

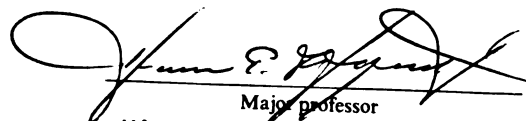
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SPEECH AND NONSPEECH MOTOR BEHAVIOR IN
SCHOOL-AGED STUTTERERS AND NONSTUTTERERS

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SPEECH AND NONSPEECH MOTOR
BEHAVIOR IN SCHOOL-AGED
STUTTERERS AND NONSTUTTERERS

by

Jay Richard Greiner

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Psychology

1986

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ABSTRACT

SPEECH AND NONSPEECH MOTOR BEHAVIOR IN SCHOOL-AGED STUTTERERS AND NONSTUTTERERS

By

Jay R. Greiner

Theoretical and empirical research suggest that normal, developmental disfluency and stuttering have common mechanisms but differ on the degree of lateralized speech and lateralized motor disorganization and emotional stress associated with social speaking situations. The present study compares lateralization of speech and nonspeech motor function in 60 right-handed male children, 30 stutterers and 30 nonstutterers. Measures included: (1) evaluation of language processing and production; (2) bimanual handwriting of verbal symbols; (3) concurrent bimanual handwriting and speech; (4) concurrent bimanual handwriting and lateralized allocation of attention; (5) concurrent unimanual sequential finger tapping and speech; and (6) emotional stress questionnaire.

Subjects were included in the current study only if they achieved appropriate age percentile ranks on the language processing and production measures. Bimanual handwriting results suggest that right-handed stutterers, compared to nonstutterers, have poorer left hand performance and greater frequency of left hand and right hand

mirror reversals during bimanual writing. The results suggest further, that stutterers and nonstutterers younger than age 9 lack full left hemisphere motor lead control, with stutterers younger than age 9 having the least left hemisphere motor lead control during bimanual tasks. Left hemisphere inhibition of right hemisphere activity occurs in nonstutterers after age 9. In stutterers, lack of left hemisphere motor lead control continues from age 6 to 16.

Concurrent sequential tapping results suggest that stutterers have more finger sequencing errors than nonstutterers as well as more within-word fragmentation during spontaneous speech. Both hands produced sequencing errors in stutterers and nonstutterers suggesting interhemispheric processing. Compared to nonstutterers, stutterers had fewer correct tapping sequences and higher error rates. Tapping errors increased with age in stutterers, and decreased with age in nonstutterers. These results suggest that in normal speaking children, the left hemisphere is the active hemisphere in temporal sequencing and regulation, whereas in childhood stutterers, the right hemisphere is more involved and involved in an inefficient way.

Emotional stress questionnaire results suggest that childhood stutterers have higher interpersonal stress than nonstutterers. Dimensions derived from the questionnaire suggest that childhood stutterers have lower self-esteem and confidence, higher audience sensitivity, and less interest in social interaction than nonstutterers.

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This work is dedicated to Marti.

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INTRODUCTION

There is considerable agreement that young children as compared to older children are more likely to have speech organization that is perceived to be disfluent. Cooper (1980) suggests that as many as 5 percent of all children younger than age 5 years experience periods of disfluency in speaking that are sufficiently severe to be described as stuttering. Davis (1939) suggests that the decrease with age of certain types of disfluency indicates that those disfluencies are normal and therefore can be regarded as transient or developmental. Persistence with age of syllable repetition and within-word fragmentation may be the first indication of stuttering in contrast to developmental disfluency.

Persistent stuttering stands in contrast to developmental disfluency based on the presence over time of speech, motor, or emotional involvement associated with the disfluency.

The current study assesses components of disfluency adapted from Riley and Riley (1979) suggesting that disfluency is pathological or persistent if it overloads the speech or motor system in one or a combination of the following ways:

1. respiratory air-flow breaks between syllable or part-word repetitions,
2. substitution of vowels during syllable or word repetitions,
3. variation in speech rate during syllable or word repetitions,
4. surges of motor tension in articulators, glottis, or

respiratory system occurring concurrent with syllable or part-word repetitions,

5. glottal or phonatory arrests, or

6. abnormal articulatory posturing during consonant production.

In addition, the socioemotional components that define persistent or pathological disfluency involve frustration in social situations, avoidance of eye contact, and attempts at avoiding speech communication.

Normal or developmental disfluency does not involve these aspects of speech, motor, or socioemotional disruption and is likely to consist of repetitions without the overload factors suggestive of persistent or pathological stuttering.

The hypothesis that stuttering is due to incomplete cerebral lateralization of language originated in the early part of this century (Orton, 1927, 1929; Travis, 1931) and has persisted to the present (Travis, 1978). Early attempts to test this hypothesis were not successful because of inability to establish a link between stuttering and handedness (Ballard, 1912; Bloodstein, 1981; Claiborne, 1917; Daniels, 1940; Rosenfield, 1980). Contemporary researchers have been successful at establishing differences between stutterers and nonstutterers in cerebral lateral organization (Jones, 1966; Curry & Gregory, 1969; Brady & Berson, 1975; Sussman & MacNeilage, 1975; Zimmerman & Knott, 1975; Moore & Lang, 1977; Moore & Haynes, 1980) and specifically in interhemispheric integration processes (Fitzgerald, Cooke & Greiner, 1984; Greiner, Fitzgerald &

Cooke, 1985a, 1985b) and in intrahemispheric competition during regulation of speech and motor activities (Greiner, Fitzgerald & Cooke, 1985a). The remaining literature review will cover in detail the research that differentiates stutterers from nonstutterers during perceptual and production tasks involving speech, and in addition, will discuss how school-aged stutterers have been differentiated from nonstutterers.

LITERATURE REVIEW

Stuttering and Hemispheric Contribution to Speech Organization

Stuttering behavior is best described as a temporal disruption in the unity of motor patterning of speech (Van Riper, 1971), and supraglottal articulatory activity has been implicated as a major factor in this discoordination and disruption in motor sequencing. Phonation is the central factor in speech production and is a function of integration and coordination of the complexity of glottal laryngeal factors, subglottal respiratory processes, and supraglottal articulation. The specific phonetic and linguistic aspects of a particular language are especially important because phonetic segment duration is determined physiologically by the rates of movement of the supraglottal articulators. Furthermore, Wingate (1977) has suggested that stuttering consists of defective transition from one phoneme to another. The consonant-vowel-consonant combinations most often are the source of the stuttering blocks, and it is these consonant-vowel-consonant combinations that require rapid sequencing and differentiation phonetically. Hypothetically, the phonetic transition defect is most pronounced during speech pressure and communicative stress that are typically associated with increased neuromotor speech movement (Zimmerman, 1980).

Speech production is a variable dimension described by rate, rhythm, and intonation of speech as well as vocal intensity. Slowing the rate of speech, regularizing the rhythm of speech, speaking in a monotonic voice, whispering, or speaking with much increased vocal

intensity all have been shown to reduce stuttering blocks in frequency and severity. The vocalization modification hypothesis suggests that modified vocalizing in and of itself induces fluency. Zimmerman (1980) suggests, however, that the overriding change is in reduction of movement variability as it occurs, for example, in the simplified neuromotor demands of whispering or in the imposed rhythm of singing.

Neuropsychological models of speech behavior into which stuttering might fit include models of cerebral dominance or hemispheric specialization for temporal aspects of speech and nonspeech manual performance. Studies with normal speaking adults have demonstrated that speech concurrent with manual activity interferes with manual performance. Specifically, normal speakers have poorer dominant hand performance compared to their nondominant performance (Hicks, 1975; Hicks, Bradshaw, Kinsbourne & Feigin, 1978; Lomas & Kimura, 1976; Kinsbourne & Cook, 1971; Wolff & Cohen, 1980; Hellige & Longstreth, 1981; Thornton & 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 & Peters, 1982) demand characteristics of the task (Lomas, 1980; Nachshon & Carmon, 1975; Thornton & Peters, 1982), and subject handedness (Lomas & Kimura, 1976). One neuropsychological model assumes that there is interference between concurrent activities controlled by the same hemisphere. When two cerebral control centers are concurrently active, as during the performance of unimanual

sequential finger tapping and unsequenced, propositional speech, they interfere with each other inversely with their anatomical distance from each other, and directly with the amount of activity required of each center for the particular motor task.

In addition, Lomas and Kimura (1976) suggest that the interference between speaking and manual activity is related to the "limited cerebral space" concept in that both speech and right hand movement are controlled by the same hemisphere. More specifically, these authors suggest that the overlap in the left hemisphere is for speech and rapid movement sequences of the contralateral hand. They raise the further possibility that rapid positioning of a limb or parts of a limb, with minimal visual guidance, is the factor related to lateralized decrement in concurrent speaking tasks. If this is true, the contribution of the left hemisphere to speaking may also be in the control of rapid placement of the articulatory musculature.

The articulatory sequencing aspects of speech and unimanual sequential finger tapping are both peripheral-level aspects of speech production. An overall model of neuropsychology relevant to stuttering behavior and the stuttering block, is the Aldridge (1981) hypothesis of central-level and peripheral-level processing in speech production. This model suggests that the central level of speech production requires activation of organization mechanisms also required for rehearsal of information in short-term memory, as would occur in spontaneous, propositional speech. The peripheral level of speech production involves a peripheral execution-controlling level

that places little demand on the central phonetic-organizational process.

The central-level processes involve mechanisms for active programming of articulatory gestures with the peripheral-level mechanisms executing these preprogrammed phonetic sequences. Aldridge (1981) suggests that if motor movements (speech or unimanual sequencing) can be accurately made in the absence of feedback, the inference can be made that the movement is programmed in advance, with the execution being ballistic and independent of feedback.

In a recent study (Greiner et. al., 1985a), concurrent speech (spontaneous speech, reading aloud, and singing) and unimanual sequential finger tapping resulted in interference with motor activity. The interference in this study occurred especially during spontaneous speech tasks and was measurable by disruption in ability to sequence the speech and disruption in the ability to sequence unimanually. The speech production tasks most likely programmed in advance (preprogrammed) were singing and reading aloud, and in fact, these speech tasks produced less interference on unimanual finger sequencing than spontaneous speech and, in addition, were interfered with less by finger sequencing. 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. 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). Since tapping rates did not slow down during spontaneous speech, whereas speech rates did, all 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, the song used in the Greiner et al. (1985a) study, "Row, row, row your boat," has a compound duple meter (6/8 time). Since the right hemisphere appears to be specialized for processing melody (Borod & Goodglass, 1980), the discourse function of language (Moscovitch, 1983), and certain suprasegmental features of speech (Marcie, Hacaen, Dubois, & Angelerques, 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, during the Greiner et al.(1985a) study, subjects had to simultaneously tap and think about what they were going to say relative to the context in which speech was required. 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. In addition, 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.

The results of the Greiner et. al. (1985a) study also indicate that concurrent motor tasks interfere with speech production. Concurrent spontaneous speech slowed speech rates for stutterers and nonstutterers 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 nonstutterers during concurrent spontaneous speech. With respect to speech disfluency, concurrent spontaneous speech increased disfluency in stutterers and nonstutterers. Stutterers were more disfluent than nonstutterers during pretest and concurrent spontaneous speech, but no differences occurred during concurrent reading or singing.

Some researchers 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, Bowman, Methot, Finlayson, Quintal & Boissonneault, 1983). However,

in the Greiner et al. (1985a) study, interference occurred 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 & Cohen, 1980).

Peters (1980) suggests 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 the sequential manual performance during concurrent speech and manual tasks. For right-handed subjects, disruption seem to involve primarily intrahemispheric competition. The activation-inhibition imbalance would seem to disrupt the timing of neural control processes regulating the integration of speech and motor activity (Kelso, Tuller, & Harris, 1983).

The results from the Greiner et al. (1985a) study suggest, then, 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 interferes with

the balance between the right and left hemisphere activation and inhibition.

Development of Hemispheric Contribution to Speech Organization

The temporal organization of speech in most righthanders arises from the left hemisphere, which is specialized for temporal sequencing of motor tasks. The development of temporal organization in speech and nonspeech motor tasks is of interest relevant to three separate hypotheses differing on the age at which lateralized function emerges, either at puberty, at age 5 or at age 3. The earliest hypothesis suggests progressive development of cerebral dominance with the implication that the infant and young child have bilateral language . skill and gradually develop increasing lateralization (Lenneberg, 1967). This progressive lateralization hypothesis suggests that by puberty, the left hemisphere has increased specialization and the right hemisphere has a decreased role (Gaddes, 1980). A later view of the progressive lateralization hypothesis suggests that full maturation and lateralized function occurs by age 5 (Krashen, 1973).

The progressive lateralization hypothesis has been weakened, however, by research demonstrating lateralized function in infants and preschoolers (Kinsbourne, 1975b; Hiscock & Kinsbourne 1978; White & Kinsbourne, 1980). White & Kinsbourne (1980) had children ages 3 to 12 tap on a Morse key with their index finger while they either recited a nursery rhyme, recited animal names, or memorized shapes. White and Kinsbourne (1980) suggest that testing lateralized function in young children is possible by predicting

interference of motor tasks controlled by the same hemisphere when concurrent performance is required. Right hand tapping and talking both are controlled by the left hemisphere whereas left hand tapping and talking are controlled by different hemispheres. Relevant to silent tapping, concurrent tapping and talking caused a greater drop in right hand tapping than in left hand tapping in rhyme and animal recitation conditions. Shape memorization interfered with tapping equally for both hands. Moreover this left hemisphere lateralization of speech output control did not vary with increasing age supporting the view that speech output control is fully lateralized at least by age 3 years.

The issue in speech development and in the development of attentional organization is central language development and peripheral-level speech production. Assuming there are no central language processing or production difficulties, difficulties in speech production such as stuttering might be addressed by the attention allocation hypothesis. This hypothesis suggests that what is required in learning to speak fluently is the ability to automatize motor performance in addition to organizing thoughts. Rather than two separate processes occurring at different points in time, concurrent formulation of thought and peripheral execution of speech in varying social contexts is what is expected of the speaker.

Assuming it is this concurrent formulation and production that produces disfluency, it is necessary to examine more closely speech development and the development of mechanisms responsible for

temporal sequencing and integration of temporal organization of competing speech and nonspeech motor tasks.

Developmental Mechanisms of Speech and Nonspeech Motor Coordination

The development of speech and nonspeech manual fine motor coordination can be discussed as arising from: 1) the development of left hemisphere specialization for temporal sequencing; or 2) an increase in the efficiency of interhemispheric transfer of information and hemispheric integration.

The development of left hemisphere specialization. The strongest evidence currently suggests that as early as age 3, right-handed children have left hemisphere specialization for speech since these children have lower right hand compared to left hand tapping while concurrently talking. (Ramsay, 1979; Hiscock & Kinsbourne, 1978; Kinsbourne & McMurray, 1975).

Ramsay (1980) found evidence that a relationship exists between the onset of bimanual handedness and acquisition of dissimilar syllables in babbling, with data suggesting that the structural changes in infants' vocalizations indicate the use of different articulatory units and reflects successive levels of hemispheric specialization during the first year of life. Ramsay (1980) speculates that what matures are the motor programs that sequence the separate movements of the vocal apparatus and that these programs are controlled by the left hemisphere.

Wolff and Hurwitz (1976) studied the development of finger tapping in boys and girls and found that from ages 5 to 16 years,

girls were consistently more accurate than boys in entraining their tapping rate to an external beat and in tapping to a steady rhythm. The right hand of all children in this study was steadier than the left, but the manual asymmetry for regularity of tapping was greater in girls than boys. Wolff and Hurwitz (1976) suggest that the left hemisphere is specialized for cortical functions controlling the serial organization of simple motor repetitions, and these functions mature earlier in girls than in boys. The authors point out that girls are developmentally advanced relative to boys in other selected functions such as onset of speech, expressive language, speech articulation, and verbal fluency, and that inasmuch as all of these cortical functions are associated with left hemisphere specialization, implying later left hemisphere specialization for speech in boys.

Given that the ratio of stuttering in boys and girls is considered to be 4 or 5 to 1 (Bloodstein 1981), one possible developmental mechanism for stuttering, then, might be a delay in left hemisphere specialization resulting in difficulty with temporal sequencing tasks. However, this view does not account for right hemisphere involvement in speech and speech-related tasks, necessitating discussion of left and right hemisphere integration.

