INSPIRATORY PLACEMENT OF YOUNG STUTTERING AND NONSTUTTERING CHILDREN DURING SPONTANEOUS SPEECH

By

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A dissertation submitted to the Graduate Faculty in Speech and Hearing Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2002

UMI Number: 3047260

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This manuscript has been read and accepted for the Graduate Faculty in Speech and Hearing Sciences in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

April 26, 2002
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Abstract

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Previous research suggests that the respiratory behavior of people who stutter is different from that of people who do not stutter. Most of the research in respiratory physiology and activity in both stuttering and nonstuttering individuals has been done with adults. To support the claim that respiratory aberrance is part of the stuttering phenomenon, respiratory planning and execution should be identified as different at the earliest appearance of stuttering. Aberrant respiratory patterns, otherwise, might never be considered apart from the maladaptive complex of behaviors that appears later in the disorder.

The purpose of this dissertation was to compare inspiratory activity in relation to the location of stutters and to grammatical structure in the spontaneous speech of young children. Adults inspire consistently at grammatically appropriate junctures during spontaneous discourse. It was not known: 1) if children who have reached the age of being language users demonstrated the adult behavior, with the same degree of consistency, of placing inspirations at grammatical boundaries; 2) if stuttering and nonstuttering children were similar in their placement of inspirations; and 3)

if inspiratory activity occurred as a precursor to nonfluencies, whether or not the inspiration occurred at a linguistic boundary.

Children placed the majority of inspirations at grammatically appropriate boundaries. Stuttering children spoke fewer words and took more breaths than nonstuttering children. Stuttering children also placed more inspirations at non-boundary locations (within clauses and phrases). MlUs and speech and language testing were similar between the groups, as were percentages of appropriate grammatical boundaries generated during the spontaneous speech sample. Stuttering children's reduced verbal output is therefore probably due to high levels of nonfluencies rather than to inherent language disabilities. Grammatical boundaries and inspiratory locations were high probability sites for stuttering; however, inspiration was the better predictor of stuttering location. These findings can be applied to the treatment of stuttering.

ACKNOWLEGEMENTS

There are many people to thank who have helped me throughout the preparation of this dissertation.

To my advisor Katherine S. Harris for supporting and encouraging me in what felt like an endless endeavor.

To the members of my committee, Richard Schwartz, Laura Koenig, and Phil Schneider for their editorial help on the manuscript and their thoughtful comments.

To DA, GE, HA, NI, PE, DL, JA, JG, OW and SA and their families for participating in this research.

To my colleagues and friends at Haskins Laboratories for giving generously of their help and support over the years that I did research at the laboratory.

Special thanks go to my family, my husband Joseph W. Rocco Jr., my son, Charlie Rocco, and his sisters, Jennifer Hendricks and Debbie Johnson for their patience, love, and support while I completed this dissertation. I also acknowledge my mother, Wanda B. Russo, and my brother, Robert D. Russo Jr. MD for their support, and the memory of my dad, Robert D. Russo MD, who would have been so proud to celebrate the successful completion of this doctoral degree with me.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

FIGURE PAGE

INSPIRATORY PLACEMENT OF YOUNG STUTTERING AND NONSTUTTERING CHILDREN DURING SPONTANEOUS SPEECH

CHAPTER I

INTRODUCTION

A general characteristic of our everyday conversational speech is that it begins in an instant and flows with apparent effortlessness. As information flows, so too does air flow, in and out of our lungs, energizing the vocal folds to produce sound waves that are modified by the upper articulators into speech as we know it. Human speech, therefore, results from a thought plan and a motor plan working together in apparent harmony. There is a myriad of complexities behind this apparently simple act of speaking. Normal talkers take these complexities for granted, but the multi-facets of speech production must be examined when a breakdown in fluency occurs as it does for people who stutter.

Charles Van Riper (1982) defined stuttering as the behavioral manifestation of physically disrupted actions of the respiratory, phonatory and/or articulatory systems during speech production. In other words, the verbal representations of the thoughts of a stuttering speaker were not smooth and effortless. The classification of speech as stuttered was made generally on the basis of hearing unexpected stops and struggles to say words during any verbal offering. Physiologically, atypical subglottal, transglottal and supraglottal events have been documented both during the stuttering moment and during the perceptually fluent utterances of people

who stutter (Baken, McManus, & Cavallo, 1983; Conture, Colton, & Gleason, 1988; Lewis, 1975; Perkins, Rudas, Johnson, & Bell, 1976; Peters & Boves, 1988; Shapiro, 1980; Watson & Alfonso, 1987; Zimmerman, 1980). The question that arises in relation to stuttered speech is whether coordinated systems of respiration, phonation, and articulation are collectively disrupted or whether one system stands out when the result is nonfluent speech.

Aberrant breathing patterns are frequently associated with stuttering. Interest in respiratory issues was the focus of early experimental studies in stuttering (Blackburn, 1931; Fletcher, 1914; Fossler, 1930; Hill, 1944; Morley, 1937; Murray, 1932; Seth, 1934; Travis, 1927; Van Riper, 1936). Aberrant respiratory patterns reported to occur during stuttering for speakers of all ages were: taking multiple, prephonatory breaths; beginning voicing during inspiration; forcing air out of the lungs prior to initiating speech; under or overinflating the lungs prior to speaking; unexpectedly delaying the initiation of speech after an inspiration; interrupting speech exhalation unexpectedly; and holding one's breath in unexpected places. In comparison, non-stuttering talkers rarely demonstrate these speech-breathing abnormalities (Conrad & Schonle, 1979; Peters & Boves, 1987, 1988). The frequent unexplained occurrence of respiratory differences associated with stuttering make respiration worthy of continued exploration. If stuttering can be decreased or eliminated through changes in one of the manifestations of the disorder (i. e., respiratory behavior), especially in children, future progression of the disorder may be altered in severity.

Respiration is a physiological event. It is also a linguistic event in that speech is organized respiratorily into breath groups. Inspiratory refills that

initiate breath groups usually occur at syntactic boundaries (Winkworth et al., 1995). It is not known if the syntactic predictability of inspiratory refills is preserved in stuttering speakers. Syntactic boundaries, however, are known sites for the occurrence of stuttering for both children and adults (Bloodstein & Grossman, 1981; Brown, 1945; Colburn & Mysak, 1982a; Jayaram, 1984; Quarrington, 1965; Wall, 1978; Wall, Starkweather, & Cairns, 1981). A fairly frequent (but not invariant) finding differentiating children who stutter from adults who have stuttered for years is that while adults do stutter more frequently at sentence, clause, and phrase beginnings, their stutters may also occur on specific sounds and words at other locations in the speech text (Bloodstein, 1960b, 1974, 1995). That is not to say that some children do not stutter on specific sounds or at different locations, but for the majority of young children, stuttering appears at the beginnings of syntactic units. This location of early stuttering at the beginnings of syntactic units is preserved into adulthood if stuttering persists. Thus, analysis of the physiological events and linguistic locations of inspiratory behavior in the spontaneous speech of young people who stutter will provide valuable insights into the nature or nurture of this speaking disorder.

CHAPTER II

REVIEW OF THE LITERATURE

Physiological Studies of Respiratory Function in Stuttering and Nonstuttering Speakers

Subglottal Air Pressure

The general purpose of the physiological studies of speech respiration in the stuttering population is to confirm that the aberrant breathing patterns observed in stuttering speakers are typical within this group and not common among normal talkers. Confirmation of differences is based on comparisons of speech breathing patterns among groups of experimental and control subjects performing various speech tasks. Some physiological measures were made on a group of subjects' perceptually fluent utterances or on their stuttered utterances only. Occasionally, a study has included comparisons of speech breathing activity between stuttered and fluent utterances for the same speaker.

Lewis (1975), Peters and Boves (1988) and Zocchi, Estenne, Johnston, Del Ferro, Ward, and Machlem (1990) studied the management of subglottal air pressure (Ps) in the perceptually fluent speech of stuttering and nonstuttering adults. Lewis compared subglottic pressure and oral airflow rates for four stuttering and seven nonstuttering subjects during the reading of three passages of equal syllable length. Subglottal pressure was measured directly by inserting a needle into the subglottal, tracheal space between the first and second tracheal rings. The needle, which was connected to a pressure transducer, sensed changes in Ps that were recorded on FM tape. Intraoral air pressure was measured with a nasal catheter. Pressure drops were measured

across the mesh screen of a pneumotachograph as oral air flowed through it. Twenty-eight CVC monosyllabic words including plosive consonants were embedded within each of the reading passages. The monosyllable words occurred in the stressed position in the same sentence in all passages. Subglottal pressure and airflow rates were examined for the initial consonant only. All subjects read one passage in their usual manner of speaking. The experimental subjects read two additional passages, one paced to a metronome set at 60 beats/minute, and another passage paced to a metronome rate of 100 beats/minute. Collectively, the stuttering group initiated speech at lower levels of subglottic pressure and with lower airflow rates than the control group did during the habitual speaking condition. During the paced speech conditions, especially the 60-beats/minute, the stuttering subjects' Ps and airflow rates appeared to become more 'normalized' in relation to the findings for the control group. Under the rhythmic stimulation of the metronome, two things occurred for the stuttering group as a whole: 1. They took more air into their lungs prior to speaking, thus increasing the driving force (Ps) beneath the vocal folds for voice initiation; and 2. They allowed the air to flow more freely, without impedance, past the vocal folds and the upper articulators.

Peters & Boves (1988) measured subglottic pressure build-up patterns for their experimental (ten stuttering) and control (seven nonstuttering) subjects prior to perceptually fluent productions of single words. To measure Ps directly, the authors positioned a tiny pressure transducer in the posterior commissure. Electroglottographic and speech acoustic signals were recorded simultaneously with the Ps measurements. Seven different types of build-up

patterns were identified, three normal and four aberrant, which served as the basis for differentiating the two groups. Non-stuttering talkers were found to generate smooth, build-up gradients of subglottal pressure. The pressure peaks of the control group generally occurred simultaneously with the onset of phonation or slightly before or after the pressure peak, depending on the voicing characteristic of the first phoneme in the target word. In contrast, stuttering talkers might demonstrate an apparently normal pressure build-up, but would not phonate until 100ms or more after the pressure peak regardless of the voicing characteristics of the phoneme initiating the target word. Other patterns seen in the experimental group consisted of inappropriate stops and restarts of the rise in subglottic pressure, and pressure peaks prior to phonation onset that were too high or too low for speech to be initiated adequately.

Zocchi et al. (1990) measured suglottic pressure for five nonstuttering and eight stuttering subjects during reading and spontaneous speech tasks. For two of the experimental subjects, the authors were able to contrast subglottic pressure management for both perceptually fluent and stuttered utterances. The control subjects maintained fairly constant levels of subglottal pressure and a relaxed diaphragm during speech (inferred from balloon-catheters placed in the esophagus and stomach). For the stuttering subjects, diaphragmatic contractions were observed during stuttering (two subjects) and subglottal pressure levels during speech appeared to vary unpredictably, regardless of whether the speech produced was fluent or stuttered. Zocchi et al. further reported that the subglottal pressure peaks prior to speech initiation varied dramatically for the stuttering group, fluctuating between

too high or too low, in contrast with the overall consistency in pressure peak attainment of the control group.

Physiological studies that measured subglottic air pressure directly indicate that stuttering speakers manage the initiation and maintenance of respiratory forces behind phonation (initiatory lung volume and airflow) differently than nonstuttering speakers. Specifically, stuttering speakers do not generate speech initiatory and maintenance airflow pressures with the same degree of consistency as nonstuttering speakers, and they demonstrate pre-speech pressure buildup patterns not associated with normal talkers.

Metabolic breathing (i.e., neural control), which is associated with life support, is controlled by the medulla and pons. Denny and Smith (2002) hypothesized that the neural control systems for speech versus metabolic breathing might differ for stuttering and nonstuttering talkers, and that differences could cause disfluent speech. They applied bilateral surface electrodes to the respiratory muscles of 10 fluent speakers and 10 stuttering speakers to assess if metabolic respiratory control was suppressed in stuttering speakers as it was in normal talkers during a reading task. Speech breathing was compared to deep breathing and speech-like breathing maneuvers. The measurable output from EMGs at the separate sites was high frequency oscillations in the range of 60 -110Hz associated with inspiratory-related neural activity. A clearly defined peak in the coherence function between the two sites establishes neural participation in the respiratory activity. Some stuttering speakers exhibited patterns never seen in normal talkers, suggesting that the stuttering speakers could not suppress metabolic respiratory control during speech. It was hypothesized that stuttering

persons with this "reverse" EMG pattern might be those most at risk for respiratory-related speech disruptions. However, there was no clear indication that not suppressing metabolic respiratory high frequency output during speech would be sufficient to produce nonfluent speech. It was unknown also whether emotional arousal, which could affect EMG results and which was not assessed, contributed to different results for the stuttering speakers.

In summary, stuttering speakers exhibited aberrant respiration in the management of subglottic pressure. They were inconsistent in maintaining pressure gradients and achieving sufficient pressure peaks to start and continue speech as initially planned. Studies on neural control of the respiratory system in normal and stuttering talkers indicated that respiratory control is compromised by nonfluencies in stuttering speakers. Respiratory muscles affect the dynamics of air pressure changes (lung volume) within the chest wall when speech is the goal. Therefore, the next physiological questions concern differences in the organization of the chest respiratory components (rib cage and abdomen) for speech initiation for nonstuttering versus stuttering speakers.

Chest Wall Kinematics and Lung Volume Changes

Physiological Factors

Lung volume changes are an index of speech respiratory behavior that has been examined frequently in normal talkers (Russell & Stathopoulos, 1986; Weismer, 1984). Measuring the actual amount of air in the lungs requires invasive procedures that are generally not tolerated well by, nor are acceptable to, many potential subjects. An easier, non-invasive method is to

use an instrumental technique that derives lung volume from changes in the circumferences of the rib cage and the abdomen. The rib cage and the abdomen are the component parts of the chest wall that expand when air inflates the lungs and contract when air exits the lungs. By measuring the changing circumference of these structures separately and additively as they move during speech, researchers can estimate lung volume displacements and study chest wall dynamics from the pre-utterance breath to the termination of the utterance/breath cycle (Russell & Stathopoulos, 1988; Winkworth et al., 1994; Winkworth et al., 1995).

Baken, McManus, and Cavallo (1983), using Whitney gages (mercury filled, flexible tubing that encircles the rib cage and the abdomen and transduces size changes into electrical signals), measured lung volume changes and chest wall dynamics in a group of stuttering and nonstuttering adults. All subjects were instructed to say /a/ or /ha/ as quickly as possible after hearing an auditory stimulus tone. The auditory cue was delivered at various times during the tidal breathing cycle, thus giving the experimenters insight into how subjects prepared the chest wall for speech.

Analysis of the kinematic signals revealed that there was no significant difference between the stuttering and nonstuttering talkers with regard to chest wall posturing for speech. In over 90% of the trials for both groups, oppositional movements of the rib cage and the abdomen (i.e., the abdomen compressed at approximately the same time as the rib cage expanded) were the predominant pattern regardless of where in the tidal breathing cycle the stimulus occurred. The rate of change in the movement of the chest wall from the ventilatory phase in progress to vowel production was found to be

longer if the stimulus occurred when the subjects were at low lung volumes, a condition that occurred more frequently among the stuttering subjects. The stuttering subjects exhibited a consistently different lung volume maneuver. They exhaled prior to phonating following cue delivery. The nonstuttering subjects generally phonated immediately upon cue delivery, stopping the prestimulus ventilatory phase in progress to produce the verbal target requested. The loss of lung air observed in the stuttering speakers prior to phonation was attributed to a delay in vocal fold adduction, rather than to inefficiency in respiratory control. However, it is not clear whether an aberrant lung volume maneuver preceded or followed a laryngeal reaction time delay.

