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SPEECH FLUENCY AND HAND PERFORMANCE ON A SEQUENTIAL TAPPING TASK IN LEFT- AND RIGHT-HANDED STUTTERERS AND NONSTUTTERERS

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The purpose of this study was to examine hemispheric functioning in right- and left-handed stutterers and nonstutterers using tasks that require concurrent speech and unimanual sequential tapping activity. Twenty adult stutterers (15 right-handers and 5 left-handers) and 20 adult nonstutterers (15 right-handers and 5 left-handers) performed four experimental tasks: tapping, tapping–spontaneous speech, tapping–reading, and tapping–singing. Subjects performed each task for 120 sec (8 trials of 15 sec per trial), alternating tapping hands after each trial.

Results indicated that subjects' speech and manual performance were hindered by the concurrent motor activities and that stutterers demonstrated more interference than the nonstutterers. In addition, the tapping–spontaneous speech task resulted in the greatest interfering condition. Results suggest that both intrahemispheric competition and interhemispheric integration processes are involved in the regulation of speech and motor activities. Moreover, the possibility exists that a key difference between stutterers and nonstutterers may be linked to the degree to which these activities are synchronized.

INTRODUCTION

Studies with normal speaking adults have demonstrated that speech concurrent with manual activity interferes with their manual performance. Specifically, normal speakers have poorer dominant hand performance compared to their nondominant performance (Hicks, 1975; Hicks et al., 1978; Lomas and Kimura, 1976; Kinsbourne and Cook, 1971; Wolff and Cohen, 1980; Hellige and Longstreth, 1981; Thornton and Peters, 1982). However, the degree of interference varies as a function of such factors as speech task complexity (Hicks, 1975; Hicks et al., 1978; Thornton and Peters, 1982), demand characteristics of the task (Lomas, 1980; Nachshon

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and Carmon, 1975; Thornton and Peters, 1982), and subject handedness (Lomas and Kimura, 1976).

Several investigators emphasize the role of intrahemispheric competition between speech and motor control systems to explain interference effects in speech and concurrent manual tasks (Kinsbourne and Cook, 1971; Lomas and Kimura, 1976). Lomas and Kimura (1976) suggest that the left parietal region of the brain plays an important role in mediating competition between speaking and concurrent manual performance. Other investigators suggest that interference may occur interhemispherically as well. Wolff and Cohen (1980) required normal speaking adults to perform unimanual and bimanual motor tasks while concurrently speaking nursery rhymes or reading unfamiliar texts. Their results suggest that normal speakers may shift control of specific functions between the hemispheres particularly when coordinated activities require one hemisphere to inhibit the function of the other hemisphere. Finally, Kelso, Tuller, and Harris (1983) argue that concepts such as interference, competition, or dominance cannot fully account for the interdependence of speech and motor control systems because they are insensitive to the dynamic organizational properties that regulate linkages between the two systems.

Recently, Fitzgerald, Cooke, and Greiner (1984) evaluated speech fluency and bimanual handwriting performance in right-handed stutterers and nonstutterers. Stutterers performed more poorly than nonstutterers on all speech measures and showed significantly poorer nondominant hand performance during the simultaneous handwriting task. Fitzgerald and coworkers argued that idiosyncratic neural control processes for speech and motor systems require temporal, spatial, and motor integration interhemispherically for the production of fluent speech. Thus, speech disfluency would involve disorganization in the regulatory processes that control interhemispheric coordination of speech and motor systems, at least for right-handed individuals. Their argument, however, is constrained by at least two factors: first, the tasks used did not involve concurrent speech and motor task performance; second, the results applied only to right-handed stutterers and nonstutterers.