The development of interhemispheric transfer and inhibition. Communication between the two cerebral hemispheres is attributed to fibers of the corpus callosum and the myelination of these fibers is seen as the mechanism for emergence of developmentally successive

phases of the organization of behavior patterns (Yakolev, 1962; Yakolev & Lecours, 1967; Lecours, 1975).

The functional importance of the corpus callosum in development is not yet well established (Selnes, 1974), and much of the evidence of corpus callosum function comes from studies of partial and complete commissurotomy patients (O'Leary, 1980). Denkla (1974) reported findings that in right-preferring children, right sided function is established first, then a rapid increase occurs in left sided function, so that by the age of 8 years, there is a very small mean right superiority within individuals. Denkla (1974) suggests that the interhemispheric connections develop around age 8 resulting in complete left hemisphere control of fine motor output. Yakolev and Lecours (1967) note that while myelination of the callosum is largely complete by age 6, it continues at a slow rate until at least age 10. Denkla (1974) suggests that maturation of the interhemispheric connections is an appealing hypothesis based on reports that in contrast to the closely similar right and left tapping rates of normal adult subjects, patients with commissurotomy had a left inter-tap interval 40 to 70 milliseconds longer than their right (Kreuter et al., 1972), inferring delayed interhemispheric communication.

Ellenberg and Sperry (1980) studied commissurotomy patients and their ability to voluntarily maintain independent left and right side performance during double simultaneous hand performance. Their results suggest that the cerebral commissures force the two

hemispheres to work together and maintain attentional unity in the intact brain. Practice increases the capacity for simultaneous processing in normals, but this enhancement is most readily interpreted as the result of automation of performance which decreases the need for attentional supervision of each of the independent left and right side functions during simultaneous handwriting.

Supporting this view, Dennis (1976) and Chiarello (1980) suggest, on the basis of studies of congenital acallosal persons, that the corpus callosum provides the inhibition necessary for the development of accurate topographic somatosensation and also for precise motor control. the role of interhemispheric communication in the control of precise motor coordination has also been extensively studied. Preilowski (1975) demonstrated that commissurotomy patients were able to perform bimanual coordination tasks postoperatively if those tasks had been well learned prior to the surgical division. In contrast, the patients were unable to maintain synchronous bilateral movements with apparent lack of attentional unity and usually performed at different rates with the right and left hands. Preilowski (1975) indicates that complete commissurotomy patients find the bimanual coordination tasks easier and perform it more accurately when the task requires mirror-image production as opposed to asymmetric movements. Preilowski (1975) suggests that limb movements are negatively influenced by simultaneous action of the contralateral extremity and that the interference occurs at the cortical level via

callosal interhemispheric connections.

Cohen (1970) suggests that interference occurs when limited-capacity of a central processor for movement-generated feedback is exceeded. Simultaneous, bimanual mirror-image movements involve homologous muscles and ostensibly redundant feedback, whereas simultaneous parallel movements involve nonhomologous muscles and generate a greater amount of feedback. The corpus callosum functions as the inhibitor of feedback and this function would seem to be completely developed around the age of 8 to 10 years.

Bimanual simultaneous handwriting has traditionally been used as an indicator of laterality (Harris, 1957) and as a tool to differentiate school-aged stutterers and nonstutterers (Spandino, 1941; Travis, 1930). Travis (1930) found that normal-speaking adults usually write with the same orientation with both hands when writing simultaneously with the right and left hands with vision occluded. By contrast, stutterers very frequently show the opposite orientation in the script written with one hand as compared to the other, and this, Travis suggested was indicative of immaturity since it is more prevalent in children than adults.

Bryngelson (1935), in a study of 700 stutterers ages 4 to 18, found that 80% wrote mirror script during bimanual handwriting compared to 15% of a normal population of adults. Ninety-two percent of the stuttering children between ages 9 and 16 had mirror reversals in bimanual handwriting. In the children older than age 17, mirror writing occurred in 60 to 70% of stutterers.

Spandino (1941) studied 70 stuttering and nonstuttering children ages 8 to 12 on a test of bimanual simultaneous drawing of letter-like designs. There were no significant differences between the stutterers and nonstutterers. Corballis and Beale (1976) suggest that it is easier to write backwards with the nondominant hand while writing forward with the dominant or preferred hand. Further, Clark (1957) tested 11 and 12 year old normal children on a test requiring them to write digits rapidly with both hands simultaneously. Over 50% wrote normally with the preferred hand and reversed with the nondominant hand.

What seems conclusively important during development of motor skills is the increasing ability to allocate attention and counteract interfering feedback. Counteraction of feedback occurs through the callosal interhemispheric inhibition effects so that what occurs by the age of 10 to 12 is seen as the development of neural circuitry to make possible the attentional control of lateralized performance.

Development of Hemispheric Control of the Gradient of Attention

According to Kinsbourne (1970), a motor response is facilitated in relation to the direction of orientation of attention. Any simple response controlled by the left hemisphere will benefit from environmental stimulation that elicits an orientation to the right side of space. When the focus of attention must be straight ahead, the hemispheres are mutually inhibited. The orientation model is an expectancy model, which suggests that when subjects know where the stimulus will be presented and what type of stimulus to expect,

interhemispheric transmission times are reduced to an almost negligible nerve conduction time across the callosum. Thus, hemispheric specialization may be exaggerated or obscured merely by shifting attention between hemispheres, so if the right hemisphere is cued, the advantage of the left hemisphere in any given task is diminished or eliminated. During bimanual handwriting of language symbols, one expects priming of the left hemisphere. Kinsbourne suggests that this priming of the left hemisphere results in an orientation movement to the right hand and renders the right hemisphere more ready for its characteristic performance, which would produce mirror script in the left hand. The corpus callosum functions in communication of attentional bias and therefore inhibits production of this mirror script. Both the young child and the callosally sectioned adult lack this inhibition, which amplifies the effect on attention of concurrent lateralized cognitive activity. When interhemispheric communication occurs, a person can write normally with the contralateral extremity because of the minimal need for allocation of attention.

Interference on automatic processes can occur at several different levels in motor tasks. For example, in speech production, the hemispheric orientation or attentional bias model predicts that speaking will create an attentional bias to the right hand in righthanded persons. In stutterers, one might speculate that the automaticity of the peripheral level speech process is not possible because of interfering speech organization from the right

hemisphere (Moore & Lang, 1977; Moore & Haynes, 1980) and that a major difficulty for stutterers is temporal regulation of the right hemisphere. It is important to reiterate that vocalization that is right hemisphere specialized, such as singing and whispering, diminishes stuttering (Bloodstein, 1981). In addition, temporal regulation is the key executive function of a laterally specialized hemisphere so that if the right hemisphere is not efficiently regulating temporal sequencing in stutterers, singing or speaking in metronomic rhythm will eliminate stuttering. Shames and Florence (1980) also suggest that conscious monitoring of the speech signal will assist in regularizing its rate and rhythm. The difficulty for the stutterer arises when the attention required for supervision of the speech signal is required for central formulation of speech as in spontaneous speech under social pressure.

There is evidence from research with adult stutterers (Fitzgerald, Cooke & Greiner, 1984; Greiner, Fitzgerald & Cooke, 1985b) that, compared to adult nonstutterers during bimanual handwriting, stutterers show significantly poorer handwriting organization of the left hand and more mirror image reversals with the left hand. Fitzgerald et al. (1984) concluded that what might appear to be incomplete cerebral dominance may be inefficient interhemispheric coordination or disfunctional interhemispheric integration of information. For stutterers, the underlying difficulty may be inability of the left hemisphere to achieve control over the right hemisphere due to a general deficiency in

interhemispheric integration of motor, spatial, and/or temporal components of speaking.

If the left hemisphere is actually specialized for the temporal regulation of speech by the age of 3 years, then what is it that the left hemisphere has to regulate during development of speech and nonspeech motor skills?

In light of recent studies of developmental disfluency occurring immediately prior to age 3 (Yairi, 1982), it is possible that this transient stuttering in children is occurring simultaneous with the developing organization of lateralized motor skills. Tingley and Allen (1975) studied the development of speech timing control in 5 to 11 year-old children and found that both the timing control of speech and finger tapping increased with age. Similar variability in speech control and tapping occurred suggesting a common timing-control mechanism. Tingley and Allen (1975) reported also that individual differences existed in children's timing control and suggested that clinical test procedures be developed to identify future stutterers or to give a better understanding of the lack of improvement in cases of functional or normal disfluency.

Existing literature on normal, developmental and pathological disfluency and the development of speech organization will now be discussed.

Speech Organization and Developmental Disfluency

There is considerable agreement that young children as compared to older children are more likely to have speech organization that is

perceived to be disfluent. Cooper (1980) suggests that as many as 5 percent of all children younger than age 5 years experience periods of disfluency in speaking of sufficient severity to be described as stuttering. Davis (1939) studied the speech fluency of 62 boys and girls ranging in age from 2 to 5 years and found that phrase repetitions were the most common kind of disfluency, followed by whole-word repetitions. These phrase and whole-word repetitions comprised 25 percent of the disfluencies and were considered "normal disfluency". Less common disfluencies were syllable and part-word repetitions. Whole-word and phrase repetitions decreased in the older children whereas the part-word and syllable repetitions remained at the same level.

Davis' (1939) study suggests that the decrease with age of certain types of disfluency means that those disfluencies are normal and can be considered transient or developmental disfluency. Yairi (1981, 1982) suggests that transient disfluency peaks between the ages of 2 and 3. Beyond age 3, the disfluency that persists is likely to consist of syllable and part-word repetitions. Within-word repetitions in speech indicate more fragmentation of speech organization than phrase or whole-word repetitions.

Differentiation of Developmental and Pathological Disfluency

The developmental disfluency question can be addressed from two viewpoints. The first is the view that disfluent speech in a child younger than age 5 can be used to differentiate a stutterer from a nonstutterer. The second view is that no differences exist between

stuttering and nonstuttering children (Johnson, 1955) and that stuttering emerges out of the recognition and labelling of normal disfluencies as "stutters". Johnson (1942) concluded that in 92 percent of the children diagnosed as stutterers, stuttering involved effortless repetitions of words, phrases, and syllables. This second viewpoint is the diagnosogenic theory of stuttering, which has not been totally supported by stuttering research. Johnson, Young, Sahs and Bedell (1959) revised the theory to more comprehensively address the importance of listener reaction to the stuttered speech and the impact of this reaction and social interaction on the stutterer.

Today most researchers do agree, then, that early disfluency can be differentiated as stuttering as opposed to developmental disfluency based on the presence of syllable or part-word repetitions. Bjerkan (1975) concluded that the fragmentation of a word before the whole word is pronounced is the most characteristic feature that distinguishes the speech of stuttering from nonstuttering children. These fragmentations have been more clearly defined (Bjerkan, 1980; Wingate, 1964) to include part-word repetitions, silent or audible prolongations within words, or interjections within words.

Bjerkan (1980) studied 110 nursery school children between the ages of 2 and 6 years and concluded that the nonstuttering children had whole-word repetitions, which decreased with increasing age, and also, had no within-word fragmentations.

The persistence with age then, of syllable repetition and within-word fragmentation may be the first indication of pathological disfluency or stuttering in contrast to developmental disfluency. Stuttering can be differentiated from normal developmental disfluency by the presence of disrupted speech sequencing within words, in addition to the persistence of total disfluency with increasing age. This basis for differentiation, however, only includes speech assessment. Persistent stuttering stands in contrast to developmental or normal disfluency based on the presence over time of speech, motor, or emotional system components associated with the disfluency.

Components of Disfluency

The differentiation of developmental and pathological disfluency needs to include aspects of speech and nonspeech system coordination. Phonation is the central factor in speech production and is a function of integration and coordination of the complexity of glottal laryngeal factors, subglottal respiratory processes, and supraglottal articulation. Research describing persistent stuttering in adult stutterers suggests that in comparison with childhood stutterers, adults are more likely to exhibit articulatory, phonatory or laryngeal, and respiratory correlates of stuttering. The persistence over time of speech, motor, or emotional system involvement associated with the disfluency differentiates pathological stuttering from normal developmental disfluency.

Disfluency is pathological or persistent if it overloads the

speech or motor system in one or a combination of the following ways:

1. respiratory air-flow breaks between syllable or part-word repetitions,
2. substitution of vowels during syllable or word repetitions,
3. variation in speech rate during syllable or word repetitions,
4. surges of motor tension in articulators, glottis, or respiratory system occurring concurrent with syllable or part-word repetitions,
5. glottal articulatory posturing during consonant production,
6. abnormal articulatory porturing during consonant production.

In addition, the socioemotional components that define persistent or pathological disfluency involve frustration in social situations, avoidance of eye contact, and attempts at avoiding speech communication.

Normal and developmental disfluency do not involve these aspects of speech, motor, or socioemotional system disruption and are likely to consist of repetitions without the overload factors suggestive of persistent or pathological stuttering.

In further description of the components of pathological disfluency, evidence exists for a progressive increase in component involvement with age in that children younger than age 8 or 9 years may not have the complexity of speech, motor, or emotional system involvement that appears in older children and adults who stutter (Cullinan & Springer, 1980); Schmitt & Cooper, 1978). Cullinan and Springer (1980) report that stutterers under the age of 8 years do

not differ from nonstutterers on phonation measures of voice initiation time and voice termination time, whereas stutterers above 8 years of age demonstrate slower initiation and termination of phonation than do nonstutterers. These researchers suggest that phonatory differences develop after the child has been persistently stuttering and possibly as a result of stuttering experience.

Schmitt and Cooper (1978) compared stuttering and nonstuttering children (ages 7 to 12 years) with respect to fundamental frequency as a central measure of phonatory behavior. These researchers found that on an oral reading test, there were no significant differences between stuttering and nonstuttering children on mean fundamental frequency, the lowest fundamental frequency, the highest fundamental frequency, or the difference between the lowest and highest fundamental frequency of the voice. Many researchers have found phonatory differences between adult stutterers and nonstutterers on measures of phonatory processes (Schwartz, 1974; Adams & Reis, 1971; Adams & Hayden, 1974; Conture et al., 1974; Freeman & Ushijima, 1974; Agnello, 1975; Freeman, 1975; Kerr & Cooper, 1976).

Schmitt and Cooper (1978) suggest that lack of differences in phonatory behavior between childhood stutterers and nonstutterers supports the view that the differences between adult stutterers and nonstutterers may be the result of "habituated compensatory phonatory adjustments" in response to disfluency. This view suggests that disfluency in childhood is a relatively automatic speech process and that in attempting to avoid or prevent stuttering, the older child

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and adult stutterer attend to the peripheral speech system and de-automize the process.

One would expect, then, that this de-automization of the peripheral speech process in stuttering children is one of the factors producing speech and motor aspects of pathological disfluency. Therefore, study of the developmental progression of these speech and motor components will describe the peripheral-level production deficits of persistent or pathological disfluency.

The literature suggests, then, that childhood stutterers may exhibit one or any combination of factors which define their individual stuttering behavior (Riley & Riley, 1979; Riley & Riley, 1980; Cullinan & Springer, 1980). Overall there is considerable agreement that childhood stutterers are a heterogeneous population. The nature of the differences among them can probably be described on the basis of differing types and degrees of speech and nonspeech motor involvement as well as social and emotional stress. To assist in definition of the heterogeneity within stutterers, a diagnostic system is suggested.

Diagnostic Components of Speech Disorganization in Children

Cullinan and Springer (1980) suggest that stuttering-only children need to be differentiated from stuttering-plus children, or children who have other language disorders in addition to stuttering. Riley and Riley (1980) suggest that a diagnostic system be used with children and that this analysis include observation and testing of the following neurological or neurogenic areas: 1) disorders of

attention; 2) disorders in coordination and planning of speech and nonspeech motor systems; 3) disorders in central speech and language formulation; and 4) disorders in processing auditory information.