In consecutive studies, Watson and Alfonso (1983, 1987) examined chest wall dynamics of a group of stuttering and nonstuttering adults in a laryngeal reaction time (LRT) study similar to the cued vowel production study of Baken et al., 1983. In the first study (Watson & Alfonso, 1983), pre-speech, chest-wall adjustments were similar for both the experimental and the control groups. However, in the 1987 study, Watson and Alfonso divided their stuttering subjects on the basis of stuttering severity. Individuals producing severe stuttering differed from those producing mild stuttering in pre-phonatory chest wall adjustment times. Given a series of intervening 'readiness' time intervals, talkers exhibiting mild stuttering demonstrated that they could organize voice initiation to follow inspiration within a time period similar to that of normal speakers. Stuttering persons whose speech was rated as severe were always slower to reach maximum lung inflation and slower to initiate speech, regardless of the amount of time they were given to

prepare for the task. Despite the reduced LRT when stuttering was severe, Watson and Alfonso did not rule out inefficient respiratory control in favor of a sluggish laryngeal-response system for this group as the primary contributor to the reaction time lag.

Although a significant finding in stuttering adults, voice reaction time delays have not been found to be discriminatory between stuttering and nonstuttering children below the age of six years. Developmentally, voice reaction times in general decrease with increasing age for stuttering and nonstuttering children alike (Cross & Luper, 1979). In a study by Caruso, Conture, and Colton (1988), onsets, offsets, and duration of respiratory and laryngeal movements and supralaryngeal muscle activity was measured for five normally fluent and five stuttering children. The children, who were between the ages of 3:5 and 6:8 years, were asked to produce monosyllable words with labial and bilabial consonants in the short carrier phrase, "Say __ again", and in short sentences, such as, "We bake cookies with Betty." Respiratory movements were sensed using Respitrace Inductance Plethysmography (RIP), laryngeal activity with an electroglottograph, and lip closure with small, surface EMG electrodes. Only the stuttered productions of the stuttering children were analyzed and compared to the fluent words said by the nonstuttering children. The fluent and stuttered speech of children and adults was similar in the relative temporal sequences of muscle activity and movement onsets. The stuttering children demonstrated greater variability than the normal talkers in the timing of onsets and offsets during stuttering, but not in the organization of the movements associated with the speech task.

A study of speech breathing in 80 children between the ages of 7 and 16 years found similar patterns of chest-wall function for all subjects during both reading and speaking, except when speech fluency was compromised by voiced fillers (um) and unvoiced pauses (Hoit, Hixon, Watson, & Morgan, 1990). The disfluent subjects tended to expend less lung volume per syllable and to lose substantial lung volume during the unvoiced pauses. Pairs of linearized magnetometers were used to sense anteroposterior diameter changes of the rib cage and abdomen synchronized with each subject's speech output. Speech output consisted of passage-reading and spontaneous speech for two trials, each consisting of approximately 10 to 20 breath groups.

Stuttering talkers of all ages demonstrate approximately the same pattern of chest wall movements as normal talkers prior to speech production (Cavallo & Baken, 1985; McFarland & Smith, 1992). Weismer (1984) hypothesized that rib cage enlargement establishes an air reservoir for speech while abdominal compression stabilizes the air pressure to allow a speaker to execute an utterance in its entirety. This process of chest wall refinement appeared to be complete by 11 or 12 years of age (Hoit et al., 1990), because the major differences in function were seen between the 7-year-old group and all the older subjects.

Cognitive Factors

Respiratory patterns change as a result of the cognitive level of a speech task, regardless of whether the speech is subvocal or vocal (Conrad & Schonle, 1979). Using a respiratory time quotient (RTQ) as the standard of measurement, the relationship of inspiratory to expiratory duration was

analyzed for the following speech tasks repeated under subvocal and vocal conditions: 1. reciting automatic sequences, such as counting from 121-200; 2. reading; 3. telling biographical information; and 4. performing arithmetic tasks such as counting to 100 while omitting any number with a 3 in it. A chest pneumograph, consisting of resistance transducers housed in a stiff, plastic band wound around the chest at the level of the nipples, was used for quantitative analysis of speech breathing movements and was coincided with audiotapes of the speech tasks. The pneumograph tracings revealed distinguishable respiratory patterns for each of the four tasks. The shortest inspiratory and the longest expiratory phases occurred during spontaneous speech and arithmetic activities. Inspirations occurred at pauses in the reading and monolog tasks, and these inspired pauses were found to occur at syntactic boundaries. Speech respiratory patterns automatically activated the speech motor system whether the speech was produced subvocally or outloud, and that the level of cognitive involvement in the speech task also controlled respiratory activity.

Vital capacity is the total amount of air a person can exhale from the lungs after a maximum inspiration. Tidal volume is the amount of air a person uses during quiet, non-speech breathing and during the inhalation and exhalation phases of speech breathing. Vital capacity is usually the measuring standard for percentage of air used during the inspiratory and expiratory phases of both quiet and speech breathing (Hixon, Goldman, & Mead, 1973; Weismer, 1984). Adults have been found to inhale approximately 60% of their vital capacity prior to initiating speech, conversation or reading, at a comfortable level (Hixon et al., 1973). Speech exhalation generally ends

slightly above or at resting expiratory level (REL), where muscular and respiratory efforts are most relaxed. For loud speech and longer utterances, Hixon found that adults frequently adopted a strategy of inspiring and expelling increased amounts of air directly proportional to the increase in intensity level or to the increase in utterance length.

Inspiratory changes in lung volume are cognitively influenced by the length (Winkworth et al., 1995) and loudness (Hoit, Hixon, Watson & Morgan, 1990; Russell & Stathopoulos, 1986; Stathopoulos & Sapienza, 1993; Winkworth et al., 1995;) of the speech material. Winkworth et al., 1995 examined increases in lung volume relative to an increase in voice intensity and to increases in utterance length for six adult, female speakers. Lung volume changes were measured during spontaneous speech samples collected over several sessions. Their subjects initiated speech at an average of 47.46% vital capacity (VC). Inspiratory lung volumes ranged from 86 to 22% VC. In most instances (97.8%) lung volume at the beginning of a breath group was at or above REL. Approximately 58.6% of the breath groups were terminated at lung volumes at REL or below. The subjects were variable in their inspiratory and expiratory lung volumes across sessions. Two subjects did not increase lung volume when speech was made louder, but all subjects consistently inhaled more deeply prior to longer utterances. A number of other authors have reported increases in inspiratory lung volume prior to long utterances (Gelfer, Harris, & Baer, 1987; McFarland & Smith, 1992), but Winkworth et al. (1995) were the first to observe this during the spontaneous speech condition for adult speakers.

Russell and Stathopoulos (1988) studied speech respiratory strategies for a group of normal speaking children, ages 8 to 10 years. When reading at comfortable loudness levels, the children frequently ended expiration below resting respiratory level (REL). This finding differs from that for adult speakers. Adults had been reported to occasionally end-expire below REL when reading or speaking at a comfortable voice level (Hixon, 1987; Hoit et al., 1990; Winkworth et al., 1994; Winkworth et al., 1995), but they did not do so as often nor push as far below REL as the children did. Also, when the children were asked to speak in a loud voice, some of them did not increase the amount of air they inspired (as did most adults), but instead pushed farther below REL in order to achieve and maintain sufficient air pressure to satisfy the loud voice requirement. Thus, it appears that concomitant increases in age and language experience may affect speech respiratory strategies in talkers in general.

Speech respiratory strategies can change as a result of speech therapy when the program used focuses on awareness of and changes in the physiological aspects of the disorder (Story, 1990: Story, Alfonso, & Harris, 1996). Respiratory function for three stuttering, adult speakers changed significantly post therapy (became more normalized), and the respiratory changes resulted in increased fluency. The speech task pre- and post-therapy consisted of each subject's random reading of four, CVC words (/pit/, /pet/, /fit/, /fet/) in the carrier phrase, "he say ___ again". All subjects completed the same speech therapy program, which focused on the following objectives for establishing fluent speech: 1. increase inspiratory lung volume prior to speaking (Full Breath); 2. initiate speech with an easy, voice onset (Gentle

Onset); and 3. increase the duration of syllabic elements (Stretched Syllable). Post-therapy, aerodynamic changes were reflected in increases in respiratory phase duration, inspiratory lung volume, and average expiratory airflow rate. Ancillary respiratory changes that also contributed to the normalization of respiratory function and fluency post therapy included the elimination of aberrant subglottal pressure build-up patterns, similar to the ones described by Peters and Boves (1988). The abnormal inspiratory patterns, which were observed for all of Story's subjects pre-therapy, had been eliminated by the post therapy experiment.

Linguistic Factors

Linguistic factors, such as structural boundaries have been found to predictably regulate speech breathing in nonstuttering adults (Winkworth et al., 1995). There is general agreement among researchers, that inspiratory refills occur at linguistically logical locations, such as sentence and clause beginnings, during read and spontaneous speech (Conrad & Schonle, 1979; Goldman-Eisler, 1968; Winkworth et al., 1994; Winkworth et al., 1995).

In an attempt to assess how grammatical structure influences the location of inspirations during speech, Winkworth et al. (1994) had six adult, female subjects read outloud at a comfortable loudness level during a series of sessions scheduled over a three-week period. Respitrace instrumentation was used to sense changes in the cross-sectional diameter of the rib cage and abdomen signaling inspiratory and expiratory activity. Lung volume was estimated from the calibrated sum signal (a continuous, instantaneous, arithmetic sum of the two chest wall signals) of the Respitrace, and validated with vital capacity maneuvers using a spirometer. The number and location

of inspirations were tabulated for the reading passage. Grammatically appropriate inspirations occurred at clause boundaries. For all subjects, the location of the majority of inspirations during the reading was on the first sentence of a paragraph (98%) and at the start of sentences within paragraphs (92.7%). Only 3.19% of all inspirations were not at clause boundaries. Their conclusion was that the high percentage of grammatically appropriate inspirations at sentence beginnings was influenced by the use of reading material, which provided text and punctuation cues.

Winkworth's following study (Winkworth et al., 1995) focused on inspiratory activity during monologs for the same six subjects. Breathing patterns during spontaneous speech, that is, the location of inspirations, varied over a wider percentage range (22-92%) than during the reading task (65-100%). The majority of inspirations during spontaneous speech were taken at sentence and clause beginnings (63.4% of the total number of inspiratory breaths), indicating that inspiratory breaks in the flow of speech are generally taken at appropriate linguistic junctures. Winkworth's subjects took a breath approximately every third clause. Two adults inspired more often and planned the location of their inspirations to coincide with grammatically appropriate places in the text of their conversation. For subjects in this "short breath group", the highest percentage of inspirations still occurred at clause boundaries.

The drive to preserve clause boundaries as inspiratory sites was shown in another study of healthy adult subjects. Bailey & Hoit (2002) created high respiratory drive conditions (breathing high CO^2 air in a sealed enclosure) that caused their adults to inspire more often while performing a

reading task. The need to inspire more often is associated with chronic respiratory ailments such as asthma. Results showed that subjects manipulated their inspirations to coincide with grammatical boundaries. Bailey and Hoit did not examine this behavior in individuals with true respiratory disease.

Disfluencies, such as syllable and word repetitions, filler words, and restarts, in each subject's speech, did have a negative effect on individuals' inspiratory behavior during spontaneous speaking conditions (Winkworth et al., 1995). The total number of disfluencies for the adults ranged from 2.63 to 6.14 per 100 syllables. Type of disfluency was not significantly different for any subject. Individuals who demonstrated the highest number of disfluencies in their speech had the lowest percentage of breaths taken at grammatically appropriate places. Thus, a higher percentage of disfluencies meant less predictable linguistic locations of inspirations. The presence of disfluencies (reformulation, repetitions, and filler words), not the number of inspiratory refills, may predict irregular speech breathing patterns (p. 133). The proximity of disfluencies to inspirations was not identified in this study.

Respiration and Stuttering

Stuttering tends to occur most frequently at the beginning of sentences (Bernstein-Ratner & Sih, 1987; Bloodstein, 1960a; Brown, 1945). This holds true for children and adults who stutter (Bloodstein, 1974; Jayaram, 1984), but it has been found to be especially true for stuttering children (Bloodstein, 1974; Bloodstein & Grossman, 1981; Quarrington, 1965; Van Riper, 1982; Wall, 1978; Wall, Starkweather, & Cairns, 1981; Wall, Starkweather, & Harris, 1981; Yairi & Lewis, 1984). Jayaram (1984) had stuttering adults read a series of short

sentences and then a set of longer sentences in which the short sentence was included either as the initial or final clause. The highest percentage of stuttering occurred on the short sentences when they appeared as the initial clause in a long sentence, followed by the short sentence alone, and then the short sentence as the final clause. Stuttering also occurred frequently at clause boundaries in the spontaneous speech of four and five-year-old children (Wall, 1978). However, none of these studies examined the respiratory influence on stuttering at sentence and clause beginnings or at other locations. For children, word-specific stuttering generally surfaces later in the disorder (Bloodstein, 1960b, 1974, 1995). If there is stuttering on specific phonemes in the early stages of the disorder, the phonemes targeted for stuttering may change as the age of the speaker increases (Bloodstein, 1974). We still do not know why the loci of stuttering changes from the beginning of syntactic units for young stuttering talkers to include the beginning of words at other locations as the disorder progresses (Bloodstein, 1995). The loci of inspiratory refills in relationship to the loci of stuttered words may hold an answer to this question.

Wall, Starkweather, and Harris (1981) examined the voicing characteristics - vowel, voiceless consonant, or voiced consonant - of the phonemes initiating stuttered words in the spontaneous speech of nine stuttering children between the ages of 4 and 6 1/2 years. Each subject's conversation was tape recorded during a free-play period. Transcripts were made of the speech samples that were then marked for 1. stuttering occurrences; 2. sentence and clause boundaries; 3. pauses. Stuttering appeared most frequently after a pause, and pauses occurred most often at the

beginnings of sentences or clauses. The voicing characteristics of the phonemes initiating stuttered words varied randomly among the sound categories, thus contradicting the previous hypotheses that the voicing aspect of the initial phoneme was influential in the occurrence of stuttering on particular words (Brown, 1945).

Syllable and word stress might also influence pause and stuttering locations (Wingate, 1984). Stuttering adults frequently stuttered on stressed syllables during a paragraph reading task. However, they also stuttered on unstressed syllables at the beginning of sentences or after a pause. None of these studies looked at speech breathing patterns in relation to the location of stutters or pauses. Given that stuttering frequently occurs after pauses and at proper grammatical boundaries, and is associated with atypical breathing patterns, stuttering loci should be examined in relation to pauses, inspiration, and grammatical structure.