In general, research with stutterers has not used the speech and the concurrent manual task to study inter- or intrahemispheric function. In part, this may reflect the fact that the focus of such research with normal speakers has been on cerebral lateral specialization of function rather than on questions relating to the regulation of speech fluency. Thus, studies of speech and concurrent manual activity with normal speakers emphasize the effects of speech on motor performance and neglect the effects of motor performance on speech. Therefore, the purpose of the current study was to examine hemispheric processes in right- and left-handed stutterers and nonstutterers as reflected by their performance on tasks requiring speech concurrent with manual activity.

METHOD

Subjects

The subjects were 40 men, including 15 right-handed stutterers (mean age = 25.9 yr; range, 16–54), 5 left-handed stutterers (mean age = 22 yr; range, 16–34); 15 right-handed nonstutterers (mean age = 27.2 yr; range, 16–34), and 5 left-handed nonstutterers (mean age = 26.2 yr; range, 20–42). Handedness was determined by performance on the Harris Test of Lateral Dominance (Harris, 1957; Sappington, 1980). Stutterers were recruited through the Michigan State University Speech and Hearing Clinic, whereas nonstutterers were recruited from psychology classes at the same university. All subjects received descriptions of the study and gave their informed consent prior to participating.

Design

The sequence of events involved assessment of pretest speech followed by the presentation of experimental tasks requiring speech concurrent with unimanual sequential finger tapping. A Leuden Square design was used to randomly distribute the order of concurrent speech tasks (silent tapping, tapping while speaking spontaneously, tapping while reading aloud, tapping while singing) over four blocks of eight trials per block (Table 1). The first 2 blocks of 16 trials for subjects assigned to Condition

Table 1. Leuden Square Experimental Design Used to Investigate Speech Fluency and Motor Performance in Stutterers and Nonstutterers

	Subject					Subject			
Condition A	n_1	n_2	n_3	n_4	Condition B	n_5	n_6	n_7	n_8
Left, Right	1	2	3	4	Right, Left	1	2	3	4
	2	4	1	3		2	4	1	3
	3	1	4	2		3	1	4	2
	4	3	2	1		4	3	2	1
Left, Right	2	1	4	3	Right, Left	2	1	4	3
	4	2	3	1		4	2	3	1
	1	3	2	4		1	3	2	4
	3	4	1	2		3	4	1	2
Right, Left	4	3	2	1	Left, Right	4	3	2	1
	3	1	4	2		3	1	4	2
	2	4	1	3		2	4	1	3
	1	2	3	4		1	2	3	4
Right, Left	3	4	1	2	Left, Right	3	4	1	2
	1	3	2	4		1	3	2	4
	4	2	3	1		4	2	3	1
	2	1	4	3		2	1	4	3

Task 1 = silent tapping; Task 2 = tapping while speaking spontaneously; Task 3 = tapping while reading; Task 4 = tapping while singing.

A involved tapping sequences with the left, then the right hand. The third and fourth trial blocks involved right, then left hand tapping for 16 trials. Condition B was exactly the opposite of Condition A with respect to which hand led during the block. but used the same random order of concurrent speech tasks that were used in Condition A. Each experimental trial lasted 15 sec and there was a 30-sec rest period between tasks. Each subject, therefore, was in the experiment for approximately 20 min.

Procedure

Tapping Task. Subjects performed a left- and right-hand unimanual sequential finger tapping task in each of four experimental conditions. Three of the four conditions (spontaneous speech, reading aloud, singing) required subjects to speak concurrently with tapping. The remaining task (silent tapping) only involved tapping. The tapping task was adapted from that used by Lomas and Kimura (1976). The tapping apparatus contained eight tapping keys, four each for the left and right sides of the apparatus. Subjects were instructed to tap sequentially as fast as they could beginning with the index finger, tapping outward to the little finger, and returning to the index finger to begin tapping again. Light offset signaled the beginning of a trial, light onset signaled its end. Half of the subjects started with the right hand and half with the left hand, then alternated hands on each trial thereafter. Subjects were not able to see their hands while tapping because an opaque screen was placed between their hands and their line of sight. The keys on the tapping apparatus sent digital signals to a computer that recorded individual key presses. Each time the subject pressed the index key, the computer coded a new sequence. Data were scored for correct tapping sequences (e.g., 1, 2, 3, 4) and total tapping rate per trial.