In addition to neurological or neurogenic components in the developmental progression of stuttering, Riley and Riley (1979) suggest that emotional stress and emotional overload is apparent in cases of persistent or pathological disfluency in children. Research with adult stutterers suggests that interpersonal and emotional stress is important in the description of stuttering in finding avoidance behavior (Bloodstein, 1981; Prins & Lohr, 1972) and significantly higher levels of general anxiety as measured by the Revised Willoughby Personality Schedule (Greiner, Fitzgerald, Cooke & Djurdjic, 1985). The Greiner et al. (1985) study also suggests that stutterers have higher social sensitivity and social isolation and lower levels of social confidence as measured by the WPS-R. Greiner et al. (1985) suggest that these WPS-R differences between adult stutterers and nonstutterers be conceptualized as points on a continuum, much as Adams and Runyan (1981) have proposed about fluency-disfluency itself. Some stutterers do not exhibit high social sensitivity, social isolation, or low social confidence. Janssen and Kraaimaat (1980) suggest that the influence of general anxiety may be restricted to stutterers whose speech is excessively fast and repetitive and to those whose speech is dominated by excessively slow repetitions. There will be individual stutterers whose stuttering is affected by word-specific

anxiety, speech-situation anxiety, or general anxiety. In addition, there will be some stutterers for whom anxiety is not a contributing factor in their disfluency.

It is apparent, then, that speech rate and emotional stress can be coexisting components which define and thereby affect therapy for individual stutterers. Assessment of stuttering needs to include speech, nonspeech motor, and emotional stress instruments to completely diagnose stuttering components. This is particularly critical given the possibility that stuttering involves inefficient right hemisphere regulation of speech in addition to regulation of negative emotions (Campbell, 1982). The emotional component and the speech regulation component are controlled by the same hemisphere, so that when emotional stress occurs simultaneous with the demand for speech regulation, temporal regulation is disrupted.

Children who stutter may have other speech and language disorders that need to be differentiated in the therapy plan. Stuttering-only children or "functional" stutterers in whom stuttering is the only speech difficulty have been found to differ on neuropsychological tests, which suggests that there is a lack of homogeneity even in this subgroup of stutterers (Daly & Smith, 1976; 1979; Daly, Kimbarrow & Smith, 1977). Daly and Smith (1979) suggest that functional stutterers with three or more neuropsychological deficits might have organic cerebral or neurological dysfunction.

To establish a theoretical framework for discussion of neuropsychological deficits and organic cerebral or neurological dysfunction (Daly & Smith, 1979), and neurological or neurogenic components (Riley & Riley, 1979) in childhood stutterers, it is first necessary to discuss the relationship between the development of speech organization and the development of attention.

Speech Organization and Attentional Development

The normal developmental progression of learning to speak involves transient disfluency between the ages of 2 and 3 (Yairi, 1982). To understand the commonality between disfluency as a developmental process and disfluency as a persistent disruption in adults, the Aldridge (1981) hypothesis of two levels of processing in speech production seems useful. The Aldridge hypothesis suggests that speech production involves a central-level process requiring speech organization and active conscious processing, and a peripheral-level process controlling execution of speech automatically and placing little demand on the central organizational process. The degree of automaticity indexes the degree of learning of particular tasks, and Sperry (1961) suggests that highly overlearned motor functions may descend to lower brain functions. The conscious working memory required in generative organization of thought would involve the cortical central-level process. Speech motor tasks at any point in time are organized and therefore are dependent on the degree of maturation of brain structure, degree of language learning, and, in addition, the type of speech task being

performed.

Speaking is generally an automatic process, with the exception of spontaneous propositional speech, which is full of disfluency, hesitations and pauses in normal speakers (Goldman-Eisler, 1968). Spontaneous propositional speech is also associated with increased stuttering in stutterers, whereas singing is likely to decrease stuttering in stutterers (Greiner et al., 1985a). Therefore, when the speech task is automatic, fluency is expected in stutterers and nonstutterers. However, stutterers learn during speech development to fear certain words or speaking situations (Bloodstein, 1981) resulting in acute awareness of the peripheral-level process of phonetic production. This conscious processing of the peripheral-level process decreases the automaticity of its execution. Rieber et al. (1976) suggest that when attention and/ or expectation is shifted from its appropriate central-level operation of cognitive planning to the peripheral-level operation of phonetic production, this tends to de-automize the communicative behavior.

This view suggests that disfluency can be a relatively automatic speech process and that in attempting to avoid or prevent stuttering, the childhood or adult stutterer attend to the peripheral speech system and de-automize the process. Adult stutterers are usually very aware of phonetic combinations or speaking situations that exacerbate their stuttering. The anticipatory struggle hypothesis of stuttering reflects this expectation. This hypothesis suggests a degree of conscious awareness of the speech apparatus prior to and

associated with stuttering blocks.

If, indeed, the conscious processes associated with speaking underlie stuttering and developmental disfluency, it is conceivable that conscious strategies such as monitoring are influential in resolving stuttering and developmental disfluency by diminishing attentional demands on right hemisphere processing.

General Procedure and Hypotheses

The present study was designed to assess components of speech disfluency in male stutterers and nonstutterers between the ages of 6 and 16. Hypotheses reviewed suggest that developmental and pathological disfluency have common mechanisms but differ in the degree of associated speech and nonspeech motor disorganization and on the presence of social and emotional stress.

Based on the preceding literature review, the following predictions were made:

- 1) During bimanual handwriting tasks, stutterers will have poorer handwriting organization and greater frequency of mirror image writing with their nondominant hand than nonstutterers;
- 2) During concurrent spontaneous speech and unimanual sequential finger tapping, stutterers will be more disfluent and have more finger sequencing errors than nonstutterers;
- 3) Demand for spontaneous speech will cause a greater increase in disfluency in stutterers than in nonstutterers;
- 4) Demand for spontaneous speech will cause a greater increase in within-word fragmentation in stutterers than in nonstutterers;
- 5) Older stutterers will have higher emotional stress and social sensitivity and lower sociability, social confidence and self esteem than will nonstutterers and younger stutterers.

METHOD

Subjects

The subjects were 60 right-handed boys, including 30 stutterers (age 6 to 8.11, n=7; age 9 to 11.11, n=12; age 12-15, n=11), and 30 nonstutterers (age 6 to 8.11, n=9; age 9-11.11, n=9; age 12-15, n=12). The stutterers were recruited from the Michigan State University Speech and Hearing Clinic, The University of Michigan Speech and Hearing Sciences Clinic, and the Lansing School District. The nonstutterers were recruited from the Lansing School District.

Informed consent was obtained from the children's parents prior to their participation in the study (see Appendix A).

Procedure

Screening evaluation of language processing. Language processing was assessed using the elementary and advanced (as age appropriate) screening tests of the CELF (Clinical Evaluation of Language Functions; Semel & Wiig, 1980). Initially the subject observed the experimenter during demonstration items and then received three practice trial items. Test trials involved the subject listening to directions and responding correctly to stimulus statements (e.g., Simon says: Touch your head above your ears.).

The language processing screening items were scored by marking an appropriate score of 1 for correct and 0 for incorrect and the total raw score was converted to an age appropriate percentile rank.

Screening evaluation of language production. Language production was assessed using the elementary and advanced (as age

appropriate) screening tests of the CELF (Clinical Evaluation of Language Functions; Semel & Wiig, 1980). Initially the subject observed the experimenter during demonstration items and then received three practice trial items. The test trials involved the subject listening to directions and responding correctly to the stimulus statement (e.g., "Repeat this word after me: 'Tachapheminopia'").

The language production screening items were scored by marking an appropriate score of 1 for correct and 0 for incorrect and the total raw score was converted to an age appropriate percentile rank.

Subjects were not included in the current study if they did not achieve age-appropriate percentile ranks on the language processing or production screening tests.

Evaluation of hand preference. Hand preference was assessed with the Harris Tests of Lateral Dominance (Harris, 1957). On this test, the subject is expected to simulate ten hand preference items. The items to be simulated are throw a ball, wind a watch, hammer a nail, brush your teeth, comb your hair, turn a door knob, hold an eraser, use scissors, cut with a knife and write. Since this study involved right-handed subjects only, all subjects had to perform 80% of 10 hand preference items with the right hand to be included.

Bimanual handwriting. Bimanual handwriting performance was assessed using a simultaneous handwriting task requiring bimanual coordination modified from previous research (Fitzgerald et al., 1984; Greiner et al., 1985b). The stimuli for the bimanual task

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a
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t

w
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L
f

q
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Th
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were the digits from 1 to 12 and the letters from A through L (see Appendix B). Bimanual handwriting was assessed for digits and letters across five separate tasks: Task 1 (bimanual handwriting task with no speech or lateralized attending); Task 2 (task 1 replication); Task 3 (concurrent bimanual writing and saying aloud each digit or letter as it was being written); Task 4 (concurrent bimanual writing and lateralized attention allocation to the left hand) and ; Task 5 (concurrent bimanual writing and lateralized attention allocation to the right hand). Tasks 4 and 5 were distributed across all subjects so that half of the subjects received task 4 prior to task 5 and half received task 5 prior to task 4.

For the bimanual handwriting tasks, the subject sat at a table with one pencil in each hand. Subjects were told that they would have to write the digits from 1 to 12 and the letters from A through L with both hands simultaneously, and that they would be prevented from seeing their hands.

Subjects were instructed to write the digits and letters as quickly as possible without going off the sides or bottom of the page. A card was placed about 10 inches above the writing surface so that the subject could not see the digits or letters being written. The data from the handwriting task were scored by raters who were blind to the hypotheses. Each individual digit in a column was rated against a standard Artype transfer digit (10 mm high) arranged in a column from one to twelve and a standard Artype transfer letter (10 mm high) arranged in a column from A through L. Each column of

written digits and letters was mounted on poster board in order to minimize any obvious cues that they were written by the left or right hand. Raters received training sessions during which they practiced scoring according to nine criteria.

Each digit and letter was rated against its Artype standard on each of nine criteria by subtracting points from an assigned score of 15 depending on the rater's judgement of the following dimensions:

- 1) **Alignment.** One point deducted if a digit or letter deviated from the general alignment of the symbols in a column by at least 1 cm.
- 2) **Scatter, compactness.** One point deducted if spacing of the elements of double digits was judged to sufficiently deviate from its Artype.
- 3) **Incompleteness.** One to three points deducted for each deviation from the Artype.
- 4) **Excess structure.** One to three points deducted for each excess structure attached to the symbol.
- 5) **Orientation, slant.** One to two points deducted for 10 to 45 degree slant and an additional point deducted if greater than 45 degrees.
- 6) **Legibility.** One point deducted if the symbol was illegible.
- 7) **Contour.** One to two points deducted if symbol was judged to sufficiently deviate from Artype contour and roundness.
- 8) **Overlap.** One point deducted if the symbol overlapped

another symbol in the column.

- 9) **Pressure.** One point deducted if the symbol was lighter than that simultaneously written with the other hand.

Criterion nine was scored last, since a direct comparison between the left and right hand digit or letter was required.

Concurrent speech and bimanual handwriting of digits and letters was assessed using the same procedure as the traditional handwriting task except that the subject was instructed to count aloud from 1 to 12 and to say the letters aloud from A through L while writing.

During tasks 4 and 5, bimanual handwriting was assessed using the same procedure as described for tasks 1 to 3 except without concurrent speech. In addition, subjects were instructed to think about their left hand or their right hand performance depending on the allocated left or allocated right tasks. Half of the subjects received instructions to bimanually write and allocate attention to the left hand first then to repeat the procedure while allocating attention to the right hand. The remaining subjects received the opposite instructions, i.e., allocate right followed by allocate left. This distribution of tasks 4 and 5 was used so as to control for a possible order effect in comparing performance during lateralized attending and concurrent bimanual writing.

Concurrent speech and unimanual sequential finger tapping.

On the unimanual sequential tapping test, subjects were instructed to tap with each hand separately during each of two 30-second practice trials. Each subject was instructed to start with the index finger

and tap outward to the little finger and then to start a new sequence. The subject was instructed to tap as fast as possible without making any sequential errors while tapping.

Test trials were randomly distributed (see Table 1) and required the subject to unimanually sequence with the left and right hand separately in four conditions: 1) silent tapping without auditory feedback of tones; 2) silent tapping with auditory tone feedback with individual fingers having different frequency tones; 3) tapping while saying aloud the lyrics of "Twinkle, twinkle, little star"; and 4) tapping while spontaneously telling a story about stimulus card picture drawings from a semi-projective test of Engagement Style (McKinney, 1980) which were placed on the platform approximately 12 inches from the subject's face and in such a position as to prevent the subject from seeing his fingers. The eight stimulus picture cards were randomly assigned across subjects. The stimulus picture cards used to elicit spontaneous generative speech were drawings from McKinney's semi-projective Test of Engagement Style (McKinney, 1980). They depicted two boys in a variety of settings and participating in activities typical for children of approximately age 10. The stimulus pictures were drawn to depict children approximately 10 years old. The subject was instructed to tell a story about what might be happening in the stimulus picture.

Unimanual sequential finger tapping rate and accuracy was scored and the measures used in later analysis for each of the 32 15-second trials were total sequential tapping rate, correct sequential

Table 1

Experimental Design Used to Investigate Speech Fluency and Tapping in Childhood Stutterers and Nonstutterers. Task 1=Silent Tapping; Task 2= Tone Feedback Tapping; Task 3= Rhythmic Speech-Tapping; Task 4= Spontaneous Speech-Tapping.

Condition A	<u>Subject</u>				Condition B	<u>Subject</u>			
	n1	n2	n3	n4		n5	n6	n7	n8
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

tapping, and sequential error rate. Sequential error rate is the difference between total and correct sequential tapping rate per trial.

Speech fluency. Pretest speech fluency was assessed prior to the concurrent speech and unimanual tapping task described above. Fluency was assessed using the Riley Stuttering Severity Instrument (Riley, 1980). The subjects were asked to read aloud age-appropriate materials from the reading booklet of the Durrell Analysis of Reading Difficulty (Durrell & Catterson, 1980) for later analysis of oral reading fluency. In addition, to elicit spontaneous speech for analysis of fluency, subjects were shown stimulus picture cards from the same semi-projective test of Engagement Style described above (McKinney, 1980) with different picture cards than those used during concurrent tasks.

All speech was recorded on a Panasonic tape recorder for later analysis of speech fluency by scoring the total number of disfluencies and calculating a percentage of fluency. In addition to oral reading and spontaneous speech tasks, subjects were asked to repeat the words of the song "Twinkle, twinkle, little star" as a rhythmic speech task, which was also scored for fluency percentage.

Speech during sequential tapping was recorded and scored for total number of disfluencies and fluency percentage. In addition, 10 separate disfluency criteria were scored in an attempt to differentiate stuttering from normal and developmental disfluency. The ten criteria were: airflow breaks between repeated or prolonged

syllables, audible prolongations, vowel substitutions in repeated syllables, tense surges during repetitions or prolongations, part-word repetitions, whole-word repetitions, phrase repetitions, interjections, revisions, and disrhythmic phonation.

Emotional stress questionnaire. Each subject was asked to respond to 34 questions related to interpersonal and emotional stress and specifically designed to measure social confidence and self esteem, audience sensitivity, and social interest or sociability. The subject was instructed to respond by pointing to his answer on a response board that had the numbers from 1 to 5 and the following description below each number: 1) no, never; 2) sometimes; 3) middle amount; 4) quite a bit; 5) yes, always. (See appendix C for 34 item questionnaire.)

The current study consisted of eight separate instruments. The total time required for administration was approximately 50 to 60 minutes.

Data analysis. Initially, analysis of variance (Speech Group (2) by Age Group (3)) was used to ascertain whether stutterers and nonstutterers differed on the five bimanual handwriting tasks.

Analysis of variance (Speech Group (2) by Age Group (3)) was then performed on speech fluency measures including rhythmic speech, spontaneous speech, and oral reading adapted from the Riley Stuttering Severity Instrument (Riley, 1980).

Analysis of variance of concurrent speech and unimanual sequential finger tapping was performed using BALANOVA. The repeated

measures (within-subjects) in the BALANOVA analysis were total speech fluency percentage, ten individual speech disfluency criteria percentages, total sequential tapping rate, correct sequential tapping rate, and tapping error rate.

Finally, analysis of variance (Speech Group (2) by Age Group (3)) was performed to determine whether stutterers and nonstutterers differed on the emotional stress questionnaire total score. The questionnaire data were then factor analyzed using PACKAGE (Hunter & Cohen, 1969), a sequence of routines that involve exploratory and confirmatory factor analysis. In PACKAGE, exploratory factor analysis is used to estimate the minimum number of underlying dimensions measured by the items contained in the instrument. Then the hypothesized dimensions are submitted to confirmatory factor analysis. Each item is assigned a loading factor that is the correlation of that item with other items in the dimension. A loading factor of more than .50 indicates that the item is a reliable measure of the dimension. The grouping of items in a dimension is confirmed by the standard score coefficient alpha (ssca). A dimension with an ssca of greater than .50 is considered to be reliable. Following the confirmatory factor analysis, an analysis of variance of the mean dimension scores was performed.

