comparable procedures and methods. Hemispheric activation in stutterers does not appear to be a dichotomous variable but rather a continuous variable. The relationship of stuttering severity to hemispheric processing may prove to be a critical variable in the interpretation of studies that have reported subgroups of stutterers showing left or right hemispheric processing and may help to understand the overlap in the distributions between stutterers and nonstutterers seen in the processing literature. Significant negative correlations between stuttering and alpha ratios were found only for the recall condition, which suggests the need to interpret results from hemispheric processing studies with stutterers in regard to task demands relative to the processing resources of the cerebral hemispheres. The type and the duration of clinical management that the subjects have received may also be a variable that can influence the results from hemispheric processing research and will need to be given greater consideration in future studies.

Consistent with findings reported by Daly (1981) and Moore, Craven, and Faber (1982), a reduced capacity for stutterers to recall words from lists and connected reading passages was found. This finding may be a reflection of the right hemisphere's shorter span for verbal short-term memory (Zaidel, 1979). The stutterers' recognition scores were also significantly less than those of the nonstutterers. Interestingly, Moore and Haynes (1980) did not find stutterers to differ from nonstutterers in "comprehension" (recognition) of connected verbal material. The reason for this difference may be accounted for by the examination of the material used in the two studies. Moore and Haynes had subjects listen to a 3-min reading passage from the congressional record whereas we used reading material that was concrete and at approximately the 7th grade reading level (*The Hardy Boys*). It is conceivable that Moore and Haynes's previous results reflected a difficulty factor (and a possible attention factor considering the perceived banality of the material) resulting in a suppression in both groups' recognition scores. These observations suggest that the nature of the stimulus material used is an important independent variable that must be considered when making comparisons between investigations. (See Faber-Clark and Moore [1983] for a discussion of hemispheric activation and recall and recognition relative to stimulus material.)

In one of our previous reports (Moore, Craven, and Faber, 1982), we recorded alpha during the first 4 sec following word offset. In the current study, we gathered alpha suppression data during stimulus presentations only. Both procedures have shown greater right hemisphere alpha suppression in male stutterers. This observation indicates that initial hemispheric activation during stimulus presentations is similar to hemispheric activation during "storages" stages of processing for stutterers, at least within the constraints of the temporal parameters explored in these two studies.

As reported in the beginning of this article, an examination of the linguistic variables associated with increased stuttering and hemispheric processing supports a hypothesis of greater right hemispheric activation in many more stutterers than nonstutterers. As the work of Dennis and her associates has shown (Dennis, 1980a, 1980b; Dennis and Whitaker, 1976), the language of the right hemisphere is qualitatively different from that of the left hemisphere. In fact, right hemispheric processing has been found to be related to other speech–language disorders in addition to stuttering (q.v., Segalowitz, 1983; Thatcher, 1980; Ludlow and Doran-Quine, 1979; Segalowitz and Gruber, 1977) and suggests that we go beyond the observation of peripheral speech behavior in attempting to understand the etiology of disordered human communication. The relationship between the variables that are known to increase stuttering and those that the right hemisphere is less capable or incapable of processing has not been systematically investigated and may help to understand the complex relationship between brain and stuttered verbal behavior. The language deficits (q.v., Homzie and Lindsay, 1984) seen in many stutterers may reflect the use of right hemispheric information processing strategies.

There is also recent data (Moore, 1984; Boberg et al., 1983; Wood et al., 1980) that provide evidence of a shift from right to left hemispheric activation in stutterers with increased fluency. In the studies by Boberg and associates and Wood and associates, the right hemisphere has been implicated in motor programming in stutterers with reduced alpha and increased blood flow in the right anterior hemisphere during periods of increased stuttering. These findings support a motor programming disruption hypothesis of stuttering (Kent, 1983; Moore and Haynes, 1980) linked to the use of right hemispheric strategies–resources for motoric-programming (a reflection, perhaps, of the longer time required by the right hemisphere in information processing [Kent, 1983; Thatcher, 1980]). These findings seem to be related to the current finding of a relationship between stuttering severity and right hemispheric activation during recall tasks and underscore the need for future investigations to study the co-variation between measures of disfluency and hemispheric processing.

This project was supported, in part, by a grant for scholarly and creative activity awarded to W. H. Moore, Jr., by California State University, Long Beach. I would like to thank the following laboratory assistants for their help during the data gathering stages of this investigation: Paula Jenkins, David McFarland, Cece Lux, Scott Swinehart, Lynne Gower, Liz Isaacs, and Cristy Clouse. Special thanks to Linda Rendall for preparation and word processing of the manuscript.

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