Speech Tasks. All speech tasks were presented concurrently with tapping. For spontaneous speech, subjects were instructed to say whatever came to mind in response to a word spoken by the experimenter. However, they were not permitted to give simple word associations, but rather had to produce complete sentences. The reading condition involved the use of two 155-word paragraphs, one for the left hand and one for the right hand. The paragraphs were long enough so that a subject could not finish them before the end of a trial. Order of paragraphs and order of starting hand were counterbalanced across the subjects. The singing condition required subjects to sing "Row, row, row your boat" and to repeat it if they finished before a trial ended. Subjects did not know which speech task was to be performed until just prior to the onset of a trial. All speech samples were recorded on audiotape.

Scores for speech fluency were derived for each of the speech tasks.

Disfluencies were defined as repetitions (whole word and syllable) or audible prolongations. A word was considered fluent or disfluent regardless of the number and the type of within-word behaviors produced. A fluency percentage was determined separately for each of the speech tasks by dividing the number of fluent words by the total number of words and multiplying by 100. For the reading task, determination of speech fluency only involved the middle 100 words of the 155-word passage. Speech fluency was scored by two raters who received a training session during which they practiced scoring speech fluency using the fluency/disfluency rating system described above. Pearson Product correlations were used to calculate interrater reliabilities, which ranged from 0.88 to 1.00, with a mean reliability of 0.96 across all speech tasks.

Speech rate, defined as the number of words spoken per min, was calculated by determining the number of words spoken per 15-sec trial and multiplying by 4. Speech rate was determined separately for each of the speech tasks.

Pretest Session. After receiving a general description of the tapping and speech tasks, the subject was seated facing the tapping apparatus. There were four 30-sec practice trials, two for each hand. During the first two practice trials subjects were able to see the keys while they were tapping. During the last two practice trials they could not see the keys, as was the case during all experimental trials. After the tapping practice trials, subjects received practice with the speech tasks. Each subject was asked to speak spontaneously for 3 min, sing two rounds of "Row, row, row your boat," and read aloud a 155-word passage. Speech fluency and speech rate scores were derived as described above.

RESULTS

Sequential Tapping Rates

Handedness. The only significant effect revealed by analysis of variance was a hand preference × hand used for tapping interaction ($F(1,36) = 7.08$, $p < .01$). Tapping rates were highest (least interfered with) for the left hand of left-handed subjects.

Speech Groups. Figure 1 presents the mean sequential tapping rates (taps per 15-sec trial) for stutterers and nonstutterers during each of the experimental tasks. Analysis of variance revealed significant main effects for tasks ($F(3,108) = 11.68$, $p < .0005$) and trial blocks ($F(3,108) = 46.90$, $p < .0005$). Interpretation of the trial blocks effect is straightforward: tapping rates increased over trials. Moreover, because trial blocks did not interact with any other effect, particularly with tasks, it seems rea-