RESULTS

The results will be presented in the following order: bimanual handwriting (handwriting organization and mirror-image reversals); unimanual sequential tapping (sequential tapping rates, correct tapping sequences, and tapping error rates); speech fluency (pretest speech tasks and speech during tapping tasks); speech disfluency during tapping (airflow breaks, audible prolongations, vowel substitutions, tense surges, part-word repetitions, whole-word repetitions, phrase repetitions, interjections, revisions and disrhythmic phonations); emotional stress questionnaire (total questionnaire score and factor analysis).

Bimanual Handwriting

Handwriting organization. Analysis of variance of the mean organization scores for each hand revealed significant between-speech group differences in performance during each of the five handwriting tasks. During performance of five tasks, there were significant interactions with subject age group. Table 2 through Table 6 summarize the results of the analysis for handwriting organization during the five handwriting tasks. As shown in Table 2, when compared to nonstutterers, stutterers had significantly poorer dominant right hand performance for letters when no speech or lateralized attending was required. A speech group by age group interaction [$F(2,29)=3.37$, $p < .04$] suggests that youngest stutterers (age 6 to 8.11) performed more poorly with the right hand than did older stutterers when writing letters. In addition, a speech group

Table 2

Bimanual Handwriting Organization in Three Age Groups of Stutterers
and Nonstutterers With No Speech or Lateralized Attending
Task 1

	Stutterers			Nonstutterers			P
	Age	Mean	SD	Mean	SD	F	
Righthand Digits	6-15	11.52	.86	11.59	1.18	.33	ns
	6-8.11	10.85	.86	11.22	1.30	.44	ns
	9-11.11	11.50	.60	11.94	1.25	1.18	ns
	12-15	11.75	.98	11.60	1.06	.11	ns
Lefthand Digits	6-15	9.15	1.35	9.45	1.40	.72	ns
	6-8.11	8.38	1.39	8.38	1.62	.00	ns
	9-11.11	9.10	1.08	10.20	1.44	4.10	ns
	12-15	9.73	1.42	9.72	.51	.001	ns
Righthand Letters	6-15	10.84	.97	11.41	1.10	4.70	.03
	6-8.11	10.12	1.40	10.95	1.23	1.61	ns
	9-11.11	10.90	.77	11.75	1.25	3.71	ns
	12-15	11.24	.59	11.50	.70	.96	ns
Lefthand Letters	6-15	8.72	1.52	9.34	1.50	2.51	ns
	6-8.11	7.66	1.40	8.32	1.64	.71	ns
	9-11.11	8.87	1.37	9.75	1.62	1.83	ns
	12-15	9.24	1.52	9.80	.90	1.16	ns

by age interaction [$F(2,29)=3.53$, $p \leq .04$] suggests that the youngest group of nonstutterers had significantly poorer left hand performance for letters than the older nonstutterers.

The results of Task 2 (Task 1 replication) are summarized in Table 3 and indicate replication of findings from Task 1, except that in Task 2 there were no significant differences between stutterers and nonstutterers in right hand performance. During Task 2, when writing digits with the right hand, younger stutterers performed more poorly than older stutterers [$F(2,29)=7.65$, $p \leq .002$]. Also during Task 2, when writing letters with the left hand, younger nonstutterers performed more poorly than older nonstutterers [$F(2,29)=5.75$, $p \leq .008$].

The results of Task 3, (bimanual handwriting with concurrent vocalization of each digit or letter) are summarized in Table 4. No significant between speech group differences occurred during this task. There were, however, speech group by age group interactions. When writing letters with the right hand, younger stutterers performed more poorly than older stutterers [$F(2,29)=4.41$, $p \leq .02$]. In addition, during left hand performance for letters, younger stutterers performed more poorly than older stutterers [$F(2,29)=7.02$, $p \leq .003$] and younger nonstutterers performed more poorly than older nonstutterers [$F(2,29)=3.67$, $p \leq .04$].

The results of Task 4, (bimanual handwriting with lateralized attending to the left hand) are summarized in Table 5. Across all age groups, stutterers performed more poorly than nonstutterers in

Table 3

Bimanual Handwriting Organization in Three Age Groups of Stutterers
and Nonstutterers With No Speech or Lateralized Attending
Task 2 (Task 1 Replication)

	Age	Stutterers		Nonstutterers		F	df	P
		Mean	SD	Mean	SD			
Righthand Digits	6-15	11.41	.95	11.57	1.30	.28	1,58	ns
	6-8.11	10.46	.74	11.22	1.88	.99	1,14	ns
	9-11.11	11.49	.66	11.83	1.14	.75	1,19	ns
	12-15	11.94	.93	11.64	.89	.63	1,21	ns
Lefthand Digits	6-15	8.86	1.34	9.65	1.40	5.06	1,58	◀.02
	6-8.11	8.08	1.42	8.86	1.95	.79	1,14	ns
	9-11.11	8.71	1.41	10.11	1.27	5.58	1,19	◀.03
	12-15	9.52	.94	10.00	.66	1.28	1,21	ns
Righthand Letters	6-15	10.93	.86	11.19	1.22	.91	1,58	ns
	6-8.11	10.32	1.01	10.54	1.51	.11	1,14	ns
	9-11.11	10.03	.71	11.62	1.26	1.88	1,19	ns
	12-15	11.21	.80	11.36	.77	.20	1,21	ns
Lefthand Letters	6-15	8.39	1.48	9.14	1.44	3.88	1,58	◀.05
	6-8.11	7.50	1.27	7.96	1.70	.39	1,14	ns
	9-11.11	8.42	1.71	9.53	1.30	2.64	1,19	ns
	12-15	8.96	1.10	9.72	.71	4.05	1,21	◀.05

Table 4

Bimanual Handwriting Organization in Three Age Groups of Stutterers
and Nonstutterers With Concurrent Speech
Task 3

	Age	Stutterers		Nonstutterers		F	df	P
		Mean	SD	Mean	SD			
Righthand Digits	6-15	11.41	.79	11.56	1.10	.32	1,58	ns
	6-8.11	10.91	.73	11.25	1.67	.25	1,14	ns
	9-11.11	11.40	.64	11.95	1.07	2.17	1,19	ns
	12-15	11.76	.84	11.49	.37	.98	1,21	ns
Lefthand Digits	6-15	8.95	1.33	9.30	1.32	1.04	1,58	ns
	6-8.11	8.12	1.54	8.63	1.74	.36	1,14	ns
	9-11.11	8.82	1.22	9.56	1.39	1.71	1,19	ns
	12-15	9.62	1.05	9.61	.65	.002	1,21	ns
Righthand Letters	6-15	10.98	.95	11.28	1.21	1.12	1,58	ns
	6-8.11	10.21	1.12	10.87	1.60	.88	1,14	ns
	9-11.11	11.04	.85	11.58	1.24	1.44	1,19	ns
	12-15	11.42	.63	11.36	.82	.04	1,21	ns
Lefthand Letters	6-15	8.35	1.52	9.02	1.33	3.37	1,58	ns
	6-8.11	6.96	1.35	8.10	1.58	2.33	1,14	ns
	9-11.11	8.31	1.37	9.35	1.29	3.11	1,19	ns
	12-15	9.26	1.10	9.46	.78	.25	1,21	ns

Table 5

Bimanual Handwriting Organization in Three Age Groups of Stutterers and Nonstutterers With Lateralized Attending to the Left Hand
Task 4

	Stutterers			Nonstutterers			F	df	P
	Age	Mean	SD	Mean	SD				
Righthand Digits	6-15	11.11	.85	11.68	1.22	4.28	1,58	4.043	
	6-8.11	10.61	.83	11.42	1.43	1.74	1,14	ns	
	9-11.11	10.98	.77	11.76	1.48	2.47	1,19	ns	
	12-15	11.58	.75	11.81	.87	.43	1,21	ns	
Lefthand Digits	6-15	9.14	1.60	9.60	1.18	1.64	1,58	ns	
	6-8.11	7.64	1.66	8.46	1.42	1.11	1,14	ns	
	9-11.11	9.38	1.51	10.22	.73	2.36	1,19	ns	
	12-15	9.83	1.08	10.01	.52	.27	1,21	ns	
Righthand Letters	6-15	10.72	.81	11.04	1.15	1.60	1,58	ns	
	6-8.11	10.05	.92	10.44	1.39	.41	1,14	ns	
	9-11.11	10.77	.59	11.31	1.20	1.81	1,19	ns	
	12-15	11.08	.73	11.29	.79	.44	1,21	ns	
Lefthand Letters	6-15	8.49	1.44	9.25	1.38	4.32	1,58	4.04	
	6-8.11	7.61	1.24	7.79	1.42	.07	1,14	ns	
	9-11.11	8.68	1.64	9.61	.97	2.29	1,19	ns	
	12-15	8.85	1.18	10.07	.57	10.35	1,21	4.004	

right hand performance for digits. In addition, during Task 4, across all age groups, stutterers performed more poorly than nonstutterers in left hand performance for letters. Younger stutterers and nonstutterers did not differ significantly in left hand performance for letters. However, the oldest age group of stutterers performed more poorly than the nonstutterers during this task. Also during this task, younger stutterers had significantly poorer performance than older stutterers in right hand performance for digits [$F(2,29)=3.64$, $p \leq .04$], left hand performance for digits [$F(2,29)=5.46$, $p \leq .01$] and right hand performance for letters [$F(2,29)=4.37$, $p \leq .02$]. The three age groups of stutterers did not differ during left hand performance for letters. Finally, younger nonstutterers performed more poorly than older nonstutterers in left hand performance for digits [$F(2,29)=9.98$, $p \leq .0006$] and left hand performance for letters [$F(2,29)=14.06$, $p \leq .0001$].

The results of Task 5, (bimanual handwriting with lateralized attending to the right hand) are summarized in Table 6. Across all age groups, stutterers performed more poorly than nonstutterers in left hand performance for digits and letters with no significant between speech group differences in right hand performance. Also during Task 5, younger stutterers had significantly poorer performance than older stutterers in right hand performance for digits [$F(2,29)=4.39$, $p \leq .02$], and left hand performance for digits [$F(2,29)=6.24$, $p \leq .005$]. The three age groups of stutterers and nonstutterers did not differ in left hand performance

Table 6

Bimanual Handwriting Organization in Three Age Groups of Stutterers and Nonstutterers With Lateralized Attending to the Right Hand Task 5

	Age	Stutterers		Nonstutterers			
		Mean	SD	Mean	SD	F	P
Righthand Digits	6-15	11.14	.95	11.54	1.20	2.15	1,58 ns
	6-8.11	10.37	.74	11.26	1.63	1.77	1,14 ns
	9-11.11	11.17	.55	11.81	1.16	2.83	1,19 ns
	12-15	11.59	1.14	11.57	.86	.003	1,21 ns
Lefthand Digits	6-15	8.25	1.52	9.26	1.24	8.05	1,58 <.006
	6-8.11	7.17	1.28	8.20	1.26	2.58	1,14 ns
	9-11.11	7.99	1.52	9.74	1.31	7.60	1,19 <.013
	12-15	9.21	1.11	9.69	.57	1.83	1,21 ns
Righthand Letters	6-15	10.86	.96	11.28	1.06	2.62	1,58 ns
	6-8.11	9.98	1.20	10.95	1.47	1.99	1,14 ns
	9-11.11	10.89	.65	11.44	.94	2.48	1,19 ns
	12-15	11.39	.71	11.42	.79	.01	1,21 ns
Lefthand Letters	6-15	8.20	1.78	9.22	1.32	6.36	1,58 <.014
	6-8.11	7.17	1.23	8.21	1.61	2.00	1,14 ns
	9-11.11	8.26	1.63	9.67	1.05	5.07	1,19 <.037
	12-15	8.80	2.06	9.65	.82	1.77	1,21 ns

for letters. In addition, during Task 5, younger nonstutterers performed more poorly than older nonstutterers in left hand performance for digits [$F(2,29)= 6.51$, $p < .005$] and left hand performance for letters [$F(2,29)= 4.82$, $p < .01$].

Relevant to the hypothesis about bimanual handwriting organization, across all writing tasks, stutterers did have poorer handwriting organization with their nondominant left hand. In addition, during the traditional bimanual handwriting task (Task 1), stutterers, as compared to nonstutterers, had significantly poorer dominant right hand performance and this can be attributed to the youngest age group of stutterers (age 6 to 8.11). During Task 2, (replication of Task 1 representing practiced performance) stutterers and nonstutterers did not differ in right hand performance.

During concurrent vocalization and bimanual writing, no significant differences occurred between stutterers and nonstutterers. However, younger stutterers' left hand organization was more disorganized than older stutterers and more disorganized than on Task 1 and Task 2.

Both tasks (Task 4 and 5) involving lateralized allocation of attention produced more disruption in stutterers than in nonstutterers. Specifically, during Task 4 (allocation of attention to the left hand), compared to nonstutterers, stutterers had significantly poorer right hand and left hand performance. This task was most disruptive for stutterers and was slightly more disruptive than the other bimanual tasks for the youngest nonstutterers compared

2
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to the older nonstutterers.

During Task 5 (allocation of attention to the right hand), compared to nonstutterers, stutterers had significantly poorer left hand performance with no speech group differences in right hand performance.

Mirror-image reversals. Table 7 summarizes the results of the analysis for reversals during bimanual handwriting across five tasks, including right and left hand reversals of digits and letters. As indicated in Table 7, compared to nonstutterers, the three age groups of stutterers had significantly more reversals across all five bimanual handwriting tasks. The results of the age group comparisons suggest that stutterers had significantly more reversals than nonstutterers in the two older age groups, i.e., 9 to 11.11 and 12 to 15. The youngest age group of stutterers and nonstutterers (6 to 8.11) did not differ significantly in the presence of reversals during bimanual handwriting. The youngest group of nonstutterers had significantly more reversals than the older nonstutterers [$F(2,29)=25.53$, $p < .0001$], whereas the three age groups of stutterers did not differ significantly in the number of reversals.

Tables 8 through 12 summarize the results of the analysis for reversals during each of the five bimanual tasks. The results of the analysis for reversals during Task 1 are summarized in Table 8. Across all age groups, stutterers had significantly more reversals than nonstutterers in left hand performance for digits and letters with no significant between speech group differences in right hand

Table 7

Total Reversals in Bimanual Handwriting in Three Age Groups of Stutterers and Nonstutterers Across Five Tasks

	Age	Stutterers		Nonstutterers		F	df	P
		Mean	SD	Mean	SD			
Total Righthand and Lefthand Reversals of Digits and Letters	6-15	29.60	18.40	8.50	14.30	24.53	1,58	<.0001
	6-8.11	40.00	18.65	25.89	15.67	2.71	1,14	ns
	9-11.11	26.92	12.54	2.00	3.43	33.24	1,19	<.0001
	12-15	25.91	22.39	.33	.65	15.71	1,21	<.0007

Table 8

Reversals in Handwriting in Three Age Groups of Stutterers and
Nonstutterers With No Speech or Lateralized Attending
Task 1

		Stutterers		Nonstutterers				
	Age	Mean	SD	Mean	SD	F	df	P
Righthand Digit Reversals	6-15	.40	1.16	.07	.37	2.25	1,58	ns
	6-8.11	1.29	2.21	.22	.67	1.89	1,14	ns
	9-11.11	.17	.39	.00	--	1.63	1,19	ns
	12-15	.09	.30	.00	--	1.10	1,21	ns
Lefthand Digit Reversals	6-15	3.27	1.20	1.30	2.15	13.70	1,58	<.0005
	6-8.11	3.86	1.68	3.78	2.49	.01	1,14	ns
	9-11.11	3.08	1.88	.44	.73	15.77	1,19	<.0008
	12-15	3.09	2.30	.08	.29	20.25	1,21	<.0002
Righthand Letter Reversals	6-15	.27	.52	.20	.66	.18	1,58	ns
	6-8.11	.57	.77	.56	1.13	.001	1,14	ns
	9-11.11	.33	.49	.11	.33	1.36	1,19	ns
	12-15	.00	--	.00	--	--	1,21	ns
Lefthand Letter Reversals	6-15	1.70	1.62	.56	1.28	9.04	1,58	<.004
	6-8.11	1.71	1.38	1.67	1.94	.003	1,14	ns
	9-11.11	2.00	1.13	.22	.44	19.85	1,19	<.0003
	12-15	1.37	2.20	.00	--	4.62	1,21	<.043

performance. During Task 1, the youngest group of stutterers and nonstutterers did not differ in reversals in left hand performance for digits or letters. Also during Task 1, younger nonstutterers had significantly more reversals than older nonstutterers in left hand performance for digits [$F(2,29)= 19.65$, $p \leq .0001$] and left hand performance for letters [$F(2,29)= 6.76$, $p \leq .004$]. There were no significant between age group differences in reversals for stutterers.