Language and Stuttering

The language performance of stuttering talkers has been studied extensively. Research on the co-occurrence of language problems and stuttering has yielded inconclusive results (Gaines, Runyan, & Meyers, 1991; Nippold, 1990; Ryan, 1992;). Standardized tests indicate that the overall language proficiency of stuttering children was in the normal range (Ryan, 1992). Children who stutter are reported to have more speech-articulation disorders when compared to their nonstuttering counterparts (Bloodstein, 1995; Louko, Edwards, & Conture, 1990; Wolk, Edwards, & Conture, 1993). Articulation problems occurred more often when stuttering was present, but the percentages of children who stuttered and produced speech sound errors

varied greatly from study to study (Louko, 1995). The type of speech errors exhibited by the stuttering group was not significantly different from the phonologically disordered population in general.

Disfluency and Stuttering

The following indicate the distinction between normal disfluencies and stuttering (Wingate, 1976):

1) Elemental repetitions and prolongations are reliably identified as the sine qua non of stuttering. Even parents have proven to be just as reliable as speech pathologists in identifying stutters from normal nonfluencies;

2) Disfluencies (interjections, incomplete phrases, revisions, phrase repetitions, one or two unit part word and whole word repetitions) are present in normal speech, and unlike stutters, these disfluencies go unheard;

3) Investigators assign subjects (children and adults) to experimental groups based on these criteria;

4) Investigators report stuttering frequency data for subjects with interjudge and intrajudge reliability coefficients in excess of .90.

Stuttering has been described as "a sticking", i.e., "an involuntary but very brief inability to move one or more parts of our speech mechanism" (Van Riper, 1982). Van Riper also referred to stuttering as "a glueness", the presence of something in his speech which made it difficult for him to proceed with his intended verbal message.

Wendell Johnson (1959) coined the terms "nonfluencies" and "disfluencies" to describe the nonfluent behavior of stutterers and normal talkers alike. He did not consider that there was something that caused "a sticking" (the popular 'it' of stuttering), but rather, he proposed that it was

the listeners, predominantly parents, who caused stuttering by calling attention to, and thereby exacerbating, early childhood nonfluencies.

Stuttering has also been defined as a "disruption in the fluency of verbal expression, which is characterized by involuntary, audible or silent, repetitions or prolongations in the utterance of short speech elements, namely: sounds, syllables, and words of one syllable. These disruptions usually occur frequently or are marked in character and are not readily controllable" (Wingate, 1976, p. 488).

Van Riper, Johnson, and Wingate represent the early schools of thought that have spawned the major theories of stuttering. Also, with the recognition that normally developing talkers can exhibit nonfluencies, (i.e., stutters and disfluencies) the words "stutterer" and "stuttering" acquired a degree of ambiguity that they have never lost (Bloodstein, 1995; Wingate, 2001).

Perceptual judgments are the most practical method available for distinguishing between stuttering and disfluencies. The most common disfluencies in the speech of children who do not stutter are single-unit word repetitions, phrase repetitions, interjections, and revisions of incomplete phrases (Bjerkan, 1980). These disfluencies have been found also in the nonstuttered, nonfluent speech of children who do stutter (Bloodstein, 1995; Bloodstein & Grossman, 1981; Culp, 1984; Ham, 1990; Yairi & Lewis, 1984).

Johnson (1959) interviewed two groups of parents, 69 fathers and 80 mothers of children whose parents considered them to be normal talkers and 143 fathers and 146 mothers who considered their children to be stuttering. Parents characteristically described normal disfluencies as phrase repetitions,

pauses, and interjections. Parents of stuttering children consistently described stuttering as syllable repetitions, sound prolongations, and the use of unusual force in getting words out. Of 55 families who brought young children to the speech program at Temple University, all except one family validly identified their children to be stuttering, exhibiting the excessive repetitions, prolongations and struggle consistently associated with stuttering (Starkweather & Gottwald, 1990).

The work of Yairi and colleagues examined the onset of stuttering and the use of disfluencies in the speech of young children as early as two years of age. A longitudinal study of disfluency rates and types for a large sample of nonstuttering children from preschool through high school ages found disfluency rates declined from approximately 8 per 100 words spoken by preschoolers to 4 per hundred words for high school seniors (Yairi & Clifton, 1972). During the preschool years, children experienced periods of nonfluency that included both stutters and normal disfluencies - interjections, revisions, incomplete phrases, pauses, whole word repetitions, part word repetitions, prolongations, and struggle (Yairi, 1982). However, by age three to four, only the stuttering children continued to exhibit part-word repetitions, prolongations, and struggle and at noticeably high rates (Yairi, 1983). The rates for normal disfluencies declined for both groups in general as language skills improved with age. Haynes and Hood (1978) looked at language and the presence of disfluencies in normal speaking children: ten 4 year olds; ten 6 year olds; and ten 8 year olds. They found that as language developed the typology of disfluencies changed: a) the total number of disfluencies decreased; and b) there were fewer repetitions and more

revisions. Colburn and Mysak (1982b) and Yairi (1982) observed that some children became more disfluent as language developed, but, in general, disfluencies of nonstuttering children decreased with age.

What conditions appeared to facilitate the appearance of nonfluencies in the speech of young talkers in general? Normal talkers were nonfluent occasionally in situations where there was pressure to communicate. Davis (1940) reported on the speech of 62 two to five year olds during one hour of free play in a preschool setting. Whole word and part word repetitions were heard at all age levels, but occurred most often (in 1% to 2% of the utterances overall) when a child: 1) was excited; 2) wanted to direct another's activity; 3) tried to get someone's attention (another child's or a teacher's); 4) was forced to stop an activity in favor of a new one; or 5) wanted an object someone else possessed. The whole-word and part-word repetitions of the nonstuttering children usually occurred at the initiation of an utterance or on a conjunction preceding the utterance. Meyers and Freeman (1985) found that both nonstuttering and stuttering children were more disfluent when they interrupted their mothers than when either group was interrupted by their mothers or by other children. This conflicts with Johnson's diagnosogenic theory of stuttering that hypothesized that "external forces", such as interruptions, were a major factor in perpetuating fluency breakdown in children. All of these studies with normal talkers reported no differences between boys and girls with regard to the type of disfluencies observed. However, there was one significant gender difference: more boys than girls were disfluent, at a ratio of about four boys to every girl.

When did stuttering occur in the speech of children who stuttered?

1) Stuttering occurred consistently at the beginning of syntactic units, that is at the beginning of a sentence or clause (Bernstein, 1981; Bloodstein & Grossman, 1981; Wall, Starkweather, & Cairns; 1981).

2) Stuttering rates were generally the same in all speaking situations.

3) Stuttering typology changed with increasing age. Adults stutter at sentence and clause beginnings, but their stutters may also occur on specific sounds and words at other locations.

4) Stuttering severity varied from the time of onset. While the majority of young children stutter predominantly at the beginnings of syntactic units, (i.e., sentences and clauses), the typology of children's stuttering changes to include specific sounds and words at other locations if stuttering persists into adulthood.

Syntactic boundaries are known sites for stuttering in both children and adults although typology and severity of nonfluencies change over time. Speech-respiration appears unstable in the speech of stuttering individuals. On these bases, examination of the inter-relationship of inspiratory locations, syntax, and nonfluencies appeared warranted.

Purpose

The purpose of this dissertation was to explore inspiratory placement in the spontaneous speech of stuttering children. Spontaneous speech was used because it is a thought-driven sequence of utterances punctuated by inspirations that refill air-depleted lungs. To maintain a spontaneous discourse, the respiratory system needs to respond instantaneously, making prephonatory and phonatory adjustments that meet the immediacy, length, complexity, and intensity demands of the verbal task. Spontaneous speech,

therefore, appeared to offer more information with regard to on-line respiratory planning than did cued or rehearsed speech.

Children between 4:0 and 8:0 years were selected to separate long-term behavioral reactions to stuttering from basic aspects of the disorder. Over 90% of four-year-old children are using complex sentences containing conjoined and embedded clauses (Miller, 1981), and stuttering occurs at sentence and clause boundary locations for stuttering talkers of all ages. The strategy of timing inspirations with structural boundaries appears to be characteristic of adult fluent talkers, but it is not known if children use the same strategy. Also, five- and six-year-old children can tell stories with a fully developed plot, main characters and an integrated sequence of events (Culatta, Page, & Ellis, 1983; Westby, 1984; Schober-Peterson, & Johnson, 1989).

Questions not previously asked regarding the interconnection between stuttering, language and respiratory planning were:

1. What was the locus of inspirations in the speech of normal children and children who stutter?

2. Was the placement of inspirations the same in the two groups?

3. Did inspiratory activity occur as a precursor to stuttered words, whether or not the stutter was at a grammatical boundary?

Hypotheses

The general hypothesis was that prephonatory respiratory behavior is an important part of stuttering symptomotology in the speech of young children who stutter. The specific hypotheses were:

1. Children inspire consistently at linguistically expected locations, beginnings of sentences, clauses, and phrases, similar to adult inspiratory behavior.

2. Stuttering children inspire at linguistically expected locations, but also at other locations more often than nonstuttering children due to high levels of nonfluency.

3. Stuttering occurs at grammatical boundaries, but inspiration location is the primary determiner of stuttering sites.

If inspiratory activity occurs immediately prior to stuttered words, stuttering children may be using atypical respiratory control strategies that result in the strengthening and maintenance of nonfluent speech. If atypical respiration is a perpetuating influence, then ameliorating the problem in children, nearer to the onset of stuttering, takes on greater importance. By changing the rules associated with early stuttering (i.e., changing atypical inspiratory patterns), stuttering use and frequency could be diminished or eliminated in the earliest stages of its development.

CHAPTER III

METHOD

Participants

Two groups of children completed this study, the nonstuttering group with five nonstuttering children and the stuttering group consisting of five stuttering children. Only children between the ages of 4:0 and 7:5 years were considered for this study. Table 1 provides identification, age, and grade of each participant at the time of the experimental session. Table 2 presents eight potential participants who failed to finish the experiment for the indicated reasons.

Children were recruited from public schools, local pediatricians' offices, and from the author's private practice, in Fairfield County, Connecticut. An introduction letter and doctoral candidacy verification notice were sent to pediatricians and supervisors of speech departments in the region's public schools and speech-language pathologists in private practice. This initial mailing was followed by a phone call. Speech supervisors were asked to speak with their speech-language pathologists to solicit names of stuttering children who had been identified but not treated for speech therapy. Cooperating referral sources were asked to give introductory information they had received to families of stuttering children. Public school sources expressed concern that they would be exposing families of stuttering children interested in speech services to a course of expensive treatment. Free stuttering remediation was offered to those families who participated in the study. The author is an ASHA-certified, Connecticut-licensed, speech-language pathologist with over 25 years experience in fluency training.

Participant Interviews

Children of families agreeing to participate in the study were seen for a series of approximately three interviews with the author in her private practice office. Additional sessions were scheduled to complete standardized testing. At the initial visit, the experiment was described in detail for the parent(s) and the child. The experimental procedure was demonstrated on a large Mickey Mouse doll. Children tried on the respibands and practiced breathing through a cardboard tube that was part of the experimental apparatus to be used.

Parents' consent and children's assent to participate in the experiment were obtained. Appendix A is an example of the child assent procedure. Appendix B is a copy of the letter of explanation of the procedures for the children given to the family to sign at the first interview with a copy given for their records.

The parents, all college graduates, completed Case History Forms (in Appendix C). Family background, medical, educational, social and stuttering history was obtained in order to ensure children met subject requirements. Participants were required to meet the following criteria: native English speakers; speech and language abilities within age-range expectations, based on parent report and on results of standardized testing done by the author; hearing within the normal range, based on hearing screenings done in the author's office with a Maico MA25 screening audiometer and on parent report of past hearing test results; negative medical history for chronic

middle ear or other illnesses or respiratory diseases or known neurological impairment.

Children were videotaped with an audio-track during the initial interview. For a child to be considered a stuttering subject, a minimum of three stuttered words per minute (sw/m) of stopwatch-timed talking was the general requirement (Ryan, 2001). The following characteristic speech behaviors were the basis for determining stuttering severity in this study: 1. sound and syllable repetitions; 2. word repetitions; 3. prolongations of sounds beginning or within words; 4. struggle to initiate or complete a word. Included in this category were forceful initiations of words and breaks in voicing in the middle of words. (Conture & Kelly, 1991; Johnson, 1959; Johnson, Darley, & Spriestersbach, 1963; Ryan, 2001; Starkweather & Gottwald, 1990; Van Riper, 1982; Wingate, 1976; Zebrowski & Conture, 1989).

Stuttering was rated from mild to severe based upon the frequency of occurrence of one or more of the behaviors cited above. Stuttering severity was determined as follows (Ryan, 1974): Mild - 3 to 5 stuttered words per minute (sw/m); Moderate – 6 to 9 sw/m; Severe: 9+ sw/m. Table 3 gives the stuttering rates and characteristics for the stuttering children at the initial interview.

Speech, language, and intelligence testing was conducted during subsequent sessions between the initial interview and the Haskins visit. All children performed within expected norms on a series of speech and language assessments. Speech, language and intelligence tests administered to each child are listed in Appendix D. Appendix E is a copy of the consent form Haskins Laboratories requires each family sign before the experimental

session. Haskins procedures with children are reviewed and approved by Yale University's Human Subjects Consortium on a yearly basis. The Committee on the Protection of Human Subjects at City University of New York Graduate School approved the research methodology also. The time between the initial visit and the final visit at Haskins Laboratories varied from one to two months depending on participant and experimental room availability.

Procedure

Setting and Equipment

The experiment room at Haskins Laboratories was decorated with animal posters, stuffed animals, and toys. A toy and candy treats were given to the children at the end of the experiment. The child's mother was seated in front of the child approximately 10 feet away during the experiment, so the child would not have to turn in his seat to see her.

Children were seated in a commercially available Kinderchair, Model K1 (Kaye Products Inc., Hillsborough, North Carolina). The chair is made of sturdy, laminated wood. It has a padded chair back, footrest and tray table, all of which are adjustable. The Kinderchair was chosen because the children could be comfortably seated and constrained at the same time, without impeding abdomen or rib cage movement during inspiration. Impulsive and extraneous movements of the upper body were controlled by having each child rest his/her hands on the tray table within outlines of the hands made with a damp, wipe-off marker pen.

The experiment was videotaped with an audio track so speech and body movements could be viewed simultaneously. Extreme upper or lower

body movements could be identified and noted on verbatim speech transcripts. Respiratory movements associated with laughing, coughing, and sneezing were identified easily from the speech transcripts.

A non-invasive respiratory monitoring system, Respitrace Plus, (Cohn, Watson, Weisshaut, Scott & Sackner, 1978) was used to measure expansion and contraction of the rib cage and abdomen associated with inspiratory and expiratory events. The Respitrace Plus consisted of two elastic cloth bands that contained inductance coils. One band was placed around the child's rib cage and the other around the abdomen, as depicted in Figure 1.

Table 4 shows the height, weight, chest, and abdominal-circumference measurements for each child. Respibands were connected to the Respitrace Plus unit by cables, one snapping onto the rib cage respiband and the other onto the abdomen respiband. The Respitrace Plus unit provided internal, arithmetic summing of the rib cage (RC) and abdomen (ABD) components at any point in time, as shown in Figure 2. This summation of the two signals was called the Sum Signal (SUM) and was calibrated internally within the Respitrace Plus unit.