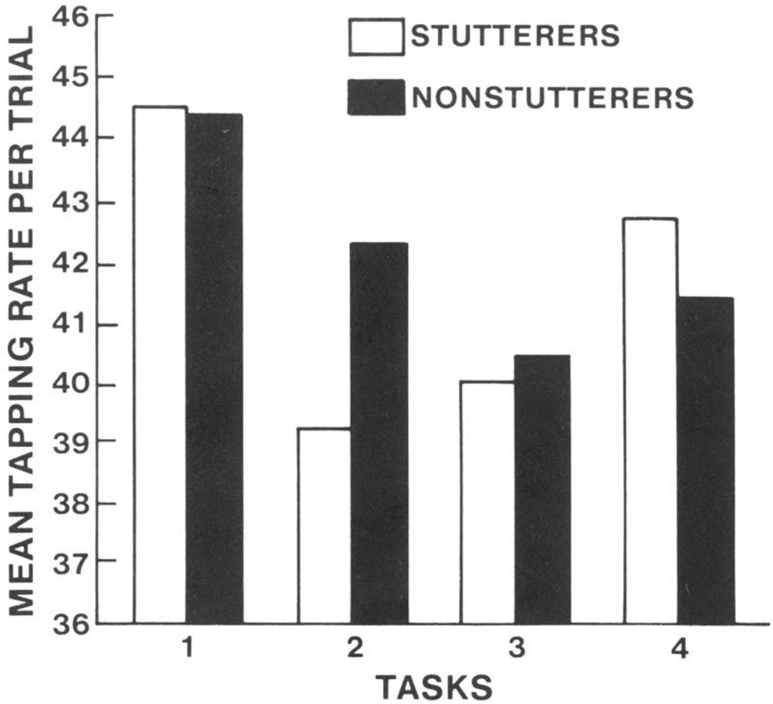

Figure 1. Mean tapping rate per trial during each experimental task for stutterers and nonstutterers (1 = silent tapping; 2 = spontaneous speech; 3 = reading; 4 = singing).

sonable to conclude that tapping rate increases were similar within each task.

Interpretation of the tasks main effect, however, must be considered in relation to a significant groups × tasks interaction ($F(3,108) = 2.68$, $p < .05$). Sheffe post-hoc comparisons indicated that the group × task interaction could be accounted for by stutterers' significantly slower tapping rates during concurrent spontaneous speech ($F(3,108) = 7.77$, $p < .01$). Differences between stutterers and nonstutterers for reading, singing, and silent tapping were not significant. Another way to illustrate this effect involves computation of percentage reduction scores using Hellige and Longstreth's (1981) formula:

$$TO = \frac{\mathrm{TV}}{\mathrm{TO}} \times 100.$$

(TO refers to the mean taps per trial during the silent condition and TV refers to the mean taps per trial during any of the concurrent motor performance–speech conditions.) This analysis yielded the following percentage reduction scores, cited within concurrent tasks first for stutterers, then for nonstutterers: spontaneous speech (12.16% vs. 4.51%), reading (9.68% vs. 8.8%), and singing (4.05% vs. 6.09%). The difference in percentage reduction for spontaneous speech was the only comparison to reach statistical significance.

Correct Tapping Sequence

Handedness. The main effect for hand-used-for-tapping was significant ($F(1,36) = 5.61$, $p < .023$). Examination of the means indicated that correct tapping sequences were highest for the left hand of left-handers (41.0) followed by the right hand (38.3)and left hand (37.4) of right-handers, and the right hand (32.9) of left-handers.

Figure 2 shows the mean correct sequential taps per trial as a function of subject handedness and hand used for tapping. Sheffe post-hoc comparisons were used to examine the hand preference × hand-used-for-tapping interaction illustrated in Figure 2. Compared to the silent tapping task, the right hand sequential tapping of right-handers was significncatly poorer during spontaneous speech ($F(3,108) = 12.75$, $p < .01$) and reading ($F(3,108) = 8.42$, $p < .05$). There were no differences between silent tapping and singing. In addition, spontaneous speech and reading also