The results for reversals during Task 2 (Task 1 replication) are summarized in Table 9. The results from Task 2 agreed with those of Task 1 except that the youngest group of stutterers and nonstutterers did not differ in reversals for digits. However, nonstutterers across age groups had significantly fewer left hand reversals of letters. In addition, younger stutterers had significantly more reversals than older stutterers in right hand performance for digits [$F(2,29)= 4.88$, $p \leq .01$] with no other between age group differences in right or left hand performance for stutterers.

The results for reversals during Task 3 are summarized in Table 10. Task 3 replicated the findings that stutterers had significantly more reversals than nonstutterers in left hand performance for digits and letters with no significant between speech group differences in right hand performance. However, during Task 3, younger nonstutterers had significantly more reversals than older nonstutterers in right hand performance for digits [$F(2,29)= 4.73$,

Table 9

Reversals in Handwriting in Three Age Groups of Stutterers and
Nonstutterers With No Speech or Lateralized Attending
Task 2 (Task 1 Replication)

	Stutterers		Nonstutterers			
	Age	Mean	SD	Mean	SD	F
Righthand Digit Reversals	6-15	.37	1.16	.00	--	3.00
	6-8.11	1.43	2.15	.00	--	4.06
	9-11.11	.00	--	.00	--	.00
	12-15	.09	.30	.00	--	1.10
Lefthand Digit Reversals	6-15	3.07	2.20	.90	1.62	18.86
	6-8.11	4.00	2.65	2.67	1.87	1.40
	9-11.11	2.92	2.23	.33	1.00	10.36
	12-15	2.64	1.86	.00	--	24.25
Righthand Letter Reversals	6-15	.47	.73	.17	.60	3.10
	6-8.11	.86	1.07	.56	1.01	.33
	9-11.11	.33	.50	.00	--	4.07
	12-15	.37	.70	.00	--	3.51
Lefthand Letter Reversals	6-15	2.07	1.84	.40	.93	19.64
	6-8.11	2.57	1.14	1.11	1.36	5.20
	9-11.11	1.67	1.61	.22	.67	6.33
	12-15	2.18	2.40	.00	--	9.95
57	6-15					
	6-8.11					
	9-11.11					
	12-15					

ns
ns
ns
ns
1,58 <.0001
1,14 ns
1,19 <.004
1,21 <.0001
ns
ns
ns
ns
1,58 <.0001
1,14 <.039
1,19 <.021
1,21 <.005

Table 10

Reversals in Handwriting in Three Age Groups of Stutterers and
Nonstutterers With Concurrent Speech
Task 3

		Stutterers		Nonstutterers			
	Age	Mean	SD	Mean	SD	F	P
Righthand Digit Reversals	6-15	.40	1.20	.10	.31	1.78	1,58 ns
	6-8.11	1.43	2.15	.33	.50	2.23	1,14 ns
	9-11.11	1.67	.58	.00	--	.74	1,19 ns
	12-15	.00	--	.00	--	.00	1,21 ns
Lefthand Digit Reversals	6-15	3.00	2.41	.97	1.80	13.78	1,58 <.0005
	6-8.11	4.14	2.34	3.11	2.03	.89	1,14 ns
	9-11.11	3.00	2.17	.00	--	16.91	1,19 <.0006
	12-15	2.27	2.61	.08	.29	8.36	1,21 <.0008
Righthand Letter Reversals	6-15	.27	.45	.27	.78	.00	1,58 ns
	6-8.11	.57	.53	.89	1.27	.38	1,14 ns
	9-11.11	.17	.39	.00	--	1.63	1,19 ns
	12-15	.18	.40	.00	--	2.44	1,21 ns
Lefthand Letter Reversals	6-15	2.47	2.08	.57	1.87	19.78	1,58 <.0001
	6-8.11	2.29	1.97	1.67	1.41	.54	1,14 ns
	9-11.11	2.67	1.56	.22	.44	20.69	1,19 <.0002
	12-15	2.36	2.73	.00	.00	9.03	1,21 <.0007

$p < .02]$ and in right hand performance for letters [$F(2,29) = 5.21$, $p < .01]$ in addition to the consistent finding across tasks of younger stutterers having more reversals than older nonstutterers in left hand performance. Also during Task 3, younger stutterers had more reversals in right hand performance for digits than did older stutterers [$F(2,29) = 4.22$, $p < .03]$.

The results for reversals during Task 4 are summarized in Table 11. This task (bimanual writing with allocation of attention to the left hand) replicated previous task findings of more reversals in left hand performance for stutterers compared to nonstutterers. However, during this task stutterers also had significantly more reversals than nonstutterers in right hand performance for letters across age groups. In addition, this task was most disruptive for the youngest age group of stutterers and nonstutterers. As occurred in Task 3, the youngest nonstutterers had more reversals than older nonstutterers in right hand performance for digits [$F(2,29) = 4.46$, $p < .02]$ and letters [$F(2,29) = 4.23$, $p < .04]$. In addition, younger stutterers had significantly more reversals than older stutterers in right hand performance for digits [$F(2,29) = 4.21$, $p < .03]$ and letters [$F(2,29) = 5.21$, $p < .01]$. It is important to note that younger nonstutterers have consistently more reversals in left hand performance than older nonstutterers. However, younger stutterers and older stutterers do not differ in left hand mirror image reversals.

The interesting finding resulting from Task 5 (allocation of

Table 11

Reversals in Handwriting in Three Age Groups of Stutterers and
Nonstutterers With Lateralized Attending to the Left Hand
Task 4

	Stutterers				Nonstutterers			
	Age	Mean	SD		Mean	SD	F	P
Righthand Digit Reversals	6-15	.40	.86		.20	.48	1.24	1,58 ns
	6-8.11	1.14	1.46		.56	.73	1.11	1,14 ns
	9-11.11	.17	.39		.11	.33	.19	1,19 ns
	12-15	.18	.40		.00	--	2.44	1,21 ns
Lefthand Digit Reversals	6-15	2.37	2.30		.90	1.56	8.37	1,58 <.005
	6-8.11	3.29	3.04		2.67	1.87	.25	1,14 ns
	9-11.11	2.17	1.70		.22	.44	11.12	1,19 <.003
	12-15	2.00	2.41		.08	.27	7.51	1,21 <.012
Righthand Letter Reversals	6-15	.47	.73		.10	.40	5.80	1,58 <.019
	6-8.11	1.14	1.07		.33	.71	3.33	1,14 ns
	9-11.11	.33	.49		.00	--	4.07	1,19 ns
	12-15	.18	.40		.00	--	2.43	1,21 ns
Lefthand Letter Reversals	6-15	2.13	2.05		.37	.76	19.62	1,58 <.0001
	6-8.11	2.14	1.35		1.22	.97	2.54	1,14 ns
	9-11.11	1.50	1.09		.00	.00	16.91	1,19 <.0006
	12-15	2.81	2.96		.00	.00	10.92	1,21 <.003

attention to the right hand) is the similarity to findings from the traditional bimanual handwriting task i.e., Tasks 1 and 2 (see Table 12). Across all age groups, stutterers had more reversals than nonstutterers in left hand performance with no between speech group differences in right hand performance. The youngest group of stutterers and nonstutterers did not differ in left hand reversals whereas the younger nonstutterers had more reversals in left hand performance than the older nonstutterers. Also, younger stutterers had more reversals than older stutterers in right hand performance for digits [$F(2,29)= 5.03$, $p < .01$].

These bimanual writing results confirm the hypothesis of greater frequency of mirror image reversals with the nondominant hand in stutterers. Across all age groups, tasks, and hand performance, stutterers had more mirror image reversals than nonstutterers. However, across tasks and hand performance the 6 to 8.11 year old stutterers and nonstutterers did not differ in reversals due to the high frequency of reversals in the youngest nonstutterers. Across tasks and hand performance, the three age groups of stutterers did not differ in the frequency of reversals.

Consistent findings during each of the five bimanual tasks were as follows: across age groups, stutterers had significantly more reversals than nonstutterers in left hand performance. However, the youngest group of stutterers and nonstutterers did not differ in left hand reversals; younger nonstutterers had significantly more reversals than older nonstutterers in left hand performance; and the

Table 12

Reversals in Handwriting in Three Age Groups of Stutterers and
Nonstutterers With Lateralized Attending to the Right Hand
Task 5

		Stutterers		Nonstutterers			
	Age	Mean	SD	Mean	SD	F	P
Righthand Digit Reversals	6-15	.33	1.03	.03	.18	2.48	1,58 ns
	6-8.11	1.29	1.89	.00	--	4.25	1,14 ns
	9-11.11	.10	.29	.11	.33	.04	1,19 ns
	12-15	.00	--	.00	.00	.00	1,21 ns
Lefthand Digit Reversals	6-15	3.50	2.19	.90	1.60	27.46	1,58 <.0001
	6-8.11	4.29	1.80	2.44	2.13	3.86	1,14 ns
	9-11.11	3.42	1.93	.44	.88	18.31	1,19 <.0004
	12-15	3.09	2.70	.08	.29	14.77	1,21 <.0009
Righthand Letter Reversals	6-15	.33	.71	.17	.59	.97	1,58 ns
	6-8.11	.57	.79	.44	1.01	.07	1,14 ns
	9-11.11	.33	.89	.11	.33	.51	1,19 ns
	12-15	.18	.40	.00	.00	2.44	1,21 ns
Lefthand Letter Reversals	6-15	2.33	1.94	.53	1.14	19.29	1,58 <.0001
	6-8.11	1.43	.98	1.67	1.58	.12	1,14 ns
	9-11.11	2.42	1.51	.11	.33	20.13	1,19 <.0003
	12-15	2.82	2.64	.00	--	13.75	1,21 <.001

three age groups of stutterers did not differ in left hand mirror image reversals. All of these consistent findings concern mirror image reversals in left hand performance.

Results not predicted were mirror image reversals in right hand or dominant hand performance. There was only one task in which stutterers had more reversals in right hand performance when compared to nonstutterers. This difference occurred during bimanual writing of letters while allocating attention to the left hand.

With the exception of Task 1 (traditional bimanual writing), all tasks resulted in younger stutterers (age 6 to 8.11) having more right hand reversals of digits than older stutterers (9 to 15). Task 4 (bimanual writing with allocation of attention to the left hand) produced the greatest frequency of right hand mirror image writing, particularly in the youngest subjects. During Task 4, younger nonstutterers had significantly more reversals than older nonstutterers in right hand digits and letters. In addition, younger stutterers had more reversals than older stutterers in right hand digits and letters.

One other task (Task 3, bimanual writing and concurrent speech) produced right hand mirror image writing in nonstutterers. During Task 3, younger nonstutterers age 6 to 8.11, had more right hand reversals of digits and letters than older nonstutterers age 9 to 16.

Overall, there appears to be a similarity between certain bimanual tasks and possibly between underlying mechanisms. Task 1 (traditional bimanual handwriting), task 2 (Task 1 replication), and

Task 5 (lateralized attending to the right hand) produced similar results in mirror image writing. Perhaps the traditional bimanual task actually involves the lateral gradient of attention to the right hand in a right-handed population, with minimal involvement of the right hemisphere or interhemispheric processing. In contrast, Task 3 (concurrent speech and bimanual writing) and Task 4 (lateralized attending to the left hand) produced more right hand reversals particularly in the children aged 6 to 8.11, possibly activating right hemisphere involvement and the need for interhemispheric efficiency.

The results of the current study suggest that developmental mechanisms supporting right hemisphere activation and inhibition via interhemispheric communication mature around age 9. In stutterers, 4 out of 5 bimanual tasks produced more right hand mirror writing in younger stutterers than in older stutterers, suggesting that stutterers age 6 to 9 years have particular difficulty in right hemisphere activation and interhemispheric processing of speech and language. In that right hand mirror writing occurred in the youngest stutterers during traditional handwriting replication and allocation of attention to the right hand, inefficient motor lead control from the left hemisphere might also be implicated in this group.

Unimanual Sequential Tapping

Sequential tapping rates. Analysis of variance revealed significant main effects for Age [$F(1,54) = 12.79$, $p < .0005$] and

Hand-Used-For-Tapping [$F(1,54) = 4.43$, $p < .04$]. The mean sequential tapping rates for these main effects are shown in Table 13. Tapping rates increased with age and the right hand had a significantly faster tapping rate than the left hand. Analysis of variance also revealed a significant main effect for Task [$F(3,162) = 11.93$, $p < .0005$]. Interpretation of the Task main effect, however, must be considered in relation to a significant Trial Block by Task interaction [$F(9,486) = 2.86$, $p < .0003$]. The mean sequential tapping rates for this task main effect and interaction are shown in Table 14. Sequential tapping rates increased over Trial Blocks during tapping concurrent with tone feedback of each key tapped. Without tone feedback, tapping rates either did not increase or in the case of tapping concurrent with rhythmic speech, rates decreased over Trial Blocks.

Correct tapping sequence. Analysis of variance revealed significant main effects for Speech Group [$F(1,54) = 11.99$, $p < .0001$], for Age [$F(1,54) = 14.75$, $p < .0005$], and Hand-Used-For-Tapping [$F(1,54) = 6.46$, $p < .01$]. Mean correct tapping sequences for these main effects are shown in Table 15. Stutterers had significantly fewer correct tapping sequences than nonstutterers. Mean correct tapping sequences increased with age and the right hand had significantly more correct tapping sequences than the left hand. Analysis of variance also revealed a significant main effect for Task [$F(3,162) = 11.64$, $p < .0005$]. Interpretation of the Task main effect, however, must be considered in relation to a significant

Table 13

Mean Sequential Tapping Rates for Age and
Hand-Used-For-Tapping Main Effects

Age	Mean Score per Trial
6-8.11 years	20.29
9-11.11 years	24.20
12-15 years	29.09
Hand-Used-For-Tapping	
Right Hand	24.80
Left Hand	24.20

Table 14

Mean Sequential Tapping Rates for Task Main Effect
and Trial Block by Task Interaction

Task		Mean Score per Trial			
Silent Tapping		25.30			
Tone Feedback Tapping		26.60			
Rhythmic Speech Tapping		23.46			
Spontaneous Speech Tapping		22.76			

Trial Block	Silent	Feedback	Rhythmic	Spontaneous
1	24.72	25.37	23.91	21.44
2	25.72	26.02	24.21	23.93
3	25.63	26.75	23.07	23.00
4	25.11	28.20	22.63	23.09

Table 15

Mean Correct Tapping Sequences for Speech Group,
Age, and Hand-Used-For-Tapping Main Effects

Speech Group	Mean Score per Trial
Stutterers	19.19
Nonstutterers	23.60
Age	
6-8.11 years	17.28
9-11.11 years	21.20
12-15 years	25.70
Hand-Used-For-Tapping	
Right Hand	21.70
Left Hand	21.10

Trial Block by Task interaction [$F(9,486)= 2.99$, $p \leq .002$]. The mean correct tapping sequences for the Task main effect and interaction are shown in Table 16. Correct tapping sequences increased over Trial Blocks during tapping concurrent with tone feedback. During silent tapping and tapping concurrent with speech, correct tapping sequences initially increased and then decreased over Trial Blocks.

Tapping error rates. Analysis of variance revealed significant main effects for Speech Group [$F(1,54)= 56.95$, $p \leq .0005$] and Task [$F(3,162)= 5.90$, $p \leq .001$]. The mean tapping error rates per trial for each task (silent tapping = 3.12, tone feedback tapping = 3.45, rhythmic speech = 2.87, spontaneous speech = 3.07) indicate fewest tapping errors occurred concurrent with rhythmic speech and the highest frequency of tapping errors occurred concurrent with tone feedback. Interpretation of the Speech Group main effect, however, must be considered in relation to a significant Speech Group by Age interaction [$F(1,54)= 5.26$, $p \leq .008$]. The mean tapping error rates for the Speech Group main effect and interaction are shown in Table 17. Stutterers had significantly higher tapping error rates than nonstutterers. Tapping error rates increased with age in stutterers and decreased with age in nonstutterers.