The Sum Signal gave proportional changes in lung volume. Therefore, the Collins II Spirometer was used as a second reference volume transducer. It is an instrument with a reported accuracy of $\pm$1% for the life of the bell (Collins Survey Spirometer Instruction Manual, 1988). It held approximately one quart of water in a sturdy metal container. A lightweight plastic bell was sealed by the water and rode freely in a narrow water well encircling the base. The bell was attached to and operated an ink pen. The pen recorded up and down movements of the bell, which corresponded to inflation and

deflation of the chest wall, on chart paper encircling a slow moving kymograph. Expired lung air filled the bell forcing it to rise. Volume measures could be taken from the ink-charted movements of the dome as the air that was trapped within moved in and out of the cylinder (lungs). Millimeters of movements were converted into milliliters of air volume. These lung volume values were recorded simultaneously while the subject was wearing the Respitrace bands and could be used to determine the net volume values of the calibrated Respitrace Plus Sum Signal. Inspiratory volume was not measured for this study that focused on inspiratory location in relation to syntax and nonfluency.

Respitrace Plus signals (rib cage, abdomen and sum) and the spirometer signal were channeled, along with the acoustic signal, through cables to another computer hardware system - Haskins Laboratories Real-Time acquisition and analysis system (HART). Channel 1 was the acoustic signal (AUDIO), channel 2 the rib cage (RC), channel 3 the abdomen (ABD), channel 4 the sum signal (SUM), and channel 5 the spirometer (SPIRO). The HART device recorded the physiological, real-time Respitrace Plus and acoustic signals, amplified and filtered based on each signal's input frequency and sampling rate characteristics, and stored them on S-VHS tape. The Avalon S-VHS Cassette Data Recorder, Model AE 5300 (Penny & Giles Data Systems, Inc., Roswell, Georgia) was the recording hardware system used for this study. The Avalon is a synchronous, multi-channel, digital recording system. It allowed several separate, wide-band (MHz) analog channels to be recorded simultaneously with negligible inter-channel timing error.

The various channels of taped data were merged into a single file that was stored on a computer designated for physiological data. The individual channels, acoustic, rib cage, abdomen, sum, and spirometer were recaptured from the multiplex condition through a dethreading or channel-separating procedure executed by a computer program designed at Haskins. Simultaneous segments of rib cage, abdomen, sum, spirometer and acoustic activity could then be viewed as individual wave displays on a graphics computer and the waves analyzed for inspiratory changes. Appendix F lists the equipment used during the experiment, and Appendix G is a schematic diagram of the equipment set-up.

Data Input

Speech transcripts were made from listening to the speech output. Speech and physiological movement data from the S-VHS tape were divided into 30-second files. These segments were determined by listening to the speech output through earphones and by insuring that each subsequent segment overlapped considerably with the previous 30-second input window so there were no breaks in continuity of the subjects' speech and inspiratory movements across segments. Each 30-second segment of speech was bracketed [ ] on the speech transcripts.

All acoustic and kinematic data were analyzed using HADES, a computer software package developed at Haskins Laboratories. HADES is an acronym for HAskins Laboratories Data Evaluation System (Haskins Laboratories, 1995). HADES was designed to facilitate the examination and labeling of signals derived from simultaneous measurements of the physiological system. The 30-second speech segments were displayed in

HADES as a series of vertical ports representing the separate data channels. For this study, four ports were used, the top one for the acoustic signal (AUDIO). The Sum Signal (SUM), positioned in the port below its time-matched acoustic output, was the waveform used to identify the location of inspiratory activity. The waveforms representing real-time, simultaneous movements of the rib cage (RC) and abdomen (ABD) during inhalation and exhalation were positioned in the lower two ports, respectively, as shown in Figure 3. Simultaneous points along the rib cage and abdomen waveforms were added to form the Sum Signal. A sharp, upward deflection of the Sum waveform indicated expansion of the chest wall as air was inhaled into the lungs; a gradual, downward deflection signified compression as air flowed out of the lungs during speech.

Each 30-second segment of speech was heard through earphones while simultaneously viewing the sum, rib cage, and abdomen waves in their respective ports using the HADES program on the graphics computer. These 30-second segments were divided into shorter segments (see Figure 3) that contained the period just prior to an upward, inspiratory waveform deflection and just after the next inspiratory rise in the Sum Waveform. Onset, peak, and offset of inspiratory activity relative to that portion of speech were easier to observe in the larger display. An inspiration was the period between the end-point of a previous exhalation (V1) and the peak (P1) of maximum lung inflation, observed in the Sum Signal waveform as the area between the end of the downward deflection associated with the end of exhalation and the peak ending the sharp upward deflection associated with

the end of inhalation. Inspiratory peaks were marked (^) on each child's speech transcript for later comparison with location of stuttering.

Speech Tasks

A unidirectional microphone was placed on a stand approximately six to eight inches from the subject's mouth. With the Respitrace Plus bands on, the subject was instructed to "sit quietly" during a 5 minute, systems-calibration period. A popular child's movie was shown on a video monitor for 5 minutes during Respitrace Plus calibration. During the speech tasks, children were instructed to sit with hands resting in front on the tray table within drawn outlines of the hands. They were instructed to speak so Mom, sitting in the chair across the room, could hear everything. Each child engaged in the following sequence of activities while connected to the Respitrace Plus:

1. Inhaling and exhaling through a party blower. The curling and uncoiling of the paper on the end of the blower provided an excellent indication of the children's mastery of the activity. This mastery then was applied to the tube at the end of the airhose attached to the spirometer.

2. Blowing in and out of a cardboard mouthpiece adapted by Collins for use with children. The mouthpiece was attached to the end of the spirometer tubing. Children were instructed to hold their nose and not to let air escape from the sides of the mouth as it circled the mouthpiece.

3. Breathing-in-and-blowing-out through the cardboard mouthpiece when it was connected to the spirometer before the graphing pen was positioned on the graph paper. Children were shown how blowing into the mouthpiece made two plastic rockets, sitting on poles atop the spirometer,

'take off' (inhalation) and 'land' (exhalation) on the 'moon' (the moveable dome of the spirometer bell). Once each child could perform the breathing maneuver, the bell was raised and the child was instructed to breathe into the tube while sealing his lips around the disposable mouthpiece attached to the tube. Six breath cycles were recorded on the spirometer graph paper.

4. Singing Baa Baa Black Sheep as follows: "I'd like you to sing Baa Baa Black Sheep for me. You may start singing when you're ready."

5. Reciting the nursery rhyme Jack and Jill as follows: "I'd like you to tell me the nursery rhyme, Jack and Jill. You may start when you're ready."

6. Retelling stories of Goldilocks and the Three Bears and The Three Little Pigs. Pictures of the stories were provided to help the child remember the story sequence.

7. Conversing with the experimenter on several topics. A list of interests was obtained from each subject's family prior to the experimental session (e.g., pets, favorite toys, hobbies, movies, TV programs, family trips, and birthdays). Conversation varied from 25 to 40 minutes in length. Longer time periods were necessary to obtain uninterrupted speech and to obtain at least 30 stutters from the stuttering subjects.

8. The child was instructed to recite the nursery rhyme Jack and Jill.

9. The child repeated the spirometer procedure where six breath cycles were recorded on the spirometer graph paper.

The speech tasks were numbered starting with the highest, and the numbers were posted on a square of flannel material attached to an easel in the child's view. A cutout of a boy or girl, depending on child gender, followed the last number. Children were told that as each task was

completed, the number of that task would be removed from the flannel board. The last piece was traded for the toy that the child had chosen prior to participating in the project. The flannel board provided visual feedback that kept many children attentive to completing the project and collecting their treat at the end. The promised toy was also in view on a side table as additional motivation to finish.

Transcriptions

Five minutes of each child's speech was taken from story-retelling tasks and general conversation when there was minimal interruption from the experimenter. Table 5 shows the portion of each five-minute speaking segment that was story retelling versus conversation. Each child's spoken words were transcribed. A high school English teacher and the author viewed the audio-videotapes and compared them with the transcriptions for word accuracy. Then the author separated the story monologs into sentences for the teacher to review for grammatical boundary locations. The minute or less of conversational speech included in a transcript (see Table 5) was typed without punctuation. The raters then placed red slashes on copies of the transcripts at the beginnings of sentences, clauses and phrases. Phrases proved difficult to define, so the raters decided which phrase types would be assigned to the phrase category and counted these as phrase boundaries consistently throughout the transcriptions.

Definition of grammatical elements determining sentence, clause, and phrase boundaries were the following (Semmelmeyer & Bolander, 1981):

1. Sentence boundaries marked the beginning of an utterance, generally included a subject and a verb, and expressed a complete thought

(e.g., Goldilocks tried Papa Bear's bed). They could begin with or be conjoined by a conjunction, (e.g., And Goldilocks tried the big chair; and it was too hard). Occasionally, sentences began with a filler word (e.g. um) or an interjection (e.g. oh).

2. Clause boundaries were independent or main clauses, containing a subject and a predicate, or subordinate, relying upon the main clause for their meaning (e.g., She fell asleep because she was tired). Clauses also followed interjections at the beginning of a sentence (e.g., Oh I went belly surfing.) I went belly surfing was coded as a clause, as interjections are not considered to have a grammatical relationship with groups of words in a sentence.

3. Phrase boundaries were determined as follows:

a. Prepositional when following a noun, (e.g., She put the crabs in the bucket;), but not following a verb (e.g. She sat in the Papa Bear's chair; They were going to go for a walk).

b. Long adverbial phrases, (e.g., Once upon a time or not by the hair of my chinny chin chin), but not short phrases following transitive verbs (e.g. The bed was too hard).

c. Series of three or more items (e.g., a papabear and a mamabear and a babybear), but not series of less than two items (e.g., a yellow rocket and a green rocket).

Transcription Analysis

Linguistic Data

The Systematic Analyses of Language Transcripts (SALT) was the computer software program used to analyze transcripts (Miller & Chapman, 1991). Coding, punctuation, and spelling conventions were followed when

typing the transcription into the computer program. An error-checking procedure scanned the transcript and provided line-specific editing of program formatting errors.

SALT determined total word counts and Mean Length of Utterance (MLU) in words and morphemes for each child. Disfluencies such as occasional word and syllable repetitions, phrase repetitions, fillers, revisions, and incomplete or abandoned utterances were marked by SALT format codes. SALT allowed the user to create special codes that were run through the program's analysis procedures. The following custom codes were also used:

B = beginning of a sentence	I = inspiration
C = beginning of a clause	X = no inspiration
P = beginning of a phrase	S = stutter
G = other non-boundary location	D = disfluency
	N = no stutter or disfluency

Inspirations [I], stutters [S], and disfluencies [D] were identified as initiating a sentence (B), clause (C), or phrase (P) if they occurred on the first word of that particular linguistic location. For example, the code [BIS] at the beginning of a sentence signified that the speaker began the sentence [B] with an inspiration [I], and that the first word was stuttered [S]. Codes also signified the non-occurrence of an inspiration [X], stutter [N], or disfluency [N]. For example, the code [CXN] indicates that the speaker began a clause [C] without taking a breath [X] and without a stutter or disfluency [N]. An inspiration, stutter or disfluency that did not occur in the first-word position at a linguistic boundary was marked by (G), (e.g., [GIS] indicates a word that

was at a non-boundary location [G], that was preceded by a breath [I], and that was stuttered [S]). Stuttering preceded by inspiration was identified by the stuttered word code only (e.g., SP). Stuttering without preceding inspiration included X in the code (e.g., SPX). See Appendix H for the all the SALT conventional and user created codes. Appendix I gives examples of all the special code combinations. Appendix J is a sample of a coded transcript, and Appendix K shows the raw data obtained from the codes for analysis.

Stuttering Data

Two speech-language pathologists, the author and a speech-language pathologist from the Fairfield Public Schools, made the stuttering judgments. Prior to looking at the experiment videotapes, the raters reviewed the definition of a stuttered word (Ryan, 2001) and listened to a demonstration tape developed by Ryan for training speech pathologists to count stuttered words. The author, who has used Ryan's taxonomy for determining stuttered words for more than 25 years, listened to the stuttering identification tape with the second rater who was hearing it for the first time to insure there was no confusion regarding stuttering types.

The two speech-language pathologists independently viewed each subject's videotaped speech segments. The raters underlined stuttered words on separate, identical transcripts for later comparison of stuttering events. Stuttering events that differed between the two raters were reviewed on the videotapes by both raters for a final determination. Table 6 summarizes inter-rater judgments of number of stuttered words for each child. Inter-rater agreement percentages were calculated by making the lowest stuttering count from one rater the numerator and the highest count from the other

rater the denominator. Inter-rater consistency for stuttering counts was 94%. Stuttering subject JG had a rapid speech rate that made part-word repetitions difficult to recognize without several replays of the speech text.

The total number of words spoken (ws) during the five-minute period was counted and divided by five to obtain the number of words spoken per minute (ws/m) (Ryan, 1974). Disfluencies were counted in the SALT codes. Table 7 summarizes, by subject, disfluencies (d), disfluencies per minute (d/m), stuttered words (sw), stuttered words per minute (sw/m), and stuttering severity ratings for the five-minute speech segments.

Statistical Analysis

There were a small number of participants (five per group). T-tests, analysis of variance, and log-linear analyses were conducted to determine the strength of the relationship among the three categorical variables: nonfluency (stuttering and disfluency), inspiration, and grammatical location. Log-linear models are described as likelihood-ratio chi squares. The base model consists of all effects nested together. From this goodness-of-fit model, factors are eliminated. The factor that causes the greatest deterioration in the fit is determined to have the stronger association (Knoke & Burke, 1980; Bakeman & Robinson, 1994). Because syntax and inspiration were expected to influence the presence of stuttering, the two conditions were examined in relation to the magnitude of their effect in the presence of a third variable, nonfluency.

CHAPTER IV

RESULTS

The questions addressed were:

1) Do four-to-eight-year-old nonstuttering children demonstrate adult respiratory behavior of placing inspirations at grammatically appropriate locations?

2) Do stuttering and nonstuttering children place inspirations in the same way with respect to grammatical location?

3) Does inspiratory activity occur before nonfluencies in stuttering and nonstuttering children?

4) For stuttering and nonstuttering children, are grammatical boundary and inspiration each significantly associated with following disfluency and stuttering?

Participants

The participants were age-matched children (see Table 1) who performed similarly on a series of speech and language tests. Table 8 details test performance for each child. Three out of five of the children from each group obtained a perfect score on the Arizona Articulation Proficiency Scale (AAPS). Two from each group had articulation errors involving production of the [r], [s], and [z] sounds. On the Peabody Picture Vocabulary Test (PPVT), a stanine of 5 corresponds to average performance for the standardization population. Nonstuttering children obtained stanines consistently above the mean, whereas stuttering children obtained a range of stanines beginning at mean level to above mean level expectations. No child scored below the mean. On the Test of Language Development-Primary (TOLD-P:2), 2nd

edition, all participants scored above the mean language quotient of 100. The language quotients on the TOLD in general were slightly higher for the nonstuttering group. All children scored above the mean stanine of the standardization population on the Kaufman Brief Intelligence Test (KBIT).

Adults Versus Children

Inspiration

The answer to the first question, whether nonstuttering children employ the adult strategy of placing inspirations at appropriate grammatical boundaries, is yes. Following grammatical boundary guidelines set forth in Winkworth et al. (1995), adults, nonstuttering, and stuttering children located the majority of inspirations at clause boundaries ($F(2, 12) = 1.72$, $p > .40$). Percentage of total breaths at clause boundary locations was determined by dividing total grammatical boundary locations preceded by an inspiration by total inspirations at all locations. Table 9 represents comparison data for percentages of inspirations at clause boundary locations for adults (67%), nonstuttering children (72%), and stuttering children (61%). Figure 4 displays percentages of total inspirations located at clause boundaries for individuals in each group.