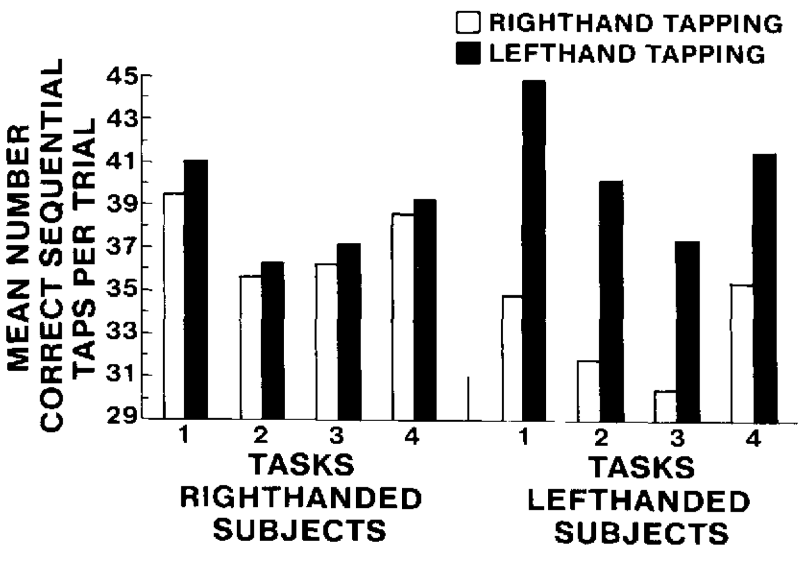

Figure 2. Mean number of correct sequential taps for right- and left-handed subjects as a function of hand used for tapping during each experimental task (1 = silent tapping; 2 = spontaneous speech; 3 = reading; 4 = singing).

interfered with left hand sequential tapping in right-handed subjects ($F(3,108) = 8.91$, $p < .05$) and ($F(3,108) = 15.78$, $p < .01$), respectively.

Figure 2 also shows data for left-handed subjects. Post-hoc comparison indicated significantly poorer right hand sequential tapping for reading ($F(3,108) = 14.89$, $p < .01$) but not for any other task when compared with silent tapping. Conversely, all speech tasks were associated with poorer correct sequential tapping in the left hand of left-handed subjects when compared with silent tapping: spontaneous speech ($F(3,108) = 22.14$, $p < .01$), reading ($F(3,108) = 4.13$, $p < .05$).

Speech Groups. Analysis of variance revealed a significant main effect for tasks ($F(3,108) = 13.18$, $p < .0005$). The mean number of taps in correct sequence for each of the four tasks was as follows: silent tapping (40.1), singing (38.7), spontaneous speech (35.9), and reading (35.8). A significant main effect for trial blocks ($F(3,108) = 5.26$, $p < .002$) reflects the fact that subjects improved the number of correct tapping sequences over trials. There were no interactions involving speech groups.

Speech Rate

Table 2 summarizes mean speech rates during pretest and test sessions for each speech × handedness subgroup. Analysis of variance failed to disclose any significant differences between or within groups for any comparisons involving pretest speech rates.

For experimental tasks, however, analysis of variance revealed a main effect for groups ($F(1,36) = 6.61$, $p < .01$) indicating that stutterers' speech rate (mean = 144 words/min) was significantly slower than that

Table 2. Mean Speech Rates (words/min) and Percent Change From Pretest to Test for Right- and Left-handed Stutterers and Nonstutterers During Each of Three Concurrent Speech and Unimanual Sequential Finger Tapping Tasks

	Concurrent Speech Task								
	Spontaneous			Reading			Singing		
Group	Pretest	Test	% Change	Pretest	Test	% Change	Pretest	Test	% Change
Right-handed stutterers	127	86.5	31.8	177	172	−2.8	153	161	+5.2
Left-handed stutterers	131	109	16.7	201	214	+6.5	164	176	+7.3
Right-handed nonstutterers	135	101.5	24.8	184	194	+5.4	161	177	+9.9
Left-handed nonstutterers	157	116.5	25.8	194	204	+5.2	172	174	+1.7

for nonstutterers (mean = 172 words/min). In addition, a main effect for task ($F(2,72) = 84.49$, $p < .0005$) showed significantly faster speech rates for all subjects combined when reading (mean = 195 words/min) than when singing (mean = 172 words/min) or when speaking spontaneously (mean = 100 words/min).