Relevant to the hypothesis of greater frequency of sequencing errors in stutterers compared to nonstutterers, stutterers had significantly fewer correct tapping sequences and significantly

Table 16

Mean Correct Tapping Sequences for Task Main Effect
and Trial Block by Task Interaction

Task		Mean Score per Trial			
Silent Tapping		22.15			
Tone Feedback Tapping		23.13			
Rhythmic Speech Tapping		20.58			
Spontaneous Speech Tapping		19.68			

Trial Block		Silent	Feedback	Rhythmic	Spontaneous
1		21.71	22.05	20.84	18.42
2		22.69	22.62	21.25	20.70
3		22.48	23.38	20.38	19.87
4		21.69	24.50	19.84	19.74

Table 17

Mean Tapping Error Rates for Speech Group
Main Effect and Speech Group by Age Interaction

Speech Group	Mean Score per Trial
Stutterers	4.14
Nonstutterers	2.11

Age	Stutterers	Nonstutterers
6-8.11 years	3.45	2.54
9-11.11 years	4.10	1.96
12-15 years	4.88	1.80

higher tapping error rates than nonstutterers. The Speech Group by Age interaction of tapping error rates, suggests tapping error rates increased with age in stutterers and decreased with age in nonstutterers. This study suggests that normal boys between the age of 12 to 15 years have maximum capability for rapid and correct unimanual sequencing compared to younger boys, with children age 6 to 9 having the slowest tapping rate and the fewest correct sequences. There appears to be a linear improvement in tapping rate and accuracy between the ages of 6 and 15. It would appear that stutterers and nonstutterers do not differ on the rapidity of sequential tapping. However, accuracy of the sequencing seems to be less for stutterers. Unimanual sequencing could meet the need for establishing potential differences between stutterers and nonstutterers in the area of motor and speech timing control (Tingley & Allen, 1975), if individual performance was monitored to assess possible manual sequential timing control difficulties. Given that across all subjects, the right hand had more rapid and accurate sequential tapping than the left hand, and that stutterers had as rapid a rate as nonstutterers, but fewer correct sequences, one might speculate that the errors in right hand sequencing might have produced the significantly lower correct sequencing rate in stutterers. This finding supports the hypothesis of a superior left hemisphere ability for manual sequencing in normal speaking right-handed children and a left hemisphere role in the disruption of sequencing found in right-handed stutterers.

Relative to the type of task during concurrent unimanual sequential tapping, results suggest that during the experiment there was an increase in the rate of tapping and in the number of correct sequences while tapping with audible tone feedback for each finger tapped. However, throughout the experiment the tone feedback tasks produced the most tapping errors. The rhythmic speech task actually slowed the rate of tapping during the experiment and was also associated with the fewest tapping errors. The imposed rhythm and external timing control of the rhythmic speech task probably improved accuracy of unimanual sequencing in all subjects.

Speech Fluency

Pretest speech tasks. As indicated in Table 18, across age groups stutterers were significantly more disfluent than nonstutterers during rhythmic speech, oral reading, and spontaneous speech. During rhythmic speech, the youngest and oldest age groups of stutterers and nonstutterers did not differ significantly in speech fluency.

Speech during tapping tasks. Analysis of variance on data obtained from the experimental concurrent speech tasks revealed significant main effects for Speech Group [$F(1,54)= 45.97$, $p < .0005$], Age [$F(1,54)= 3.22$, $p < .05$], Trial Block [$F(3,162)= 2.71$, $p < .05$], and for Task [$F(1,54)= 97.31$, $p < .0005$]. The mean percent speech fluency scores for these main effects are shown in Table 19. Interpretation of the main effects, however, must be considered in relation to a Task by Speech Group interaction

Table 18

Percent Mean Pretest Speech Fluency in Three Age Groups of Stutterers and Nonstutterers During Three Speech Tasks

	Age	Stutterers	Nonstutterers	F	df	P
Rhythmic Speech	6-15	92.7	98.9	9.86	1,59	≤.003
	6-8.11	91.0	97.3	2.19	1,16	ns
	9-11.11	93.3	99.3	6.40	1,19	≤.02
	12-15	93.6	99.7	2.94	1,22	ns
Oral Reading	6-15	92.4	97.4	25.4	1,59	≤.0001
	6-8.11	91.0	96.0	6.67	1,16	≤.02
	9-11.11	93.5	98.0	16.60	1,19	≤.0007
	12-15	92.2	98.0	8.65	1,22	≤.008
Spontaneous Speech	6-15	85.5	94.1	23.23	1,59	≤.0001
	6-8.11	81.6	92.2	7.41	1,16	≤.01
	9-11.11	85.5	93.3	7.70	1,19	≤.01
	12-15	88.5	96.0	9.17	1,22	≤.006

Table 19

Percent Mean Speech Fluency During Tapping for Speech Group,
Age, Trial Block and Task Main Effects

Speech Group	Mean Score per Trial
Stutterers	92.7
Nonstutterers	98.0
Age	
6 to 8.11 years	94.0
9 to 11.11 years	95.8
12 to 15 years	96.2
Trial Block	
1	95.1
2	94.6
3	96.0
4	96.0
Task	
Rhythmic Speech	97.8
Spontaneous Speech	92.8

[$F(1,54)= 132.19$, $p < .001$], and a Task by Speech Group by Age by Hand-Used-For-Tapping interaction [$F(1,54)= 3.26$, $p < .04$]. The mean percent speech fluency scores for these interactions are shown in Table 20. Stutterers were more disfluent than nonstutterers during concurrent speech tasks. However, examination of the mean scores in Table 20 suggests the difference in speech fluency between stutterers and nonstutterers is most significant during spontaneous speech. Speech fluency increased with age, particularly during spontaneous speech. In addition, speech fluency increased over experimental trials. In relation to Hand-Used-For-Tapping, Table 20 suggests that speech fluency was equal to or slightly lower in nonstutterers while tapping with their right hand as compared to their left hand during spontaneous speech but not during rhythmic speech. In stutterers, speech fluency was slightly lower while tapping with their left hand as compared to their right hand for spontaneous and rhythmic speech.

Speech Disfluencies During Tapping

Additional analysis of variance was performed on ten distinct speech disfluency criteria: airflow breaks between repeated or prolonged syllables; audible prolongations; vowel substitutions in repeated syllables; tense surges during repetitions or prolongations; part-word repetitions; whole-word repetitions; phrase repetitions; interjections, revisions, and disrhythmic phonations.

Airflow breaks. Analysis of variance revealed a significant main effect for Speech Group [$F(1,54)= 6.17$, $p < .01$]. Stutterers

Table 20

Percent Mean Speech Fluency During Tapping for
Task by Speech Group and Task by Speech Group
by Age by Hand-Used-For-Tapping Interactions

Speech Group	Rhythmic		Spontaneous	
Stutterers	96.2		89.0	
Nonstutterers	99.4		96.3	

	Rhythmic		Spontaneous	
	Right Hand	Left Hand	Right Hand	Left Hand
Stutterers				
6 to 8.11 yrs.	94.9	94.5	88.3	86.0
9 to 11.11 yrs.	97.5	96.7	88.5	88.0
12 to 15 yrs.	97.3	96.3	92.0	89.5
Nonstutterers				
6 to 8.11 yrs.	99.3	99.2	93.7	95.9
9 to 11.11 yrs.	99.6	99.6	95.5	96.9
12 to 15 yrs.	99.3	99.6	97.1	98.5

had significantly more breaks (.04) per trial than nonstutterers (.002).

Audible prolongations. Analysis of variance revealed significant main effects for Speech Group [$F(1,54)= 20.62$, $p < .0005$], and Task [$F(1,54)= 9.86$, $p < .003$]. Interpretation of the main effects must be considered in relation to a Speech Group by Task interaction [$F(1,54)= 8.95$, $p < .004$]. The mean scores for the main effects and interaction are shown in Table 21. Stutterers had significantly more audible prolongations than nonstutterers and more audible prolongations occurred with spontaneous as compared to rhythmic speech.

Vowel substitution. Analysis of variance revealed a significant main effect for Speech Group [$F(1,54)= 4.03$, $p < .05$]. Stutterers had significantly more vowel substitutions per trial (.047) than nonstutterers (0).

Tense surges. Analysis of variance revealed significant main effects for Speech Group [$F(1,54)= 33.99$, $p < .0005$], and Task [$F(1,54)= 6.84$, $p < .01$] and in addition, a Speech Group by Task interaction [$F(1,54)= 7.17$, $p < .01$]. The mean scores for the main effects and interaction are shown in Table 22. Stutterers had more tense surges during spontaneous speech as compared to rhythmic speech. Nonstutterers had more tense surges during rhythmic as compared to spontaneous speech.

Part-word repetitions. Analysis of variance revealed main effects for Speech Group [$F(1,54)= 65.54$, $p < .0005$] and Task

Table 21

Mean Audible Prolongation Scores for Speech Group and Task
Main Effects and Speech Group by Task Interaction

Speech Group		Mean Score per Trial
Stutterers		.312
Nonstutterers		.004
Task		
Rhythmic Speech		.072
Spontaneous Speech		.244
	Rhythmic	Spontaneous
Stutterers	.145	.480
Nonstutterers	.000	.008

Table 22

Mean Tense Surge Scores for Speech Group and Task
Main Effect and Speech Group by Task Interaction

Speech Group		Mean Score per Trial
Stutterers		.356
Nonstutterers		.001
Task		
Rhythmic Speech		.107
Spontaneous Speech		.251
	Rhythmic	Spontaneous
Stutterers	.210	.502
Nonstutterers	.003	.000

[$F(1,54)= 44.97$, $p \leq .0005$]. Interpretation of the main effects must be considered in relation to a Speech Group by Task interaction [$F(1,54)= 48.02$, $p \leq .0005$], and a Speech Group by Hand-Used-For-Tapping interaction [$F(1,54)= 5.24$, $p \leq .02$]. The mean scores for the main effects and interactions are shown in Table 23. Stutterers had significantly more part-word repetitions during spontaneous as compared to rhythmic speech. Nonstutterers had significantly more part-word repetitions during rhythmic as compared to spontaneous speech. In addition, stutterers had more part-word repetitions while tapping with the left hand as compared to the right hand. Nonstutterers had more part-word repetitions while tapping with the right hand as compared to the left hand.

Whole-word repetitions. Analysis of variance revealed a main effect for Task [$F(1,54)= 9.92$, $p \leq .002$]. There was not a main effect for Speech Group, however, the main effect must be considered in relation to a Speech Group by Task by Hand-Used-For-Tapping interaction [$F(1,54)= 5.49$, $p \leq .02$]. Mean scores for the main effect and interaction are shown in Table 24. Significantly more whole-word repetitions occurred during spontaneous as compared to rhythmic speech. During spontaneous speech, stutterers had more whole-word repetitions while tapping with their left hand compared to the right hand and nonstutterers had more whole-word repetitions while tapping with the right as compared to the left hand. During rhythmic speech, stutterers had more whole-word repetitions while tapping with the right compared to the left hand.

Table 23

Mean Part-Word Repetition Scores for Speech Group and Task Main
Effects and Speech Group by Task and Speech Group
by Hand-Used-For-Tapping Interactions

Speech Group		Mean Score per Trial
Stutterers		.474
Nonstutterers		.009
Task		
Rhythmic Speech		.085
Spontaneous Speech		.400
		Rhythmic Spontaneous
Stutterers	.156	.800
Nonstutterers	.014	.003
		Right Hand Left Hand
Stutterers	.423	.524
Nonstutterers	.020	.000

Table 24

Mean Whole-Word Repetition Scores for Task Main Effect and
Speech Group by Task by Hand-Used-For-Tapping Interaction

Task		Mean Score per Trial	
Rhythmic Speech		.056	
Spontaneous Speech		.200	
		Stutterers	Nonstutterers
Rhythmic	Right Hand	.130	.031
	Left Hand	.033	.034
Spontaneous	Right Hand	.224	.155
	Left Hand	.313	.078

Phrase repetitions. Analysis of variance revealed a main effect for Task [$F(1,54)= 11.96$, $p \leq .001$]. Significantly more phrase repetitions occurred during spontaneous speech (.10) compared to rhythmic speech (.027). There was no main effect for Speech Group. In addition, there was an Age by Hand-Used-For-Tapping interaction [$F(1,54)= 3.08$, $p \leq .05$]. The mean scores for this interaction are shown in Table 25. Phrase repetitions decreased as age increased. For the two older age groups, more phrase repetitions occurred while tapping with the right compared to the left hand. For the youngest group (6 to 8.11 years), more phrase repetitions occurred while tapping with the left compared to the right hand.

Interjections. Analysis of variance revealed a significant main effect for Task [$F(1,54)= 18.97$, $p \leq .0005$]. Interjections were more likely to occur during spontaneous speech (.343) compared to rhythmic speech (.029). There was not a main effect for Speech Group.

Revisions. Analysis of variance revealed a significant main effect for Task [$F(1,54)= 21.15$, $p \leq .0005$]. Interpretation of this main effect must be considered in relation to a Task by Hand-Used-For-Tapping interaction [$F(1,54)= 4.24$, $p \leq .04$]. Mean scores for the main effect and interaction are shown in Table 26. Significantly more revisions occurred during spontaneous compared to rhythmic speech. During spontaneous speech, more revisions occurred while tapping with the right compared to the left hand.

Table 25

Mean Phrase Repetition Scores for the Age
by Hand-Used-For-Tapping Interaction

Age	Right Hand	Left Hand
6-8.11 years	.098	.140
9-11.11 years	.056	.000
12-15 years	.040	.000

Table 26

Mean Revision Scores for the Task Main Effect and
Task by Hand-Used-For-Tapping Interaction

Task	Mean Score per Trial	
Rhythmic Speech	.096	
Spontaneous Speech	.252	
	Right Hand	Left Hand
Rhythmic Speech	.087	.110
Spontaneous Speech	.301	.202

Disrhythmic phonations. Analysis of variance revealed no significant effects.

Relevant to the hypothesis concerning demand for spontaneous speech and a greater increase in disfluency in stutterers than in nonstutterers, speech during tapping tasks resulted in more spontaneous speech disfluency in stutterers than nonstutterers. In addition, spontaneous speech fluency increased with age. Spontaneous speech also resulted in more within-word fragmentation in stutterers than in nonstutterers. The results of the ten distinct disfluency criteria during concurrent performance suggest that childhood stutterers as compared to nonstutterers have more airflow breaks, audible prolongations, vowel substitutions, tense surges and part-word repetitions. In contrast and relevant to discussion of normal developmental disfluency, childhood stutterers and nonstutterers did not differ in whole-word repetitions, phrase repetitions, interjections, revisions or disrhythmic phonations. It appears then that childhood stutterers can be differentiated from nonstutterers on the basis of within-word fragmentation.

Spontaneous speech also produced more disfluencies than rhythmic speech, specifically more audible prolongations, tense surges, part-word repetitions, whole-word repetitions, phrase repetitions, interjections, and revisions. Spontaneous generative speech is therefore disruptive across type of disfluency in both stutterers and nonstutterers.

Relevant to developmental disfluency, speech fluency

increased as age increased, and in addition, phrase repetitions which are likely to be considered normal disfluency, decreased as age increased.

The relationship between speech fluency and lateralized performance can be addressed based on the result of stutterers being more disfluent while tapping with the left hand compared to the right hand. Specifically, stutterers had more part-word repetitions and whole-word repetitions while sequentially tapping with the left hand as compared to the right hand. This would suggest an overload of the motor programming and temporal sequencing systems when the right hemisphere is activated for sequencing. This could occur through right hemisphere inefficiency for motor sequencing or through inefficient interhemispheric communication.

For nonstutterers, results of speech fluency during tapping suggest that normal speaking children were more disfluent while tapping with the right hand as compared to the left hand. Specifically, nonstutterers had more part-word repetitions, whole-word repetitions, and phrase repetitions while tapping with the right hand compared to the left. The exception to this was the youngest group (age 6 to 8.11 years) who did not differ between hands in the occurrence of phrase repetitions.

It would seem then, that in normal speaking children, time sharing tasks involving speech and unimanual sequencing, support the left hemisphere as the active hemisphere in temporal sequencing, whereas in stutterers, the right hemisphere is more involved and probably in an inefficient way.