Clause Boundaries

Children inspired significantly more often than did adults at clause boundary locations during spontaneous speech ($F(2,12) = 50.99$, $p < .001$). Table 10 gives percentages, by subject, of clause boundary locations preceded by inspiration for adults ($M = 36\%$, $SD = 9\%$), for nonstuttering children ($M = 76\%$, $SD = 5\%$), and for stuttering children ($M = 80\%$, $SD = 7\%$). The numerator for calculating these percentages was number of clause locations

preceded by inspiration and the denominator was total number of clauses. Figure 5 shows percentages for adults compared with those for nonstuttering and stuttering children for total clause boundary locations with inspiration.

In summary, nonstuttering and stuttering children placed most inspirations at grammatical boundaries (i.e., at sentence and clause boundaries), and children differed from adults by inspiring more often at these locations. Figure 6 demonstrates the similarities and differences in inspiratory activity between adults and children.

Nonstuttering Children Versus Stuttering Children

For children-only comparisons, phrases were included as a grammatical boundary category. Sentence, clause, and phrase boundaries were analyzed as contrastive categories or combined into one category of grammatical boundary locations. Non-boundary locations were those within clauses and phrases. The following questions were examined using this format:

a. Do stuttering and nonstuttering children place inspirations in the same way with respect to grammatical location?

b. Does inspiratory activity occur before nonfluencies in stuttering and nonstuttering children?

c. Do grammatical location and inspiration together predict following nonfluencies, and is one a better indicator of nonfluency sites than the other?

The children's transcripts were examined for total words spoken, mean length of utterance (MLU) in words, grammatical boundaries (including phrase boundaries), number and location of inspirations and nonfluencies at grammatical boundary and non-boundary sites.

Total Words Spoken

Nonstuttering children said more words than stuttering children during story retelling and general conversation ($t(8) = 23.22$, $p < .001$). Table 11 includes total words spoken for five minutes taken from each child's speech sample (i.e., nonstuttering children, $M = 675$, $SD = 37$; stuttering children, $M = 531$, $SD = 49$). This is approximately a 20% difference in means, but intra-group variability was high. Figure 7 shows total number of words spoken by each child.

Sentence Length

Mean length of utterance (MLU), given in Table 12, was similar for nonstuttering ($M = 8.6$, $SD = 1.4$) and stuttering children ($M = 8.4$, $SD = 1.2$), ($t(8) = .22$, $p > .40$). Average age of each group was 5:3 years for nonstuttering and 5:2 years for stuttering children. MLU was reported for each subject and ranged from 5.36 words for the younger subjects to 10.62 words for the older ones, regardless of group assignment. For example, nonstuttering participant GE, age 4:2 years, had an MLU of 6.36, and age-matched stuttering participant SA had an MLU of 6.85. On the other end of the age spectrum, nonstuttering participant PE, age 7:4, had an MLU of 10.62 words, while age-matched stuttering participant JG had an MLU of 10.01. Figure 8 shows, by pairs, mean length of utterance in words during spontaneous speech.

Grammatically Appropriate Boundary Locations

The mean percentage distribution of grammatical boundary locations for the five-minute speech segments was the following for nonstuttering children: sentences ($M = 81\%$, $SD = 2\%$), clauses ($M = 8\%$, $SD = 1\%$), and

phrases (M = 10%, SD = 2%). For stuttering children the distribution was: sentences (M = 83%, SD = 2%), clauses (M =7%, SD = 2%), and phrases (M = 10%, SD = 1%). Table 13 provides group means and standard deviations for the number of each grammatical boundary category. A specific boundary location was the numerator and total number of appropriate grammatical boundaries was the denominator. Percentages of boundary and non-boundary locations during the five-minute speech segments were approximately the same for both groups (i.e., 60% grammatical boundaries, 40% non-boundary sites). Figure 9 shows, by child, the percentage distribution of sentences, clauses, and phrases as contrastive categories.

Total Inspirations

Nonstuttering and stuttering children averaged approximately the same number of total inspirations for the five-minute speech transcripts. The nonstuttering group's total inspirations were 594, with a mean of 119 inspirations per child. The total for the stuttering group was 603 total inspirations, with a per child average of 121 inspirations ($t(8) = .10$, $p > .40$). Table 14 summarizes total inspirations and average inspirations per group. Stuttering children spoke fewer words with the same number of inspirations as the nonstuttering group whose mean word production was greater.

Nonstuttering children placed significantly more of their inspirations at grammatical boundary locations than did the stuttering group ($t(8) = 2.36$, $p < .05$). Percentage of total breaths at grammatical boundary locations ranged from 75% to 86% for nonstuttering children (M = 80%, SD = 4%) and from 53% to 84% for stuttering children (M = 67%, SD = 10%). Stuttering children inspired more at other locations (within clauses and phrases) than did

nonstuttering children. Table 15 gives percentage of inspirations per boundary location (sentence, clause and phrase boundaries). Figure 10 shows each individual's percentage of total inspirations at grammatical boundaries as a single category.

Grammatical Boundaries Preceded by Inspiration

There were several grammatical boundaries in many of the sentences the children produced. On average, nonstuttering (M = 76%, SD = 5%) and stuttering (M = 80%, SD = 7%) children inspired at appropriate grammatical boundaries with similar frequency ($t(8) = .93$, $p > .40$). Table 16 gives percentage of each grammatical boundary (sentence, clause, and phrase) preceded by inspiration. The numerator for calculating these percentages was number of a boundary location preceded by inspiration and the denominator was total number of that particular boundary. For example, number of sentences preceded by inspiration was the numerator and total number of sentences with and without inspiration was the denominator. There was a great deal of variability within groups for percentage of each grammatical boundary preceded by inspiration. Mean percentages for each child of grammatical boundaries as a single category are displayed in Figure 11.

Nonfluencies

Stuttering at the beginning of a disfluency, such as a revision, was counted only as stuttering. If there was no stuttering involved at the site of a disfluency, it was counted as a disfluency. A general category of nonfluencies was established that included stuttering and disfluencies for stuttering children and disfluencies for nonstuttering children. The number of total nonfluencies was the numerator and total words the denominator when

calculating percentage of nonfluency per child. Stuttering children, as expected, averaged significantly higher percentages of nonfluency than did nonstuttering children ($t(8) = 4.47$, $p < .01$). Percentage of disfluencies for nonstuttering children ranged from 1% to 11% (M = 5%, SD = 3%), and nonfluencies for stuttering children ranged from 10% to 18% (M = 15%, SD = 3%). Table 17 gives numerical totals and percentages of nonfluencies for nonstuttering and stuttering children. Figure 12 displays percentages of nonfluency for each child.

Locations Affected by Nonfluency

Nonstuttering children had fewer grammatical sites affected by nonfluency. For example, 16% of the sentences begun by nonstuttering children were nonfluent, whereas 49% of sentences begun by stuttering children were nonfluent. Table 18 gives percentage of grammatical boundaries and other locations (within clauses and phrases) that were affected by nonfluency. The numerator for calculating these percentages was the number of each grammatical boundary initiated by nonfluency, and the denominator was the total number of that particular boundary location. For example, number of sentences initiated by nonfluency was the numerator and total number of sentences was the denominator. The denominator signified opportunities available for nonfluencies to appear at boundaries and other locations and the numerator was actual incidences of nonfluency at these locations. Figure 13 shows percentages of locations affected by nonfluencies. In summary, nonstuttering children exhibited less nonfluency, therefore having fewer locations affected. The percentage distribution of

nonfluencies across grammatical locations, however, was similar for both groups.

Percentage of Nonfluencies at Grammatical Locations

Nonfluencies occurred predominantly at the beginning of sentences for all children. Table 19 provides percentage of total nonfluencies occurring at sentence, clause, and phrase boundaries as separate categories; at all grammatical boundaries as one general category; and at other locations as the third category. Number of nonfluencies at a designated location was the numerator and total number of nonfluencies was the denominator. For example, of 173 total disfluencies for the nonstuttering group, 47% were located at sentence boundaries, 9% at clause boundaries, and 4% at phrase boundaries. Percentages of nonfluencies at clause and phrase boundaries were small in comparison with sentence boundaries. The percentage distribution of nonfluencies was the same for both groups, with approximately 60% of nonfluencies occurring at grammatical boundaries and 40% at non-boundary locations (within clauses and phrases). Figure 14 represents the percentage distribution of total nonfluencies: 1. at categorically separate sentence, clause, and phrase boundaries, 2. at all grammatical boundaries as one category, and 3. at non-boundary, within clauses and phrases, locations.

Percentage of Nonfluencies at Grammatical Boundaries and at Non-boundary Locations with and without Preceding Inspiration

Nonfluencies at grammatical boundaries preceded by inspiration were the highest percentage category. Nonfluencies at grammatical boundaries with no preceding inspirations were the lowest category. Nonfluencies at

non-boundary locations with and without preceding inspiration varied in percentage amounts across subjects and groups, however, stuttering children inspired more often before nonfluencies at non-boundary sites. More nonfluencies were preceded by inspiration, and it appeared that inspiration was the better predictor of nonfluency locations than was grammatical boundaries. Table 20 provides percentages of nonfluencies at four grammatical loctions: at grammatical boundaries and non-boundary sites with and without preceding inspiration. Figure 15 shows the percentage distribution of the four categories for nonstuttering children, and Figure 16 shows the same distribution for stuttering children.

Log-linear Analysis of the Relationship between Nonfluency, Appropriate Grammatical Boundary Location, and Inspiration for Individual Children

The log-linear model, defined as a likelihood-ratio chi-square, is a goodness-of-fit statistic. The model examines the hierarchical effects of categorical behaviors, such as respiration [R] and syntax [S] on nonfluent behaviors [B]. The saturated model [BRS] begins with all three terms, by definition, nested together. Moving backwards from the saturated condition, terms are successively eliminated. Term elimination establishes a hierarchical series of effects. By eliminating syntax, that is, grammatical boundaries [BS], the goodness-of-fit deteriorates. The term with the greatest deterioration-of-fit is the higher order variable. The criteria that determined fit of variable interactions were expected cell frequencies as a function of all variables. Log-Linear Tables 21 - 25 presented results for nonstuttering children's

disfluencies, Tables 26 - 30 for stuttering children's stutters and disfluencies, and Tables 31 - 35 for stuttering children's stuttering only.

The indication of the strength of the association between nonfluencies, grammatical boundaries and inspiration was the size of the change in chi-square value (indicated by the symbol ΔG^2) when appropriate grammatical boundary location [BS] was omitted compared to the size of the effect of omitting inspiration [BR] in relation to stuttering and disfluencies. The size of the change consistently showed that inspiration was the higher order variable for all children in relation to nonfluencies. Table 36 presents the chi-square analyses. Figures 17 and 18 show chi-square changes for nonstuttering and stuttering children, respectively.

The change in Q^2 provided another index, along with change in G^2, that inspiratory presence was more strongly associated with the location of nonfluencies than was grammatical boundary sites for all subjects. A Q^2 larger than .90 indicates a satisfactory fit of the data. The change in Q^2 (ΔQ^2) represents "the change in the proportion of baseline chi-square accounted for by a model when a term is removed" (Bakeman & Robinson, 1994, p. 102). For example, in Table 21, the change in Q^2 (.98) when syntax (BS) was deleted increased by 0% (.00). However, the change in Q^2 (.95) when respiration was deleted increased by 4% (.04). Table 37 presents Q^2 and changes in Q^2 when syntax was the deleted term versus respiration.

In summary, nonfluencies generally were located at inspiration sites regardless of nonfluency category (disfluencies only, stuttering only, or disfluencies plus stuttering). Stuttering location was associated with

inspiratory presence and grammatical boundary sites, but inspiration was the better predictor of where stuttering occurred.

CHAPTER V

DISCUSSION

The purpose of this dissertation was to explore speech respiration in the spontaneous speech of stuttering children. Questions asked when exploring the possible interconnection between stuttering, language, and respiratory planning were:

1) Do four-to-eight-year-old nonstuttering children demonstate the adult behavior of placing inspirations at grammatically appropriate locations?

2) Do stuttering and nonstuttering children place inspirations in the same way with respect to grammatical location?

3) Does inspiratory activity occur before nonfluencies in stuttering and nonstuttering children?

4) For stuttering and nonstuttering children, are grammatical boundary and inspiration each significantly associated with following disfluency and stuttering?

Adults versus Children

It was hypothesized that stuttering children would inspire consistently at linguistic boundaries (sentence, clause, and phrase), similar to adult inspiratory behavior. The general finding for adults and children was that the majority of inspirations occurred at clause boundaries during spontaneous speech. Thus, grammatical boundaries are the prime location of inspiratory activity for adults (67%), for nonstuttering children (72%), and for stuttering children (61%). Children, however, inspired significantly more often than did adults at clause boundary locations. Winkworth et al. (1995) reported that adults averaged an inspiration approximately every third clause, resulting in

36% of adult clause boundaries preceded by an inspiration. Nonstuttering and stuttering children inspired before 76% and 80% of their clauses, respectively. Tables 9 and 10 and Figure 6 illustrate these similarities and differences between adults and children.

Inspiration provides the driving force for following speech. The location of inspirations at clause boundaries is a probable reflection of the integration between speech planning and speech breathing. Inspiratory locations are tailored to meet the structural aspects of speech (Fodor, Bever, and Garrett, 1974). Inspiration begins the verbal process of conveying meaning to listeners. An internal arrangement of action patterns becomes integrated the moment thoughts are formulated. For example, inspiratory characteristics change from resting to speech breathing durations for spontaneous speech and reading in adults whether or not the speech representation is subvocal or vocal (Conrad and Schonle, 1979). Life-function respiration and speech breathing are different behaviors that share the same physical apparatus and neural innervation. Spontaneous speech appears to be a more sensitive mode than reading for discovering age-related differences (Hoit & Hixon, 1987). Increases in age and language experience may affect speech respiratory strategies in talkers in general as children are expected to be less sophisticated language users than adults. (Hoit et al., 1990; Russell & Stathopoulos, 1988; Stathopoulos & Sapienza, 1993). Children have smaller lung capacities and therefore a more limited range of lung volumes. Thus, size, age and age-related cognitive and language skills in combination probably account for their taking more breaths at grammatical boundaries.

Nonstuttering versus Stuttering Children

Speech, Language, and Stuttering

Stuttering children and nonstuttering children in this study were comparable in speech and language test performance. Louko (1995) found in a literature review on the prevalence of articulation errors in stuttering and nonstuttering children, that the latter exhibited the same types of speech errors found in the general population. Ryan (1992) reported a trend for stuttering children to lag slightly behind nonstuttering children in language proficiency skills, but not below normative expectations. Nippold (1990), in a critical review of the literature, reported age-matched stuttering and nonstuttering children performed similarly on language and grammar competency tests. Research on MLU and language performance between age-matched stuttering and nonstuttering children has produced equivocal results (Gaines et al., 1991; Kadi-Hanifi & Howell, 1992; Meyers & Freeman, 1985; Zebrowski, 1995). Weiss and Zebrowski (1994) compared story-retelling abilities of eight nonstuttering and eight stuttering children. They found the groups performed similarly on speech and language measures, but that stuttering children produced less lengthy and elaborate stories for "inexperienced" (unfamiliar with the story) versus "experienced" listeners. Because speech and language testing and discourse skills were similar between the groups in all but one circumstance, the authors concluded that stuttering children were speaking less for reasons other than because of a deficit in language formulation.