Data in Table 2 illustrate the substantial reduction in speech rate that occurred for all groups during the concurrent spontaneous speech task. The percentage decline from pretest levels was greatest for right-handed stutterers, followed by left-handed nonstutterers, right-handed nonstutterers, and left-handed stutterers. The pretest differences between left-handed stutterers and right-handed nonstutterers, though slight, actually reversed during the spontaneous speech task, such that left-handed stutterers actually had a faster rate than right-handed nonstutterers. Conversely, in 7 of 8 possible comparisons involving pretest–test reading and singing rates, rates actually showed slight increases over pretest levels.

Finally, a main effect for trial blocks ($F(2,72) = 3.85$, $p < .02$) must be interpreted relative to a tasks × trial blocks interaction ($F(6,216) = 9.20$, $p < .0005$). Although there was a general increase in speech rates over trials, spontaneous speech rate decreased from trial block 1 to trial block 2. This exception to the general effect most likely was due to the high initial spontaneous speech rate during trial block 1 for nonstutterers (mean = 126.3) as compared to the rate for stutterers (mean = 96.8).

Speech Fluency

As indicated in Table 3, significant differences were found for pretest speech fluency: stutterers were significantly less fluent than nonstutter-

Table 3. Percent Mean Speech Fluency and Pretest–Test Difference (D) for Right- and Left-handed Stutterers and Nonstutterers During Each of Three Concurrent Speech and Unimanual Sequential Finger Tapping Tasks

	Concurrent Speech Task (percent fluency)								
	Spontaneous			Reading			Singing		
Group	Pretest	Test	(D)	Pretest	Test	(D)	Pretest	Test	(D)
Right-handed stutterers	88.0	78.3	−9.7	96.7	96.9	+0.2	99.3	99.6	+0.3
Left-handed stutterers	89.7	86.2	−3.5	99.6	99.5	−0.1	98.9	99.2	−0.3
Right-handed nonstutterers	98.9	91.0	−7.9	99.2	99.3	+0.1	100	99.2	−0.8
Left-handed nonstutterers	97.9	92.3	−5.6	98.8	99.5	0.3	100	99.8	- 0.2

ers, but only during the spontaneous speech task ($F(1,36) = 5.05$, $p < .04$). Although there was no main effect for handedness, every group × handedness comparison indicated significantly poorer ($p < .05$) speech fluency in stutterers than in nonstutterers during spontaneous speech. Note, for example, that regardless of handedness, stutterers' pretest fluency scores were 9% to 12% lower than those for nonstutterers (column 1, Table 3). Not only do these findings confirm the fact that stutterers and nonstutterers differed in their pretest speech fluency, but they also point out the relatively unimportant influence of handedness in these differences. Finally, it is important to note that no differences of any kind occurred in pretest speech fluency for the reading or singing conditions.

Analysis of variance on data obtained from the experimental tasks revealed significant main effects for groups ($F(1,36) = 5.66$, $p < .023$) and tasks ($F(2,72) = 35.46$, $p < .0005$), which were compromised by a group × tasks interaction ($F(2,72) = 4.72$, $p < .012$). Sheffe post-hoc comparisons indicated that stutterers were more disfluent than nonstutterers but only during spontaneous speech ($F(2,72) = 8.75$, $p < .01$).

Data in Table 3 also indicate that the greatest pretest–test decline in fluency occurred in the concurrent spontaneous speech task for right-handed stutterers, followed in order by right-handed nonstutterers, left-handed nonstutterers, and left-handed stutterers.

Scheffe post-hoc comparisons on data summarized in Table 4 suggest that right-handed stutterers were more disfluent than right-handed nonstutterers when tapping with either the right or left hand during spontaneous speech. Left-handed stutterers, however, were only more disfluent than left-handed nonstutterers when tapping with the left hand. Again, there were no significant differences for reading or singing.