Emotional Stress Questionnaire

Total questionnaire score. The emotional stress questionnaire total score was designed to measure interpersonal and emotional stress. High scores indicate high interpersonal and emotional stress. Analysis of variance of the total score revealed significant differences between speech groups [$F(1,58)= 13.45$, $p < .0005$]. The mean score was 93.63 for stutterers ($SD= 14.5$), and 81.67 for the nonstutterers ($SD= 10.5$). As indicated in Table 27, stutterers in each of three age groups had significantly higher questionnaire scores than nonstutterers.

Factor analysis. Factor analysis of the questionnaire items was performed for all items combined. This analysis revealed three separate and reliable dimensions which were labelled: Audience Sensitivity ($\underline{ssca}=.74$), Social Confidence ($\underline{ssca}=.77$), and Sociability ($\underline{ssca}=.65$). Analysis of variance of mean dimension scores indicated that stutterers had higher Audience Sensitivity [$F(1,58)= 15.0$, $p < .0003$], lower Social Confidence [$F(1,58)= 28.4$, $p < .0005$], and lower Sociability [$F(1,58)= 13.81$, $p < .0005$] when compared to nonstutterers. As shown in Table 28, stutterers in each of three age groups had significantly lower Social Confidence than nonstutterers. However, on the dimensions of Audience Sensitivity and Sociability, some of the age groups did not differ. Stutterers and nonstutterers age 9 to 12 years did not differ in Audience Sensitivity. However, the youngest and oldest group of stutterers had significantly higher Audience Sensitivity

Table 27

Means and ANOVA Comparing Stutterers and Nonstutterers on
Emotional Stress Questionnaire Total Score

	Age	Stutterers		Nonstutterers		F	df	P
		Mean	SD	Mean	SD			
ESQ Total Score	6-8.11	103.0	14.4	87.56	10.9	6.03	1,14	< .03
	9-11.11	87.83	9.4	76.89	12.5	5.30	1,19	< .03
	12-15	94.0	16.8	80.83	6.6	6.29	1,21	< .02

Table 28

Means and ANOVA Comparing Stutterers and Nonstutterers on Three Dimensions of the Emotional Stress Questionnaire as revealed by Confirmatory Factor Analysis

		Stutterers			Nonstutterers			P
	Age	Mean	SD		Mean	SD	F	df
Audience Sensitivity	6-8.11	22.15	8.3		12.44	1.7	11.97	1,14
	9-11.11	14.83	4.7		11.67	2.5	3.43	1,19
	12-15	16.45	6.9		12.00	2.4	4.41	1,21
Social Confidence	6-8.11	18.20	7.0		12.00	3.7	5.32	1,14
	9-11.11	19.00	3.5		14.56	5.1	5.61	1,19
	12-15	21.55	3.9		14.17	3.7	21.42	1,21
Sociability	6-8.11	11.71	4.9		9.56	1.7	1.55	1,14
	9-11.11	10.08	2.6		6.89	1.8	9.99	1,19
	12-15	10.91	3.1		7.83	2.2	7.67	1,21

than nonstutterers. On the sociability dimension, the youngest group of stutterers and nonstutterers did not differ. The older group of stutterers (age 9 to 15 years) had significantly lower sociability than the nonstutterers.

Confirmatory factor analysis with communalities was performed to identify which items were more reliable measures of each dimension for stutterers and nonstutterers. Table 29 shows the results of this analysis: questionnaire items and their respective factor loadings are ranked in order from the most to the least reliable measures of the three dimensions for each group. For stutterers, the factor analysis revealed ssca reliabilities of .76 for Audience Sensitivity, .84 for Social Confidence, and .72 for Sociability. Reliabilities for each dimension for nonstutterers were .55 for Audience Sensitivity, .43 for Social Confidence, and .55 for Sociability.

Relevant to the hypothesis concerning higher emotional stress in older stutterers compared to younger stutterers and all ages of nonstutterers, the current results suggest the total ESQ score, or general measure of emotional stress, differentiates stutterers from nonstutterers regardless of age. However, individual dimensions within the questionnaire proved to be valuable for differentiating age groups of stutterers and nonstutterers. The one dimension that seemed to affect all stutterers as compared to nonstutterers was lower social confidence. The questionnaire item that most reliably measures social confidence and self esteem for stutterers and

Table 29

Emotional Stress Questionnaire Items and Associated Loading Factors
 Ranked in Order From Most to Least Reliable Measures of Three
 Dimensions Revealed by Confirmatory Factor Analysis
 for Stutterers and Nonstutterers

Audience Sensitivity		Social Confidence		Sociability	
Stutterers		Nonstutterers		Stutterers	
item/factor	item/factor	item/factor	item/factor	item/factor	item/factor
7 86	6 69	28	87	28	93
6 95	7 60	30	84	33	82
26 68	26 43	33	76	29	71
21 50	21 43	8	70	19	39
18 40	18 11	29	64	30	18
		19	62	8	-29
				11	85
				13	66
				27	55
				14	46
				27	21
				14	75
				11	66
				13	39
				27	21

nonstutterers is item number 28 ("Do you feel that you are as good as the other children in your class?"). For the stutterers, the next most reliable item concerns thinking of oneself as a failure.

In the area of social and audience sensitivity, the youngest and oldest age groups of stutterers had the highest levels of audience sensitivity. The questionnaire items that most reliably measure audience sensitivity are item 7 ("Do you like to get up in front of class and give a speech?"), and item 6 ("Do you like to talk in front of class?"). The audience sensitivity scores remained relatively consistent across ages for the nonstutterers. However, because of a drop in audience sensitivity during the age period 9 to 12 in the stutterers, this age group of stutterers and nonstutterers did not differ.

In the area of sociability and social interest, the older age groups of stutterers did have lower sociability and social interest scores than the nonstutterers. The questionnaire items that most reliably measure sociability are item 11 for stutterers ("Do you like to meet new children?"), and item 14 for nonstutterers ("Do you like to be around other children?"). The sociability scores remained relatively consistent for all age groups of stutterers. However, the youngest group of nonstutterers age 6 to 9 years had significantly lower socialibity scores resulting in lack of significant differences between stutterers and nonstutterers in this age group.

Although the Emotional Stress Questionnaire (ESQ) seems to be particularly useful for stutterers, it might also be useful for

assessing speech and communication stress in normal speaking children or in children with other communication or speech and language disorders.

DISCUSSION

The results confirmed the prediction that, during bimanual handwriting, right-handed school-aged stutterers compared to nonstutterers have poorer left hand performance and greater frequency of left hand mirror reversals. The study also confirmed the prediction that during concurrent unimanual sequential tapping, stutterers have more finger sequencing errors than nonstutterers. Moreover, stutterers as compared to nonstutterers are more disfluent during concurrent unimanual sequencing with the demand for spontaneous speech causing a greater increase in disfluency and within-word fragmentation in stutterers than in nonstutterers. Finally, the results indicate that childhood stutterers compared to nonstutterers have higher interpersonal and emotional stress.

The predictions for the current study were based to a large extent on hypotheses derived from research with adult and childhood stutterers and nonstutterers. The data from the current study that fit the predictions best were those for the older subjects (age 9 years to 15 years old). The youngest group of stutterers and nonstutterers (age 6 to 9 years) produced data that least fit the predictions, particularly in the areas of bimanual handwriting and emotional stress.

Bimanual Handwriting

Handwriting organization. The current findings support previous research with adults (Fitzgerald et al, 1984; Greiner et al, 1984b) suggesting that stutterers' poorer nondominant hand

performance during bimanual writing may be due to inability of the left hemisphere to inhibit activity of the right hemisphere. The current findings with children support this hypothesis and give evidence of lack of full left hemisphere motor lead control until age 9 years, with young stutterers (age 6 to 9 years) having the least left hemisphere motor lead control during bimanual tasks.

The current findings support the contention that interhemispheric connections develop around age 9 at which time the left hemisphere establishes motor output control; that is, until age 9, there is poorly established inhibition of right hemisphere activity. The maturation of the corpus callosum provides the inhibition of competing right hemisphere activity necessary for the development of left hemisphere motor control. Thus, during bimanual handwriting tasks, the right hemisphere is inhibited and the left hand writes normal script with diminished need for effortful attentional supervision. The results showed inefficient speech-manual performance and mirror script writing in the left (nondominant) hand until around age 9 in normal speakers and through age 16 in stutterers.

Specific results from the current study that support these theories will now be addressed. Results of the handwriting organization comparison suggest that stutterers compared to nonstutterers did more poorly with their nondominant left hand during the bimanual replication task and the task requiring increased allocation of attention to the right hand. No differences in

organization occurred between stutterers and nonstutterers during concurrent speech and bimanual handwriting. However, during increased allocation of attention to the left hand, stutterers' right hand organization was poorer than nonstutterers. Such results tend to corroborate contentions that inefficient interhemispheric integration is characteristic of disfluent speech.

Mirror image reversals. Across bimanual handwriting tasks, stutterers had more left hand mirror reversals of digits and letters than nonstutterers. The youngest group of normal speakers had a high frequency of left hand mirror writing so that the stutterers and nonstutterers in this age group (age 6 to 8.11 years) did not differ in nondominant left hand mirror writing. During bimanual writing with increased attention allocation to the left hand, stutterers across age groups also had more mirror reversals with the right hand than did nonstutterers. Although increased allocation of attention to the left hand in older nonstutterers (age 9 to 15) was not disruptive, it did produce disorganization and mirror writing in the right hand of six- to nine-year-old nonstutterers. Increased allocation of attention to the left hand, during bimanual writing, increases attentional demands on the right hemisphere, thereby increasing right hemisphere activity. This right hemisphere activity then must be inhibited by the left hemisphere in order for coordinated speech and manual activity to occur. Difficulty in interhemispheric processing and hemispheric integration arises if the corpus callosum is functionally immature and if

the left hemisphere cannot establish and maintain motor output control. Interhemispheric processing difficulties in normal speaking boys are related to delayed maturation of connecting neural circuitry until age 9. Interhemispheric processing difficulties in boys diagnosed as stutterers are more likely related to the right hemisphere processing of speech and language. The right hemisphere becomes language-involved through lack of left hemisphere motor output control and associated lack of inhibition of right hemisphere activity.

Previous research (Fitzgerald et al., 1984; Greiner et al., 1985b) suggests that adult right-handed and left-handed stutterers have poorer nondominant hand performance than nonstutterers when writing digits and letters bimanually. These studies with adult stutterers did not find differences in dominant hand performance, which suggests that in right-handers, left hemisphere motor lead control was intact. These studies with adults did, however, find inhibitory deficiency in stutterers since right hemisphere activity was not suppressed. Conversely, the results from the current study suggest that right-handed childhood stutterers have poorer dominant right hand performance than normal speaking children. The poorer dominant hand performance was most consistent in the younger stutterers (age 6 to 9) suggesting that this group of stutterers is most deficient in left hemisphere motor lead necessary for control of coordinated motor activity during lateralized performance.

Concurrent Unimanual Sequential Tapping

The current findings support Greiner et al, 1985a, who also found that concurrent speech and unimanual sequencing produce greater speech and manual interference in stutterers than nonstutterers. Moreover, spontaneous speech produced more disfluency for stutterers than nonstutterers, and more disfluency than other speech tasks (Greiner et al, 1985a).

Some researchers attribute interference effects to an imbalance between the activation and inhibition of speech and motor control systems of the left hemisphere, implying that the difficulty in concurrent unimanual tasks arises from intrahemispheric competition. However, in the Greiner et al (1985a) study, as in the current study, interference also occurred in the left hand of right-handed subjects, which suggests that right hemisphere activity is involved. This interhemispheric processing has been related to the left hemisphere's inability to inhibit the function of right hemisphere motor activity. The results of the Greiner et al (1985a) study suggest that regulation of speech and nonspeech motor control systems is influenced more by interhemispheric integration processes than by intrahemispheric competition. When system overload occurs, as it does during the concurrent unimanual sequencing tasks, one hemisphere's role in normal interhemispheric control processes may become impaired. For right-handed stutterers, these problems seem to be related to difficulties in the temporal regulation of the right hemisphere, which interfere with the balance between the right and

left hemisphere activation and inhibition.

Manual interference. Right- and left-hand performance in sequencing errors were greater in stutterers than nonstutterers during concurrent unimanual sequencing, supporting the interhemispheric processing theory. Compared to nonstutterers, stutterers had fewer correct tapping sequences and significantly higher tapping error rates. Tapping errors actually increased with age in stutterers and decreased with age in nonstutterers.

Examination of the results of the concurrent task for developmental trends suggests improvement in speech and nonspeech manual skills with increasing age in normal speaking children and a decline in performance with increasing age in stuttering children. There are relatively few developmental investigations on time-sharing (Wickens & Benel, 1982), but what evidence does exist indicates that time-sharing ability increases with age (Birch, 1971; Lipps-Birch, 1976; Hiscock & Kinsbourne, 1978; O'Leary, 1980). The current study indicates that concurrent unimanual sequencing rates and correct tapping sequences increase with age and tapping errors decrease with age in normal speaking children. Thus it would seem that normal speaking children between the ages of 12 and 15 years have maximum capability for rapid and correct unimanual sequencing compared to younger children, with improvement in tapping rate and accuracy occurring between ages 6 and 15. Although stutterers and nonstutterers do not differ in speed of sequential tapping, accuracy of the sequential tapping is poorer for stutterers.

Given that across all subjects, the right hand had more rapid and accurate sequential tapping than the left hand, and that stutterers had as rapid a rate as nonstutterers but fewer correct tapping sequences, it appears that errors in right hand sequencing might have produced the significantly lower correct sequencing in stutterers. This supports a superior left hemisphere ability for manual sequencing in normal speaking right-handed children and a left hemisphere role in the disruption of sequencing ability found in stutterers.

Speech and manual tasks have been shown to be influenced by hemispheric specialization. Spontaneous speech, requiring generative and spontaneous temporal regulation and formulation of thought, has been seen as a left hemisphere specialized task in right-handed normal speaking males. Rhythmic speech and tone feedback were used in the current study because of the structure they bring as exogeneous sources of temporal regulation to the concurrent speech and tapping task. Although there was an increase in the rate of tapping and in the number of correct sequences while tapping with auditory feedback for each finger tapped, throughout the experiment the auditory feedback tasks also produced the most tapping errors. The rhythmic speech task actually slowed the rate of tapping and was also associated with the fewest tapping errors. Thus, the imposed exogeneous temporal control of the rhythmic speech task improved accuracy of unimanual sequencing over time, whereas the imposed rhythm of the nonspeech auditory feedback task interfered with

sequencing accuracy over time. 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). Rhythmic speech slows the rate of manual activity and speech optimizing performance, whereas auditory feedback speeds performance thereby decreasing accuracy of motor movements.

Speech interference. Spontaneous speech produced the most interference on speech organization and more speech interference in stutterers than nonstutterers as measured by disfluency. During all the concurrent speech tasks, stutterers were more disfluent than nonstutterers. Relevant to the component approach to differentiating normal from pathological disfluency, concurrent speech produced more within-word fragmentation in stutterers than in nonstutterers. Stutterers were more disfluent than nonstutterers on five of the ten disfluency-during-tapping criterion, that is, childhood stutterers compared to nonstutterers have more airflow breaks, audible prolongations, vowel substitutions, tense surges, and part-word repetitions. In contrast, childhood stutterers and nonstutterers did not differ in whole-word repetitions, phrase repetitions, interjections, revisions or disrhythmic phonations. These later criteria have been suggested as indicators of normal disfluency in children (Adams, 1982). Disrhythmic phonations as a disfluency variable produced no significant effects, supporting previous research finding no differences between childhood stutterers and

nonstutterers in phonatory behavior (Schmitt & Cooper, 1978). Speech organization skills appear to improve with age; older children had more fluent speech than younger children particularly during spontaneous speech. In addition, phrase repetitions that are considered to be part of normal developmental disfluency were less frequent in older children. These concurrent task results support the Tingley and Allen (1975) findings that speech and manual motor timing control improve with age. In addition, the results of the current study support the suggestion that stutterers as a group have less accurate speech and manual motor timing than do nonstutterers (Cooper & Allen, 1977). It is important to emphasize, however, that the subjects in Cooper and Allen's study were adults. These findings do warrant the attention of researchers and clinicians interested in identifying those stutterers who have basic motor timing control deficits so as to modify or define specific individualized therapy. Cooper and Allen (1977) suggest that adult stutterers who completed and were released from therapy are more accurate timers than are stutterers still in therapy. Perhaps current successful stuttering therapies are those that assist the stutterer in regaining control of motor timing.