The children in this study scored within the normative range on all tests. MLU (mean length of utterance) was comparable between the groups

of children, and increased on the basis of age rather than on the presence or absence of stuttering (see Table 12 and Figure 8). Stuttering children also produced the same percentages of sentences, clauses, and phrases (see Table 13 and Figure 9) as the nonstuttering children. On the basis of these findings for the small number of children in this study, stuttering children did not demonstrate speech and language problems different from nonstuttering persons at the same chronological ages. Stuttering children did produce approximately 20% fewer words than their nonstuttering counterparts (see Table 11). However, reduced speech output appears related to the presence of interrupted speech rather than to inherent language deficiencies. Stuttering children therefore have equal language output potential with age-matched fluent talkers, but produce fewer words due to higher percentages of nonfluencies.

Nonfluencies

Stuttering children had significantly more nonfluencies (see Table 17 and Figure 12). Disfluencies, apart from stuttering, reportedly occur because children are trying to correctly structure an utterance or are repairing an utterance they perceive as inadequate within a specific situation. Also, as children develop, the type and frequency of disfluent behaviors change. Interjections and revisions are associated with older children (above 4 years) who are becoming more linguistically aware, and word and syllable repetitions are associated with younger children (Colburn & Mysak, 1982). Thus, level of linguistic development may be determining the choice of repair strategy (i.e. disfluency type) when a child is disfluent. Stuttering and nonstuttering children have similar numbers of disfluencies such as revisions,

interjections, and incomplete phrases at the same ages (Johnson, 1959; Tetnowski, 1998). However, stuttering children have significantly more word and syllable repetitions, sound prolongations and broken or forced words at any age compared to nonstuttering children. Thus, stuttering differs from disfluencies at onset and with increasing age, in type and degree, and both are present in the stuttering child's speech. High rates of speech interruptions may stimulate stuttering speakers to respond with external, self-repairs, producing the various forms of movement patterns associated with stuttering events. Unfortunately for stuttering speakers their attempts at improving speech accuracy do not decrease but often intensify the stuttering (Postma, Kolk, & Povel, 1991).

Inspiration

It was hypothesized that stuttering children's inspiratory activity would occur predominantly at grammatical boundaries, similar to inspiratory locations for nonstuttering children. The majority of stuttering children's inspirations did occur at grammatical boundaries, but at lower percentages ($\underline{M}$ = 67%) than the nonstuttering children ($\underline{M}$ = 80%). Stuttering children were expected to inspire at other locations more often than nonstuttering children due to higher percentages of nonfluency. Table 14 and Figure 10 demonstrate these findings.

Inspiration, Grammatical Boundaries, and Stuttering

Another hypothesis was that children's stuttering would be associated with grammatical boundaries, but that inspiration location would be the better predictor of stuttering sites. The most significant finding in this study was that while grammatical location and inspiration contributed to the

prediction of following nonfluenices in nonstuttering and stuttering children, inspiratory activity was the better predictor of nonfluency locations. The inspiratory effect was greater for stuttering than nonstuttering children, due to higher percentages of nonfluency (i.e.stuttering) in stuttering children. Table 20 and Figures 15 and 16 demonstrate these findings.

To further examine the finding that inspiration was the better locator of nonfluencies than grammatical boundary location, a log-linear analysis was performed, as this statistic is sensitive to individual variable effectiveness levels, especially when all variables matter in a relationship paradigm. Grammatical boundary location and inspiration predicted the location of stuttering and disfluency. The log-linear analysis showed that although both inspiration and grammatical boundary locations co-varied in importance, inspiration was the stronger predictor of where nonfluencies occurred. The size of the change in chi-square and Q^2 values when deleting grammatical placement (BS) was consistently smaller than the size of the effect when deleting inspiration (BR) in relation to stuttering and disfluency. Table 36 and Figures 17 and 18 demonstrated that while the relative importance of grammatical boundaries varied among the children, the importance of respiration in the location of nonfluencies was substantial in all cases. Grammatical boundaries have been accepted as important sites of stuttering events since Brown's study in 1945 (Brown, 1945; Gaines et al., 1991; Silverman, 1974; Wall et al., 1981; Watkins & Yairi, 1997). Prior to this research with children, no studies had related the appearance of nonfluencies at grammatical boundaries and non-boundary sites to the presence of inspiratory activity.

Physiological evidence suggests that the respiratory behavior of stuttering speakers lacks the stability found in nonstuttering speakers. Peters and Boves (1988) found atypical inspiratory build-up patterns in stuttering adults, and Zocchi et al. (1990) found subglottal pressure levels in adult stuttering speakers that varied unpredictably regardless if the following speech was fluent or stuttered. Baken, McManus, and Cavallo (1983) reported respiratory instability in adult stuttering subjects' response to an auditory cue to phonate the vowel 'ah'. The stuttering subjects consistently lost lung volume prior to initiating voicing for fluent and stuttered productions, whereas normal talkers quickly inhaled. Denny and Smith (2002) found difficulty in cortical control of respiration for speech in some stuttering adults. Stuttering children in this study exhibited high percentages of inspirations at non-boundary sites that were and were not associated with stuttering events. It could be argued that high percentages of inspiratory activity associated with stuttering and at non-boundary locations is a symptom of an underlying disorder, present in the early years, or that inspiratory differences are the speech system's inefficient attempts to correct an inaccurate internal model (Neilson & Neilson, 1991; Kolk, 1991). The latter seems more likely since stuttering speakers appear unable to conceptualize and reproduce uninterrupted speech movements.

Low percentages of disfluencies in the speech of nonstuttering persons are reported generally in the literature (Haynes & Hood, 1978; Winkworth et al. 1994, 1995; Yairi, 1982; Yairi & Clifton, 1972). Nonstuttering persons participating in control groups for studies of respiratory instability in stuttering speakers produce normal disfluency types and frequencies;

otherwise they would have been classified differently. Participating nonstuttering persons also have not demonstrated any of the inspiratory aberrances reported for stuttering individuals (Peters & Boves, 1988; Zocchi et al, 1990). The nonstuttering children in this study predictably inspired before nonfluencies, but the majority of their inspirations were at grammatical boundary sites. Nonstuttering children produced higher levels of inspiratory activity with many non-boundary inspirations regardless if stuttering was present.

Why do children inspire before nonfluencies? A disruption in the speech pre-planning dynamic appears to happen prior to nonfluencies as inspiratory activity precedes their occurrence. Conrad and Schonle (1979) found the act of inspiring automatically activates the speech motor system whether or not the speech is produced subvocally or outloud. Inspirations preceding nonfluencies may reflect the unconscious interaction between the speech physiology and the language system to refresh (i.e., repair) parts of an utterance perceived by the speaker to need repair: a. at some point in the upcoming utterance for stuttering speakers and b. as a language-content repair strategy for nonstuttering speakers. Consistency of inspiratory involvement prior to nonfluencies goes relatively unnoticed when levels of disfluencies are low, but is highly visible in a nonfluent speech disorder such as stuttering. Inspiratory activity preceding nonfluencies appears to be an adaptive strategy to repair or solve the nonfluency problem. Stuttering speakers are generally unable to improve nonfluent speech behavior. Their adaptation strategies often compound the nonfluency problem rather than decrease stuttering. Thus, it appears that an inaccurate internal model may be

the source of their inappropriate inspiratory activity and of their inability to produce fluency as they hear it and intend it to happen.

CHAPTER VI

CONCLUSION

To reiterate the findings with regard to the location of stuttering and disfluency, location of inspirations, and structural boundaries:

1. Children and adults inspired most often at grammatically appropriate locations. Children inspired significantly more often than adults at these locations.

2. Stuttering and nonstuttering children differed in the placement of inspirations, with stuttering children placing significantly more inspirations at locations that were not grammatical boundaries. Not all of these other locations were associated with nonfluencies, but when stuttering did occur at non-boundary locations, it generally was preceded by inspiration. Stuttering children also spoke fewer words while maintaining high inspiratory levels.

3. With increased levels of stuttering, fewer inspirations occurred at grammatical boundaries.

4. Nonfluencies, stuttering and disfluencies, generally were preceded by inspiration, regardless of location. Nonstuttering children did not inspire before nonfluencies at non-boundary locations as often as did stuttering children.

The location of nonfluencies, disfluencies and stuttering, was primarily associated with antecedent inspiratory activity. The results supported the hypothesis that high levels of nonfluent speech behavior in stuttering children are associated with different inspiratory behaviors. Nonstuttering children also inspired preceding disfluencies. However, they maintained

more inspirations at grammatical boundary locations, demonstrating that inspiratory activation prior to disfluencies centered on language content repair issues. Inspiratory activity appears to be automatically stimulated in stuttering children as an attempt to improve nonfluent speaking behavior.

Future research should address aspects of inspirations not addressed in this study such as depth of inspiration before fluent and nonfluent grammatical boundaries and non-boundary sites for stuttering and nonstuttering children. Multiple inspirations at nonfluency sites also should be examined. Nonstuttering and stuttering children's ability to change inspiratory locations to coincide with grammatical boundary sites could be examined; and if changes in inspiratory location are demonstrated, would there be co-occurring decreases in nonfluency? Do changes in inspiratory behavior last for one group and not for the other? Stuttering children might return to original inefficient inspiratory behaviors due to the powerful influence of an inaccurate internal model or they might effect a lasting change towards increased fluency. Respiratory behaviors are known to change with age (Russell & Stathopoulos, 1988; Hoit, Hixon, Watson, & Morgan, 1990), but can they be changed in children through external input? Do children need to learn a model of speech fluency to which they can relate changing behaviors? Similar research questions have been posed for adults, and inspiratory strategies have been changed as a function of speech therapy (Story, 1990; Murdoch, Killin, & McCaul, 1989).

Questions regarding the lasting effects of changes in speech respiration in relation to improved fluency should be studied further in stuttering children and adults. Researching behaviors associated with stuttering such as

speech respiration may provide clues that will identify children who are at risk to continue to stutter and those who will cease before adulthood (Conture, 1991). Being able to change inappropriate speech behaviors early in the development of stuttering may have a positive effect on the later progression of the disorder.

Table 1. Participant ID, group, age and grade.

Participant	Group	Age	Grade
GE	Nonstuttering	4yr 2mo	Preschool
NI	Nonstuttering	4yr 10mo	Preschool
DA	Nonstuttering	5yr 5mo	Preschool
HA	Nonstuttering	5yr 5mo	Kindergarten
PE	Nonstuttering	7yr 4mo	Grade 2
	Average Age - 5yr 4mo		
SA	Stuttering	4yr 2mo	Preschool
DL	Stuttering	4yr 8mo	Preschool
OW	Stuttering	4yr 11mo	Preschool
JA	Stuttering	5yr 7mo	Kindergarten
JG	Stuttering	7yr 0mo	Grade 1
	Average Age - 5yr 3mo		

Table 2. Details of eight children who did not complete the study.

Nonstuttering	Age	Reason
IS	5yr 9mo	Would not speak above a whisper during experimental session at Haskins.
LR	5yr 4mo	Gave short answers only, no continuous speech, during experimental session at Haskins.
WH	5yr 2mo	Scored below average on speech and language tests. Recommended parents consult school for follow-up services.
TS	4yr 6mo	Refused to put on Respibands during experimental session at Haskins.
Stuttering		
AH	4yr 11mo	Would not speak at experimental session at Haskins.
DM	7yr 0mo	Requested removal of Respibands almost immediately after beginning of experimental session at Haskins. Would not continue.
MZ	4yr 3mo	Refused to speak during the experimental session. Asked to go home.
JW	4yr 8mo	Error in channel gains when inputting respiratory signals during experiment at Haskins. Could not recover signals from tape.

Table 3. Stuttering rates and characteristics for stuttering children, obtained at the first interview.

Stuttering Children	Stuttering Characteristics	Stuttered words per minute (sw/m)
JG	Prolongations Sound/syllable Repetitions	11 sw/m
SA	Prolongations Sound/syllable Repetitions	8 sw/m
OW	Struggle Sound/syllable Repetitions	8 sw/m
DL	Whole word repetitions Phrase repetitions	14 sw/m
JA	Struggle Prolongations Sound/syllable Repetitions	12 sw/m

Table 4. Summary of children's height, weight, rib cage, and abdomen measurements, including means (M) and standard deviations (SD).

Nonstuttering	Height (inches)	Weight (lbs.)	Rib Cage (inches)	Abdomen (inches)
GE	39.5	31	19.5	19
NI	41	40	21.5	20.5
DA	41	30	22	20
HA	41.5	36	22	21.5
PE	52	59	26	26.5
M	43	39.2	22.2	21.5
SD	2.3	5.3	1	1.3
Stuttering				
SA	39.5	28	19.5	19
DL	41.5	35	22.5	22.5
OW	49	50	25.5	24
JA	46	50	24	23
JG	45.5	50	25	24
M	44.3	42.6	23.3	22.5
SD	1.7	4.7	1.1	1

Table 5. Each child's story-retelling versus conversation-contribution to the five-minute experimental script.

Nonstuttering	Story Retelling (minutes)	Conversation (minutes)
DA	5	0
GE	2	3
HA	5	0
NI	2.5	2.5
PE	5	0
Stuttering		
JA	5	0
DL	5	0
JG	3	2
SA	3.5	1.5
0W	4.5	.5

Table 6. Disfluency and stuttering judgements by two raters, including percentage of inter-rater agreement at initial count.

Nonstuttering Children	Disfluencies Rater 1	Rater 2	Final	Percent Inter-Rater Agreement (initial count)
DA	31	30	31	97%
GE	20	20	20	100%
HA	8	8	8	100%
NI	84	84	84	100%
PE	30	30	30	100%
Stuttering Children	**Stuttering Rater 1**	**Rater 2**	**Final**	
JA	108	100	108	93%
DL	98	96	98	98%
JG	69	58	69	84%
SA	31	30	31	97%
OW	54	55	54	98%
Stuttering Children	**Nonstuttered Disfluencies Rater 1**	**Rater 2**	**Final**	
JA	5	5	5	100%
DL	4	4	4	100%
JG	29	30	30	97%
SA	16	16	16	100%
OW	3	3	3	100%

Table 7. Summary of disfluencies (d), disfluencies spoken per minute (d/m), stutters (s), and stuttered words per minute (sw/m), including means (M), standard deviations (SD), and stuttering severity ratings (SSR).

Nonstuttering Children	d	d/m	Stuttering Children	s	sw/m	SSR
DA	31	6	JA	108	22	Severe
GE	20	4	DL	98	20	Severe
HA	8	2	JG	69	14	Severe
NI	84	17	SA	31	6	Moderate
PE	30	6	OW	54	11	Severe
M = 34.6 disfluencies, 7 d/m			M = 72 stutters, 14.6 s/m			
SD = 13 disfluencies, 2.6 d/m			SD = 49 stutters, 7.3 s/m			

Table 8. Summary of the speech, language and intelligence tests according to subject and test score: Arizona Articulation Proficiency Scale (AAPS); Peabody Picture Vocabulary Test (PPVT); Test of Language Development-Primary (TOLD); and Kaufman Brief Intelligence Test (KBIT). See Appendix E for a complete description of the tests.