Table 4. Speech Fluency Percentages During Concurrent Speech and Unimanual Sequential Finger Tapping in Right- and Left-handed Stutterers and Nonstutterers as a Function of Hand Used for Tapping

	Concurrent Speech Task					
	Spontaneous (%) Tapping Hand		Reading (%) Tapping Hand		Singing (%) Tapping Hand	
Group	Right	Left	Right	Left	Right	Left
Right-handed stutterers	76.6	80.0	97.8	96.0	99.6	99.6
Left-handed stutterers	89.2	83.2	99.5	99.1	99.6	98.9
Right-handed nonstutterers	90.0	91.6	99.5	99.6	99.8	99.8
Left-handed nonstutterers	92.7	92.1	99.3	99.8	99.8	99.9

DISCUSSION

The purpose of this study was to examine hemispheric functioning in right- and left-handed stutterers and nonstutterers using tasks that require concurrent speech and sequential manual activity. Data were analyzed to determine the effects of the concurrent tasks on manual performance as well as speech fluency and speech rate.

Typically, the concurrent task is used to study lateral specialization in normal speaking right-handed adults, with manual performance serving as the index of lateral organization. In the current study, interference in the right hand of right-handed subjects supports intrahemispheric competition theories advanced to account for the disruptive effect of speech on concurrent manual performance (Lomas and Kimura, 1976). Some investigators attribute interference effects to an imbalance between the activation and inhibition of speech and motor control systems of the left hemisphere (Denenberg, 1980; Lomas, 1980; Young et al., 1983). Interference also occurred, however, in the left hand of right-handed subjects, suggesting that right hemispheric activity also is involved. Such interhemispheric processing has been related to the left hemisphere's ability (or inability) to inhibit the function of right hemisphere motor activity (Wolff and Cohen, 1980).

The performance of left-handed subjects also supports the interhemispheric coordination view. Interference in both hands of left-handed subjects is consistent with the view that there is a stronger tendency for bilateral organization in left-handers than in right-handers (Porac and Cohen, 1977). Moreover, interference affected the left hand of left-handers more than the right hand. For example, all speech tasks interfered with the left hand, whereas only the reading task interfered with the right hand of left-handers. Because nearly 70% of left-handers have speech represented in the left hemisphere, intrahemispheric competition should produce more right hand interference than left hand interference. Greater bilateral organization, on the other hand, would compromise the left hemisphere's ability to inhibit the right hemisphere's activation, thereby producing greater interference in the temporal coordination of left- and right-hemisphere motor control systems (Denenberg, 1980; Fitzgerald et al., 1984). Thus, an imbalance between right hemisphere activation and left hemisphere inhibition could account for both the higher pretest tapping rates for the left hand of left-handers, and the greater interference in left hand function during the concurrent tasks. For right hand tapping in left-handers, intrahemispheric competition would not be as great and interference with right hand manual activity would be attenuated.

Peters (1983) argues that temporal regulation is the key executive function of a laterally specialized hemisphere. Inasmuch as the speech musculature and the sequencing of movements involved in speech require fine-tuned temporal regulation, disturbances in the motor lead control of the left hemisphere should lead to disruption of sequential manual performance during concurrent speech and manual tasks. For right-handed subjects, disruption seems to involve primarily intrahemispheric competition, whereas interhemispheric coordination seems to be a more important factor for left-handers. In each instance, the activation–inhibition imbalance would disrupt the timing of neural control processes regulating the integration of speech and motor activity (Kelso, Tuller, and Harris, 1983).

Handedness was only one of two organismic variables of interest in this study; the other was speech fluency. With respect to manual interference as a function of speech fluency, the only significant effect occurred in the spontaneous speech task in which stutterers had slower tapping rates than nonstutterers, regardless of the hand used for tapping or subject's handedness. This is interesting because hand differences do differentiate stutterers from nonstutterers when they perform bimanual writing tasks. For example, Fitzgerald and colleagues (1984) found poorer left hand performance among right-handed stutterers than nonstutterers.