A finding that is relevant to the nature of the speech task and underlying hemispheric specialization is that spontaneous generative speech, which has high temporal organization and regulation requirements, produced more disfluencies than rhythmic speech. Specifically, spontaneous speech produced more audible

prolongations, tense surges, part-word repetitions, whole-word repetitions, phrase repetitions, interjections, and revisions. Spontaneous generative speech was more disruptive than rhythmic speech across 70% of the disfluency types for stutterers and nonstutterers. It is important to note that during concurrent speech and tapping, stutterers were more disfluent than nonstutterers during all speech tasks. However, during pretest nonconcurrent speech tasks the youngest and oldest age groups of stutterers and nonstutterers did not differ in rhythmic speech fluency. The rhythmic speech task assists fluency during a nonconcurrent speech task by providing exogenous temporal pacing and slowing the rate of speech. Further evidence for this comes from the concurrent speech tasks, during which stutterers had more tense surges or phonatory tension during spontaneous than during rhythmic speech. In contrast, nonstutterers had more tense surges or phonatory tension during rhythmic than during spontaneous speech. Perhaps the rhythmic speech task imposes exogenous speech timing control, assisting fluency in stutterers and interfering with speech fluency in nonstutterers by competing with internal pacing mechanisms (Wade, 1982).

One might speculate further that during spontaneous speech, the left hemisphere provides temporal regulation of speech in nonstutterers. In stutterers, this left hemisphere internal pacing mechanism may be easily disrupted. This speculation is supported by the part-word repetition findings. Stutterers had significantly

more part-word repetitions during spontaneous speech compared to rhythmic speech. Nonstutterers had significantly more part-word repetitions during rhythmic speech compared to spontaneous speech.

For normal disfluency variables (i.e., whole-word repetitions, phrase repetitions, interjections, and revisions) more disfluency occurred during spontaneous than during rhythmic speech for all subjects. Thus the possibility exists that normal disfluency and stuttering are regulated by different mechanisms with respect to interhemispheric processes.

Normal disfluency is susceptible, however, to the influence of lateral manual specialization as apparent in the Hand-Used-For-Tapping interactions. Specifically, stutterers had more part-word repetitions and whole-word repetitions while sequentially tapping with the left hand as compared to the right hand. This suggests an overload of the motor programming and temporal sequencing systems when the right hemisphere is activated for motor sequencing, a process which could be related to right hemisphere inefficiency for motor sequencing or to inefficient interhemispheric communication.

For nonstutterers, results of speech fluency during tapping indicate that normal speaking children were more disfluent while tapping with the right hand compared to the left hand. Nonstutterers had more part-word repetitions, whole-word repetitions, and phrase repetitions when tapping with the right hand rather than the left hand. The exception to this occurred in the youngest group of children, who did not show differences in performance between hands

in the occurrence of phrase repetitions.

It is apparent, then, that in normal speaking children results of time-sharing tasks involving speech and unimanual sequencing support the view that in right-handers the left hemisphere is the active hemisphere in temporal sequencing and regulation, whereas in childhood stutterers the right hemisphere is more active thereby producing inefficient temporal sequencing and regulation.

Interpersonal and Emotional Stress

Emotional stress questionnaire total score. The results support previous reports (Greiner et al, 1985) that stutterers have higher levels of interpersonal stress than nonstutterers. Greiner et al (1985) found that adult stutterers have higher levels of social sensitivity and social isolation, and lower levels of social confidence as measured by the Revised Willoughby Personality Schedule. Greiner et al (1985) suggest that some stutterers do not exhibit interpersonal stress, and in addition, there may be some stutterers for whom anxiety is not a contributing factor in their disfluency. Individual stutterers might, however, be affected by word-specific anxiety, speech-situation anxiety, or general anxiety.

Questionnaire dimensions and factor analysis. The results suggest that childhood stutterers generally have higher interpersonal and emotional stress than nonstutterers. Factor analysis revealed three dimensions in the questionnaire; social confidence and self esteem, social and audience sensitivity, and sociability or social interest. Stutterers of all ages show

lower social confidence and self esteem. The questionnaire item which best exemplifies the confidence factor is, "Do you feel that you are as good as the other children in your class?". Childhood stutterers are more likely than normal speaking children to think of themselves as a failure.

In responding to the items measuring social and audience sensitivity, the youngest and oldest age groups of stutterers had the highest levels of audience sensitivity. This dimension seems to be related to speech-situation anxiety and is exemplified by one of the subjects who repeatedly and anxiously asked the experimenter if he was being audiotaped. The questionnaire items that most reliably measure this dimension are related to speaking in front of class. Giving a speech or talking in front of class is a speech situation involving a peer group audience and thereby combines the related emotions of speech-situation anxiety and social sensitivity. Social and audience sensitivity are seen as similar emotions with audience sensitivity being more specific to the immediate or imagined presence of an audience.

The audience sensitivity scores remained relatively consistent across ages for the nonstutterers. For stutterers, there was a decrease in audience sensitivity in the 9 to 12 year old group. Perhaps the stutterers in this preadolescent age group can negotiate with peers and thereby diminish the fear of audience reaction. However, when stutterers reach adolescence, the imaginary audience and audience sensitivity emotions of normal adolescent development

combine with the actual negative social and peer reactions to the stuttering behavior. This produces an increase in audience sensitivity and is certainly a source of the emotional and interpersonal stress seen in the adolescent stutterer.

In the area of sociability and social interest, the older age groups (age 9 to 16 years) of stutterers had lower sociability and social interest scores than the nonstutterers. The questionnaire items that best exemplify this dimension relate to "liking to meet" or "being around other children". The sociability and social interest scores remained consistent for all age groups of stutterers. The youngest group of nonstutterers had significantly lower sociability scores than the older nonstutterers. Young normal speaking children age 6 to 9 have not had as much experience as older children in use of social skills and therefore are more likely to have lower social ability and interest scores than older normal speaking children. Childhood stutterers between the ages of 6 and 16 continue to have negative experiences with socialization and peers, thereby producing the lack of increase in social interest and social ability that is seen in normal speaking boys. A most feared speech situation for adult as well as childhood stutterers, is the task of introducing oneself and saying one's own name. This situation combines audience fear and sensitivity with speech-situation anxiety so that simultaneous negative emotions are experienced with the social skill and ability required when meeting new people and making that first impression.

The predicted difference in emotional stress between older and younger stutterers was not confirmed. This prediction arose from studies like that of Beech and Fransella (1968), indicating that the development of stuttering usually passes through stages from simple repetition of sounds and words, through exacerbation of prolongations and stuttering blocks, and then to the development of disturbances of motor activity, leading ultimately in some individuals to avoidance activities, emotional disturbances, and other forms of social and psychological disruption.

Early childhood stutterers do not differ from older childhood stutterers in social confidence and self esteem, audience sensitivity, or social ability and social interest. Stutterers between 6 and 16 years of age have higher levels of emotional stress and specifically lower confidence and self esteem than nonstutterers. Young normal speaking children age 6 to 9 have not had as much experience as older children in use of social skills and therefore are more likely to have lower social ability and interest scores than older normal speaking children.

Results from the emotional stress questionnaire (ESQ) indicate that this questionnaire is useful for assessment of dimensions of emotional stress. The usefulness of the ESQ for children who stutter is the therapeutic process that can be developed from the personalized statements made in response to the questionnaire. Perhaps a wide range of speech and communication disabled children might also relate personalized statements in response to the

questionnaire items. Validification and test-retest reliability studies of the ESQ with childhood stutterers should be done with further analysis of dimensions of emotional stress in other speech and communication disabled children as well as normal speaking children with other social, psychological, or psychiatric disturbance.

Strong negative emotions and high emotional stress exist in childhood stutterers between age 6 and 16. Stuttering is associated with inefficient right hemisphere regulation of speech. Interestingly enough, Campbell (1982) has linked negative emotion to the right hemisphere as well. If the emotional component and the speech regulation component of stuttering are concurrently controlled by the same hemisphere, system overload may cause disruption in temporal regulation which eventually interferes with the balance between right and left hemisphere activation and inhibition.

The theory that seems to best fit the data from the current study is that normal developmentally disfluent children can be differentiated from stutterers on the basis of lateralized performance. The current study supports previous research suggesting that some stutterers have poorer speech and nonspeech manual timing control than do nonstutterers (Cooper & Allen, 1977). It also supports the theory that some stutterers have timing control deficits arising specifically when the right hemisphere is responsible for temporal sequencing. Not only is the right hemisphere inefficient for motor sequencing in right-handed males, it overloads in stutterers who experience negative emotions

directly associated with the temporal disruption in motor sequencing.

Future research needs to assess how directly negative emotions and emotional stress impinge on motor programming in stutterers. Future research also needs to assess right and left hemispheric activity during a multiple concurrent task consisting of generative thought, peripheral execution of speech and nonspeech motor sequencing, and activation of negative emotions and stress. Johnson et al (1959) suggest that stuttering is a perceptual and evaluative problem that arises because of listener reaction to the childhood disfluencies. It is certainly true that disfluency is usually a transient disorder and that disruption in communication between speaker and listener exacerbates the disorder. Dyadic communication and conversational speech, in addition to possibly being generative, involves listener reaction to stuttering blocks as they occur. The more severe the stuttering and the more disruption in sequencing that occurs for a stutterer, the more likely it will be that a listener will have to react and be sensitive. The current study demonstrates the additional component in this cycle of communication; that is, the speaker's reaction to his or her own stuttering and to the listener's reaction. The results of the current study suggest that children between 6 and 15 years of age are experiencing lowered self esteem and social confidence because they stutter. The audience sensitivity arises through fear of audience reaction to the stuttering. The stutterer's reaction to his or her own stuttering is to not want to meet or be

around new children; again, to avoid confronting the emotional stress associated with being a "stutterer".

A major limitation of the current study is that it did not assess the direct relationship between negative emotions and disruption in temporal sequencing of speech and manual performance, so that the relationship exists in theory. What is apparent is that stutterers have lateralized performance deficits during time sharing tasks, and in addition, have higher levels of emotional stress when compared to nonstutterers. Possible confounding effects in the current study arise from the fact that this was an in-home study. This tends to produce less control of social and environmental influences during the actual experiment than would a laboratory setting. The social influences might relate to negative emotions associated with home. The home setting might not provoke audience sensitivity as would an experimental laboratory setting.

Other possible confounding effects are harder to control. For example, individual reaction to the stimulus picture cards vary in type and intensity based on the child's experience. Since these picture cards were used to elicit spontaneous speech that produced the most disruption for stutterers, it is important to control these stimuli differently, for example with verbal cues. For the therapist, these individual reactions are probably personal statements of emotions surrounding the picture, so that control beyond that which occurred during the study may not be desired.

APPENDICES

APPENDIX A

Project Description Letter
Research Informed Consent Form
Individual Information Form

MICHIGAN STATE UNIVERSITY

DEVELOPMENTAL PSYCHOBIOLOGY LABORATORY
Speech Development Project
Department of Psychology
Psychology Research Building
East Lansing, Michigan 48824-1117

PROJECT DESCRIPTION LETTER

Investigators in the Developmental Psychobiology Laboratory at Michigan State University are conducting a study of the relationship between behavioral and emotional aspects of stuttering.

As a participant, you will complete a questionnaire concerning your feelings about speaking situations, your reactions to various experiences, and your degree of speech fluency. The final part of this experiment will assess handedness and manual motor coordination during speech. What this means is that we will ask you to talk aloud while tapping with your fingers in sequence.

This letter is to inquire whether I may give your name to these investigators so that they or a member of their staff may contact you to discuss your participation in their study. I would like to add that in no way can any individual be identified once the information is collected. Strict confidence and anonymity are guaranteed by removing all names and identifying materials from any records that are kept. I also would like to emphasize that this research does not involve therapeutic intervention. This is basic research effort which may prove useful for therapists and researchers and may have implications for therapy.

Should you agree to consider participating in this work, I will forward your name to the project staff. What will happen next is that they will contact you and arrange an interview to discuss study participation in greater detail. The research project will require one 60-minute session and will be conducted in your home.

If you want to consider participating in this work, please sign the attached form. Signing this form does not obligate you in any way should you decide not to participate. Also, although I hope that you will decide otherwise, please indicate on the attached form if you do not wish to be contacted.

Finally, if you have any questions about this letter you may discuss the project by calling me at 353-6468 or 353-3933.

Jay R. Greiner
Project Coordinator

Hiram E. Fitzgerald
Professor
Department of Psychology

Lauren J. Harris
Professor
Department of Psychology

Paul A. Cooke
Assistant Professor
Department of Audiology and Speech Sciences

Please check one of the following:

_____ Yes, I give my permission to release my name and phone number so that the above named investigators may contact me to provide more detail about their experiments.

_____ No, I do not want to have my name released nor do I wish to participate in the project described on the enclosure.

Signature

Name: please print

Date

Phone number

Please return this form in the self-addressed, stamped envelope.
Thank you.

DEVELOPMENTAL PSYCHOBIOLOGY LABORATORY
Speech Development Project
Department of Psychology
Psychology Research Building
East Lansing, Michigan 48824-1117

RESEARCH CONSENT FORM

I have freely consented to take part in a scientific study being conducted by Jay Greiner (Research Assistant), Hiram E. Fitzgerald and Lauren J. Harris (Psychology), and Paul A. Cooke (Audiology and Speech Sciences) all of Michigan State University.

The study has been explained to me and I understand the explanation that has been given and what my participation will involve.

I understand that the results of the study will be treated in strict confidence and that I will remain anonymous. Within these restrictions I understand that general results may be presented at professional and scientific meetings and may appear in appropriate professional journals and other publications. Moreover, copies of research reports will be made available to me at my request.

I understand that my participation in the study does not guarantee any beneficial results to me directly.

Finally, I understand that, at my request, I can receive additional explanation of the study after my participation is completed and that I will not receive any financial compensation for participation in this one-hour study.

Signed: _____

Parental Signature: _____

Date: _____

NOTE: This form is to be held in locked file.

MICHIGAN STATE UNIVERSITY

DEVELOPMENTAL PSYCHOBIOLOGY LABORATORY
Speech Development Project
Department of Psychology
Psychology Research Building
East Lansing, Michigan 48824-1117

INDIVIDUAL INFORMATION

This information is to be kept in the locked file folder and used to
1) assign code numbers, and 2) provide research summaries to
participants.

Participant:

Name: _____ Phone Number: _____

Address: _____

I would like to receive summaries of the research results when they
are available.

Yes _____ NO _____

Code Number _____

APPENDIX B

Bimanual Handwriting Stimuli

Digits From 1 through 12

Letters From A through L

1
2
3
4
5
6

7
8
9
10
11
12

APPENDIX C

Emotional Stress Questionnaire

EMOTIONAL STRESS QUESTIONNAIRE

1. Do you ever think that something you do may be made fun of by other children?
2. Do you ever worry about doing something dumb?
3. Do you ever think of yourself as different from other children?
4. Do you ever worry about how you look?
5. Do you ever worry about what other children think of you?
6. Do you like to talk in front of class?
7. Do you like to get up in front of class and give a speech?
8. Do you ever feel lonely when you are with other children?
9. Do you ever feel lonely when you are with your friends?
10. If an important person (teacher, principal) came up to talk to you, would you want to talk to him/her?
11. Do you like to meet new children?
12. Do you like to play with other children?
13. When a new student comes to your school, do you go up and talk to him?
14. Do you like to be around other children?

15. Do you like to be around other people?
16. If your teacher says your work is not good, do you feel bad?
17. If you are having trouble putting a puzzle together, do you keep trying even if none of your friends could do it?
18. If the teacher asks a question in class (in front of class) and you know the answer, do you raise your hand to answer the question?
19. Do you think that your classmates are better than you?
20. Do you feel bad when you lose?
21. I get scared when I must speak in front of class.
22. I like to talk to other children at recess.
23. I like when we have to work in small groups at school.
24. I feel good when the teacher calls on someone else other than me in class.
25. I like writing better than answering outloud in class.
26. I like to read outloud in class.
27. I like to go to birthday parties and meet new children.
28. Do you feel that you are as good as the other children in your class?
29. Do you think you have many good things about you?
30. Do you think of yourself as a failure?

31. Do you often think that you can do things better than other children?
32. Do you think of yourself as lucky?
33. Do you think you are a good person?
34. Do you ever wish you could be someone else?

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