Nonstuttering Children	AAPS Percent	PPVT Stanine	KBIT Stanine	TOLD Quotient
DA	100%	9	8	129
GE	100%	9	9	147
HA	100%	8	8	132
NI	90%	7	7	107
PE	89%	8	9	117
Mean	96%	8	8	126
Stuttering Children				
DL	100%	7	8	116
JA	85%	6	8	113
JG	100%	7	6	134
OW	92%	9	8	124
SA	100%	9	9	121
Mean	95%	8	8	122

Table 9. Percentage of inspirations preceding clause boundaries for adults, nonstuttering and stuttering children, including group means (M), standard deviations (SD), and ANOVA results.

Adults

S1	S3	S4	S5	S6	M	SD
85%	62%	54%	73%	62%	67%	12%

Nonstuttering Children

DA	GE	HA	NI	PE	M	SD
74%	72%	77%	68%	69%	72%	3%

Stuttering Children

JA	DL	JG	SA	OW	M	SD
49%	78%	62%	56%	59%	61%	10%

[$F(2, 12) = 1.72$, $p = .22$, $p > .40$]

Table 10. Percentage of clause boundaries preceded by inspiration for adults, nonstuttering, and stuttering children, including group means (M), standard deviations (SD), and ANOVA results.

Adults

S1	S3	S4	S5	S6	M	SD
40%	25%	29%	46%	41%	36%	9%

Nonstuttering Children

DA	GE	HA	NI	PE	M	SD
74%	85%	74%	77%	69%	76%	5%

Stuttering Children

JA	DL	JG	SA	OW	M	SD
81%	86%	67%	82%	86%	80%	7%

[$F(2, 12) = 50.99$, $p = .0000014$, $p < .001$]

Table 11. Total words spoken (tws) per child, including means (M) and standard deviations (SD).

Nonstuttering Children	tws	Stuttering Children	tws
GE	578	SA	455
NI	787	DL	563
DA	610	OW	387
HA	705	JA	659
PE	694	JG	590
Total	3374	Total	2654
M = 675		M = 531	
SD = 37		SD = 49	

tws: $t(8) = 23.22$, $p < .001$

Table 12. Age and Mean Length of Utterance (MLU) in words, including group means and standard deviations (SD).

Nonstuttering Children	Age	MLU
GE	4:2	6.36
NI	4:10	8.87
DA	5:5	9.37
HA	5:5	7.91
PE	7:4	10.62
	Mean Age = 5.4	Mean MLU = 8.6, SD = 1.4
Stuttering Children		
SA	4:2	6.85
DL	4:8	8.42
OW	4:11	7.36
JA	5:7	9.44
JG	7:0	10.01
	Mean Age = 5:3	Mean MLU = 8.4, SD = 1.2

MLU: $t(8) = .22, p > .40$

Table 13. Percentages of sentence, clause, and phrase boundaries per child.

	Nonstuttering Children						Stuttering Children					
Boundary	DA	GE	HA	NI	PE	Boundary	JA	DL	JG	SA	OW
Sentence	78%	85%	87%	80%	77%	Sentence	84%	92%	82%	81%	78%
M = 81%						M = 83%					
SD = 2%						SD = 2%					
Clause	6%	10%	5%	9%	12%	Clause	9%	1%	5%	8%	10%
M = 8%						M = 7%					
SD = 1%						SD = 2%					
Phrase	16%	5%	8%	12%	11%	Phrase	7%	7%	13%	11%	12%
M = 10%						M = 10%					
SD = 2%						SD = 1%					

Table 14. Total number of inspirations and mean percentages of inspirations.

	Nonstuttering Children	Stuttering Children
Total Inspirations	594	603
Mean Inspirations Per Child	119	121
Percent Inspirations	17.6%	22.5%

$t(8) = .10$, $p > .40$

Table 15. Percentages of inspirations preceding sentence, clause, and phrase boundaries as contrastive categories and as one all-inclusive grammatical boundary category, including group means (M) and standard deviations (SD).

	Nonstuttering Children					Stuttering Children				
	DA	GE	HA	NI	PE	JA	DL	JG	SA	OW
Sentence	71%	64%	74%	59%	62%	46%	77%	59%	50%	53%
Clause	3%	8%	3%	9%	11%	5%	1%	3%	6%	6%
Phrase	8%	3%	8%	7%	7%	4%	6%	7%	6%	6%
Grammatical Boundaries	82%	75%	86%	75%	80%	53%	84%	69%	62%	65%
	M = 80%, SD = 4%					M = 67%, SD = 10%				

$t(8) = 2.36, p < .05$

Table 16. Percentages of contrasted sentence, clause, and phrase boundaries and all grammatical boundaries that were preceded by inspiration, including means (M) and standard deviations (SD).

	Nonstuttering Children					Stuttering Children				
	DA	GE	HA	NI	PE	JA	DL	JG	SA	OW
Sentences	77%	85%	75%	74%	72%	81%	86%	68%	80%	88%
Clauses	43%	82%	57%	100%	53%	82%	100%	60%	100%	75%
Phrases	44%	80%	91%	65%	93%	88%	86%	54%	70%	60%
Grammatical Boundaries	70%	85%	75%	76%	72%	82%	86%	66%	81%	83%
	M = 76%, SD = 5%					M = 80%, SD = 7%				

$t(8) = .93$, $p > .40$

Table 17. Total nonfluencies (disfluencies plus stuttering), total words, and percentage of nonfluencies for each child's five-minute speech segments, including means (M) and standard deviations (SD).

	Nonstuttering Children						Stuttering Children					
	DA	GE	HA	NI	PE	Total	IA	DL	JG	SA	OW	Total
Nonfluencies	31	20	8	84	30	173	113	102	99	47	57	418
Total Words	610	578	705	787	694	3374	659	563	620	455	387	2684
Percentage of Nonfluency	5%	3%	1%	11%	4%	5%	17%	18%	16%	10%	15%	16%
	M = 5% SD = 3%						M = 16% SD = 3%					

$t(8) = 4.47, p < .01$

Table 18. Percentages of sentence, clause, and phrase boundaries, all-inclusive grammatical locations, and non-boundary locations affected by nonfluency.

	Nonstuttering Children	Stuttering Children
Sentences	16%	49%
Clauses	30%	59%
Phrases	11%	50%
Grammatical Boundaries	17%	50%
Non-boundary Locations	2%	8%

Table 19. Percentage of total nonfluencies (disfluencies and stuttering) at sentence, clause, and phrase boundaries, at grammatical boundaries in general, and at other locations.

	Nonstuttering Children	Stuttering Children
Sentences	47%	49%
Clauses	9%	4%
Phrases	4%	6%
Grammatical Boundaries	60%	59%
Other Locations	40%	41%

Table 20. Per child, percentage of nonfluencies at grammatical boundaries with and without prior inspiration, and percentage of nonfluencies at non-boundary locations (within clauses and phrases) preceded and not preceded by inspiration.

Nonstuttering Children

	DA	GE	HA	NI	PE
Grammatical Boundaries W/ Inspiration	48%	55%	75%	56%	30%
Grammatical Boundaries W/O Inspiration	10%	5%	0%	12%	7%
Non-Boundaries W/ Inspiration	13%	20%	13%	17%	20%
Non-Boundaries W/O Inspiration	29%	20%	12%	15%	43%

Stuttering Children

	JA	DL	JG	SA	OW
Grammatical Boundaries W/ Inspiration	55%	75%	38%	55%	37%
Grammatical Boundaries W/O Inspiration	2%	6%	6%	6%	10%
Non-Boundaries W/ Inspiration	26%	8%	20%	26%	25%
Non-Boundaries W/O Inspiration	17%	11%	36%	13%	28%

Table 21. Log-linear model for nonstuttering child DA analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior, inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	0.99	0.01	3.5	1	BRS	3.5	1
[BR] [RS]	0.98	0.00	4.4	2	BS	0.9	1
[BS] [RS]	0.95	0.04	14.5	2	BR	11.1***	1
[RS] [B]	0.86	0.13	40.5	3	BR	36.1	1
[B] [R] [S]	0.00	0.86	282.4	4	RS	241.9	1

***$p < .001$

Table 22. Log-linear model for nonstuttering child GE analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (disfluency), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	-----		
[BR] [BS] [RS]	0.99	0.01	2.0	1	BRS	2.0	1
[BR] [RS]	0.99	0.00	2.1	2	BS	0.1	1
[BS] [RS]	0.96	0.04	12.8	2	BR	10.8***	1
[RS] [B]	0.90	0.09	30.9	3	BR	28.8	1
[B] [R] [S]	0.00	0.90	308.2	4	RS	277.3	1

***$p < .001$

Table 23. Log-linear model for nonstuttering child HA analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (disfluency), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	1.00	0.00	0.0	1	BRS	0.0	1
[BR] [RS]	0.99	0.01	3.0	2	BS	3.0	1
[BS] [RS]	0.97	0.03	12.6	2	BR	12.6***	1
[RS] [B]	0.94	0.05	24.6	3	BR	21.6	1
[B] [R] [S]	0.00	0.94	434.8	4	RS	410.2	1

***$p < .001$

Table 24. Log-linear model for nonstuttering child NI analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (disfluency), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	0.96	0.04	17.9	1	BRS	17.9	1
[BR] [RS]	0.94	0.03	30.3	2	BS	12.4***	1
[BS] [RS]	0.89	0.07	51.7	2	BR	33.9***	1
[RS] [B]	0.65	0.28	166.2	3	BR	135.9	1
[B] [R] [S]	0.00	0.65	480.7	4	RS	314.4	1

***$p < .001$

Table 25. Log-linear model for nonstuttering child PE analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (disfluency), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	0.99	0.01	3.5	1	BRS	3.5	1
[BR] [RS]	0.98	0.00	4.8	2	BS	1.2	1
[BS] [RS]	0.94	0.05	17.8	2	BR	14.3***	1
[RS] [B]	0.92	0.06	23.7	3	BR	18.9	1
[B] [R] [S]	0.00	0.92	302.4	4	RS	278.7	1

***p <.001

Table 26. Log-linear model for stuttering subject DL analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (stuttering and disfluency), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	1.00	0.00	2.0	1	BRS	2.0	1
[BR] [RS]	0.95	0.05	35.3	2	BS	33.3***	1
[BS] [RS]	0.93	0.07	47.5	2	BR	45.5***	1
[R] [S] [B]	0.49	0.46	330.6	3	BR	295.3	1
[B] [R] [S]	0.00	0.49	643.3	4	RS	312.7	1

***$p < .001$

Table 27. Log-linear model for stuttering subject IA analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (stuttering and disfluency), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	1.00	0.00	0.4	1	BRS	0.4	1
[BR] [RS]	0.94	0.06	21.8	2	BS	21.3***	1
[BS] [RS]	0.79	0.21	76.3	2	BR	75.9***	1
[RS] [B]	0.49	0.45	188.0	3	BR	166.3	1
[B] [R] [S]	0.00	0.49	369.4	4	RS	181.4	1

***$p < .001$

Table 28. Log-linear model for stuttering subject IG analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (stuttering and disfluency), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	1.00	0.00	1.0	1	BRS	1.0	1
[BR] [RS]	0.99	0.01	3.9	2	BS	2.9	1
[BS] [RS]	0.78	0.21	57.2	2	BR	56.1***	1
[RS] [B]	0.59	0.40	109.3	3	BR	105.4	1
[B] [R] [S]	0.00	0.59	265.8	4	RS	156.4	1

***$p < .001$

Table 29. Log-linear model for stuttering subject OW analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (stuttering and disfluency), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	-----		
[BR] [BS] [RS]	0.93	0.07	14.3	1	BRS	14.3	1
[BR] [RS]	0.92	0.01	15.8	2	BS	1.6	1
[BS] [RS]	0.87	0.06	27.7	2	BR	13.4***	1
[RS] [B]	0.75	0.17	51.5	3	BR	35.7	1
[B] [R] [S]	0.00	0.75	208.2	4	RS	156.7	1

***$p < .001$

Table 30. Log-linear model for stuttering subject SA analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (stuttering and disfluency), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	0.97	0.03	6.4	1	BRS	6.4	1
[BR] [RS]	0.95	0.03	13.0	2	BS	6.6**	1
[BS] [RS]	0.87	0.10	30.4	2	BR	24.0***	1
[RS] [B]	0.66	0.29	81.6	3	BR	68.5	1
[B] [R] [S]	0.00	0.66	239.6	4	RS	158.1	1

**$p < .01$; ***$p < .001$

Table 31. Log-linear model for stuttering subject DL analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (stuttering only), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	1.00	0.00	1.9	1	BRS	1.9	1
[BR] [RS]	0.94	0.06	36.9	2	BS	35.0***	1
[BS] [RS]	0.93	0.06	43.2	2	BR	41.3***	1
[RS] [B]	0.49	0.46	326.2	3	BR	289.3	1
[B] [R] [S]	0.00	0.49	635.6	4	RS	309.4	1

***$p < .001$

Table 32. Log-linear model for stuttering subject IA analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (stuttering only), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	1.00	0.00	0.4	1	BRS	0.4	1
[BR] [RS]	0.95	0.05	20.1	2	BS	19.7***	1
[BS] [RS]	0.81	0.18	68.8	2	BR	68.4***	1
[R] [S] [B]	0.52	0.43	180.1	3	BR	160.0	1
[B] [R] [S]	0.00	0.52	371.6	4	RS	191.5	1

***$p < .001$

Table 33. Log-linear model for stuttering subject IG analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (stuttering only), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	-----		
[BR] [BS][RS]	0.98	0.02	5.7	1	BRS	5.7	1
[BR] [RS]	0.98	0.00	5.7	2	BS	0.0	1
[BS] [RS]	0.76	0.22	55.1	2	BR	49.4***	1
[RS] [B]	0.63	0.35	85.3	3	BR	79.6	1
[B] [R] [S]	0.00	0.63	229.8	4	RS	144.5	1

***$p < .001$

Table 34. Log-linear model for stuttering subject OW analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (stuttering only), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	0.93	0.07	14.0	1	BRS	14.0	1
[BR] [RS]	0.92	0.01	16.1	2	BS	2.1	1
[BS] [RS]	0.88	0.06	25.3	2	BR	11.3***	1
[RS] [B]	0.76	0.16	49.3	3	BR	33.2	1
[B] [R] [S]	0.00	0.76	203.4	4	RS	154.0	1

***$p < .001$

Table 35. Log-linear model for stuttering subject SA analyzed for three factors - [B], [R], and [S], which represent nonfluent Behavior (stuttering only), inspiratory Respiration, and Syntactical location.

Model	Q^2	ΔQ^2	G^2	df	Deleted Term	ΔG^2	Δdf
[BRS]	1.00		0.0	0	----		
[BR] [BS] [RS]	0.97	0.03	5.5	1	BRS	5.5	1
[BR] [RS]	0.95	0.02	8.7	2	BS	3.2	1
[BS] [RS]	0.89	0.08	20.9	2	BR	15.4***	1
[RS] [B]	0.74	0.22	49.4	3	BR	40.7	1
[B] [R] [S]	0.00	0.74	188.2	4	RS	138.8	1

*** $p < .001$

Table 36. Change in chi-square value (ΔG^2) when deleting syntax (BS) versus deleting inspiration (BR) in relation to nonfluency.