One strategy for optimizing performance in the concurrent task would be to slow the rate of manual activity, speech, or both, in an effort to gain maximum control of one of the component processes or to allow sufficient time for integration of speech and motor movements (Helm-Estabrooks, 1983). Because tapping rates did not slow down during spontaneous speech, whereas speech rates did, subjects apparently allocated less attention to speech than they did to tapping during the spontaneous speech condition. Conversely, tapping rates for reading and singing tasks were higher than those for spontaneous speech. Singing and, to a lesser extent, reading provide inherent rhythmic cues that could serve to synchronize motor speech functions. For example, "Row, row, row your boat," has a compound duple meter (6/8 time). Because the right hemisphere appears to be specialized for processing melody (Borod and Goodglass, 1980), the discourse function of language (Moscovitch, 1983), and certain suprasegmental features of speech (Marcie et al., 1965), it is possible that the rhythmic qualities of music or prose provide exogeneous temporal regulation to the right hemisphere, which, through interhemispheric processes, allows the left hemisphere to perform synchronous speech and motor activity more efficiently.

Spontaneous speech typically does not have the same melodic or rhythmic qualities of reading or singing. Moreover, subjects had to simultaneously perform the tapping task and think about what they were going to say relative to the context in which speech was demanded. The fact that interference occurred only in the spontaneous speech condition can probably be attributed to the lack of inherent structure or rhythm in spontaneous speech as compared to singing or reading. Inasmuch as spontaneous speech parallels everyday conversation, one might suppose that the spontaneous speech condition also heightened task-dependent tension in some of the stutterers (Greiner, Fitzgerald and Cooke, in press). If the right hemisphere is specialized for negative emotions, as Campbell (1982) has argued, then there is additional evidence to support the hypothesis that interhemispheric processing deficits can be linked to the tapping rate deficits in stutterers.

In addition, the results of this study indicate that concurrent motor tasks interfere with speech production. Concurrent spontaneous speech slowed speech rates for both groups as compared to their pretest speech rates. Although there were no differences between groups during any pretest speech task or during concurrent singing or reading, stutterers' speech rate was slower than for nonstutterers during concurrent spontaneous speech. Moreover, right-handed stutterers seem to contribute more to the group difference than do left-handed stutterers. With respect to speech fluency, concurrent spontaneous speech decreased fluency in both groups. Stutterers were more disfluent than nonstutterers during pretest and concurrent spontaneous speech, but no differences were associated with concurrent reading or singing. Whereas nonstutterers and right-handed stutterers were equally fluent (or disfluent) when tapping with the left or right hand during spontaneous speech, left-handed stutterers were more fluent when tapping with the right hand than when tapping with the left. In general, these results support the contention that exogenous rhythmic cues, as in singing and reading, dampen any endogenously produced disruption in speech rate or fluency. The data are less clear with respect to hypotheses concerning the hemispheric regulation of speech and motor control systems.

Various procedures used to reduce stuttering modify speech by altering its rate, rhythm, intonation, or intensity (Andrews et al., 1983). The vocalization modification hypothesis predicts that modified vocalizing induces fluency (Zimmerman, 1980). Zimmerman argues that the overriding change in fluency that occurs as a result of such alterations is due to a reduction of speech movement variability. Lomas and Kimura (1976) attribute reduction in speech movement variability to processes in the left hemisphere. If their view is correct, one would expect speech interference in right-handed subjects when tapping with the right hand. But, it is difficult to reconcile interference during left hand tapping with their hypothesis. Similarly, the tapping hand × subject handedness effect on the speech behavior of left-handed stutterers seems at odds with an intrahemispheric explanation for speech movement variability. Thus, these results, though not as conclusive as those for tapping, suggest that regulation of speech and motor control systems is more influenced by interhemispheric integration processes than by intrahemispheric competition. Moreover, to paraphrase Moscovitch (1983), when system overloads occur, one hemisphere's role in normal interhemispheric control processes may become impaired. For stutterers, these problems seem to be related to difficulties in the temporal regulation of the right hemisphere, which interfere with the balance between right and left hemisphere activation and inhibition.

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