	Disfluencies			Stuttering		Stuttering and Disfluencies	
Nonstuttering Children	ΔG^2 [BS]	ΔG^2 [BR]	Stuttering Children	ΔG^2 [BS]	ΔG^2 [BR]	ΔG^2 [BS]	ΔG^2 [BR]
DA	0.9	11.1	IA	19.7	68.4	21.3	75.9
GE	0.1	10.8	DL	35	41.3	33.3	45.5
HA	3	12.6	IG	0	49.4	2.9	56.1
NI	12.4	33.9	SA	3.2	15.4	6.6	24
PE	1.2	14.3	OW	2.1	11.3	1.6	13.4

Table 37. Deterioration of fit of the [BR] [BS] [RS] log-linear model based on changes in Q^2 as successive terms are deleted. The importance of the deleted term is relative to the percentage increase (ΔQ^2) from the base model (Q^2).

	Nonstuttering Children					Stuttering Children				
Syntax Deleted	DA	GE	HA	NI	PE	DL	JA	JG	SA	OW
Q^2	.98	.99	.99	.94	.98	.95	.94	.99	.95	.92
ΔQ^2	0%	0%	1%	3%	0%	5%	6%	1%	3%	1%
Respiration Deleted	DA	GE	HA	NI	PE	DL	JA	JG	SA	OW
Q^2	.95	.96	.97	.89	.94	.93	.79	.78	.87	.87
ΔQ^2	4%	4%	3%	7%	5%	7%	21%	21%	10%	6%

Figure 1. Pictorial representation of Respitrace bands and their placement on the torso.

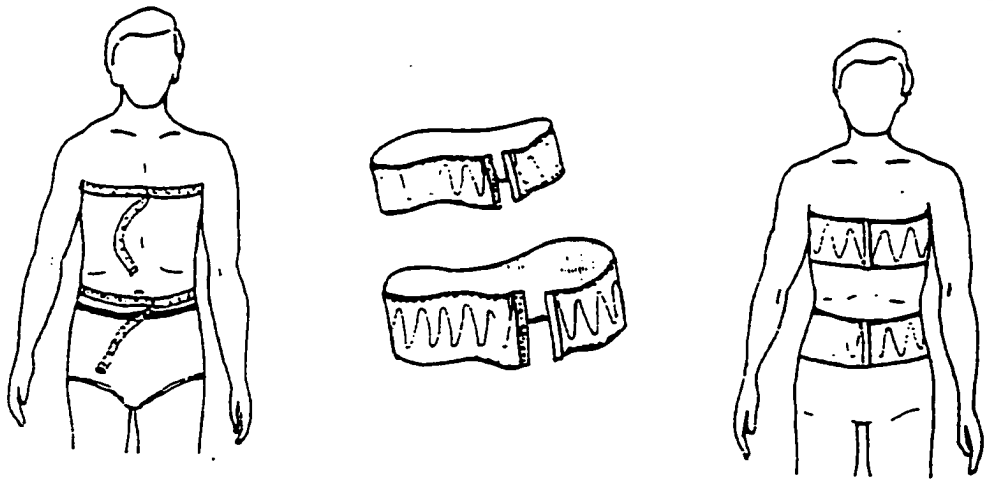


Figure 2. Pictorial representation of the arithmetical summing of the unequal contributions of the rib cage and the abdomen to obtain the Sum Signal.

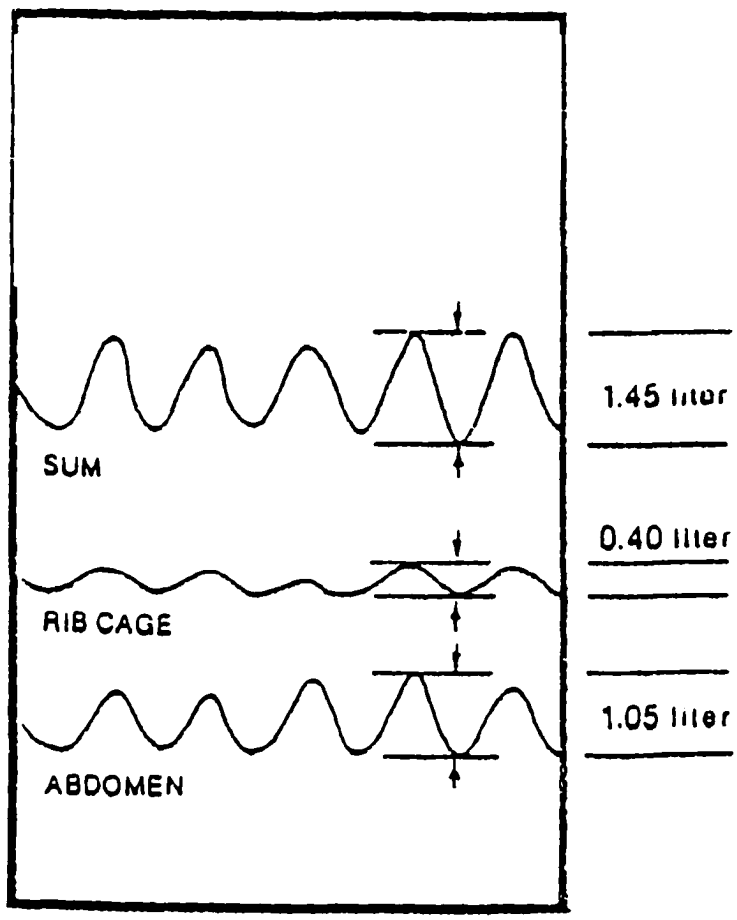


Figure 3: Magnified section of a speech file showing inspiratory (V1 to P1) and expiratory (P1 to V2/V3) activity in the sum (SUM), rib cage (RC) and abdomen (ABD) waveforms and corresponding acoustic signal (AUDIO). The speech text heard through earphones was "Once upon a time there was".

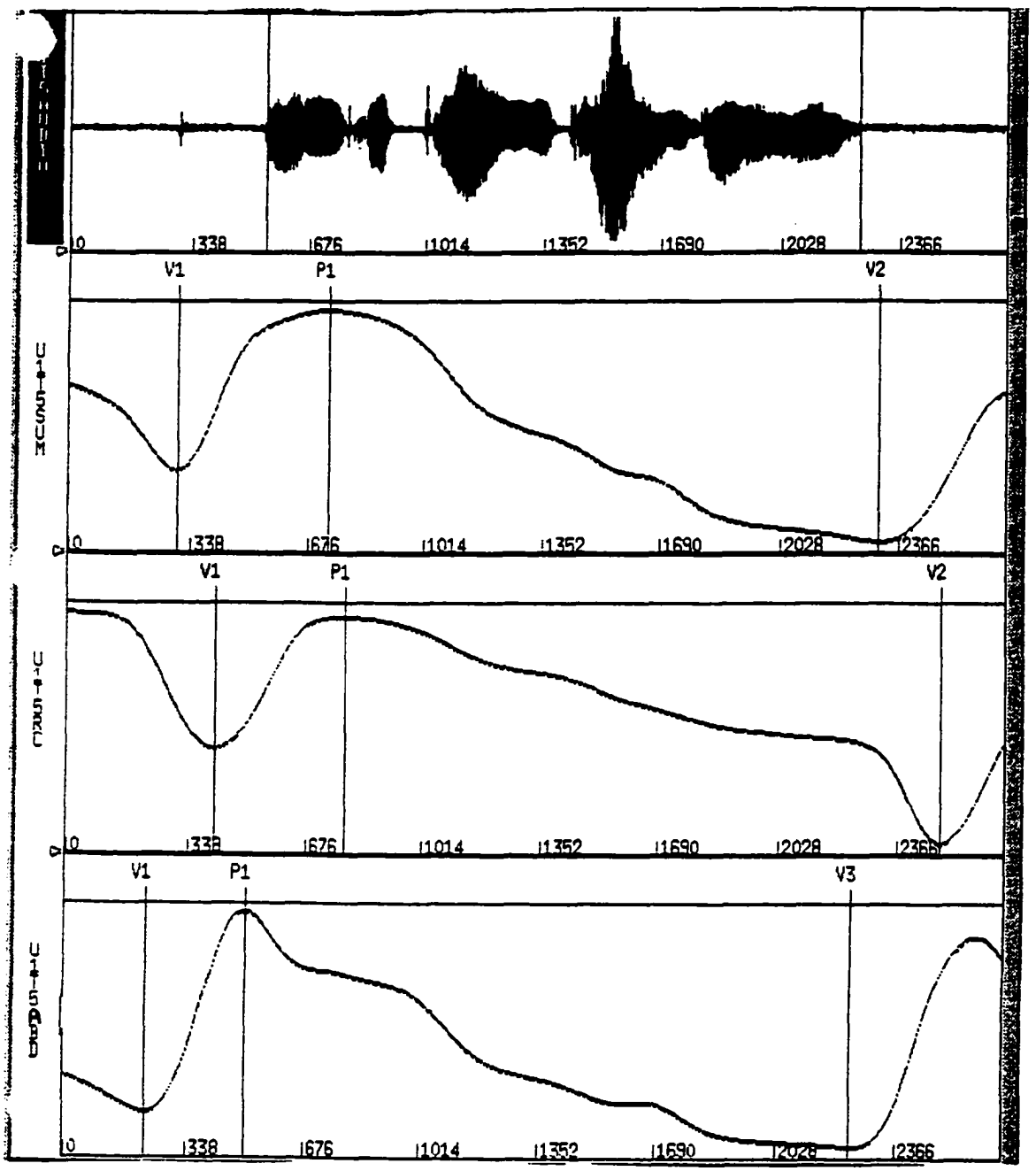


Figure 4. Percentages for adults and children of total inspirations located at clause boundaries.

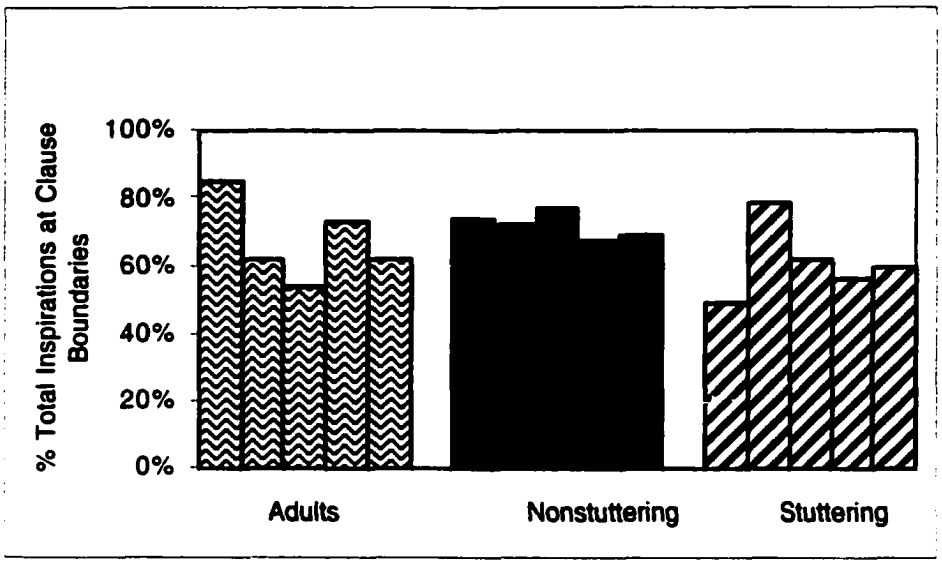


Figure 5. Percentages, for each adult and child, of total clause boundaries preceded by inspiration.

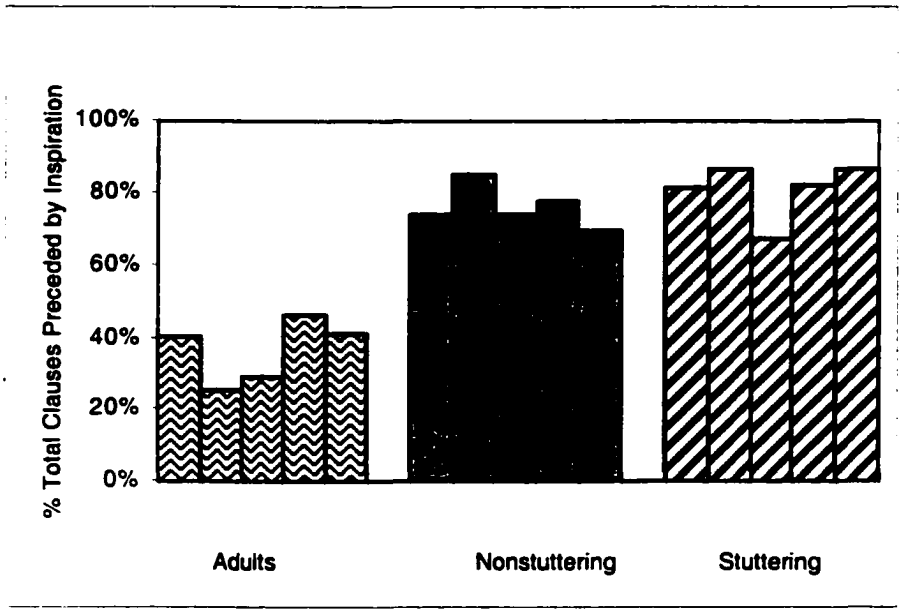


Figure 6: Percentage similarities and differences in inspiratory activity between adults, nonstuttering, and stuttering children.

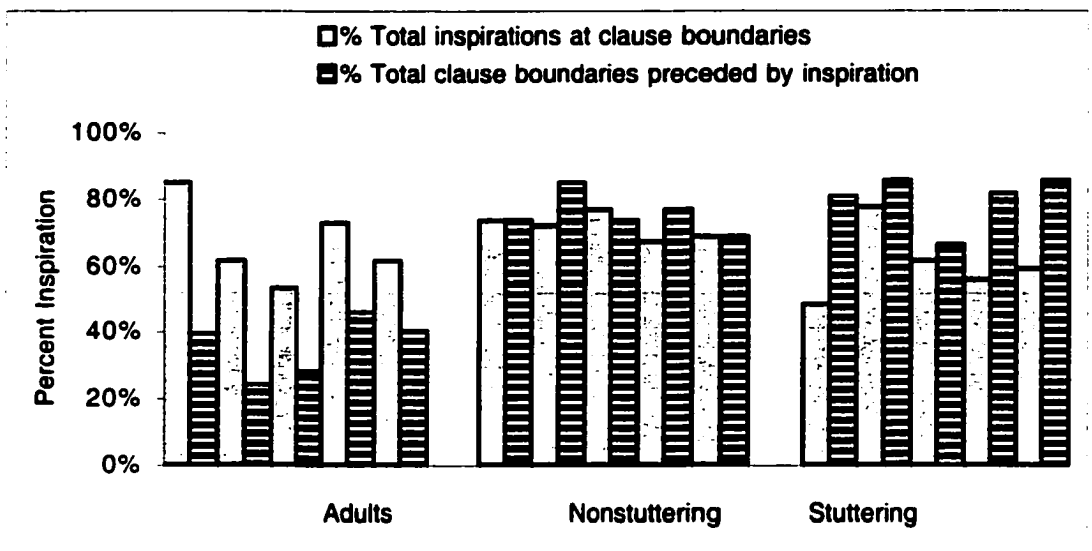


Figure 7. Number of total words spoken by each participant.

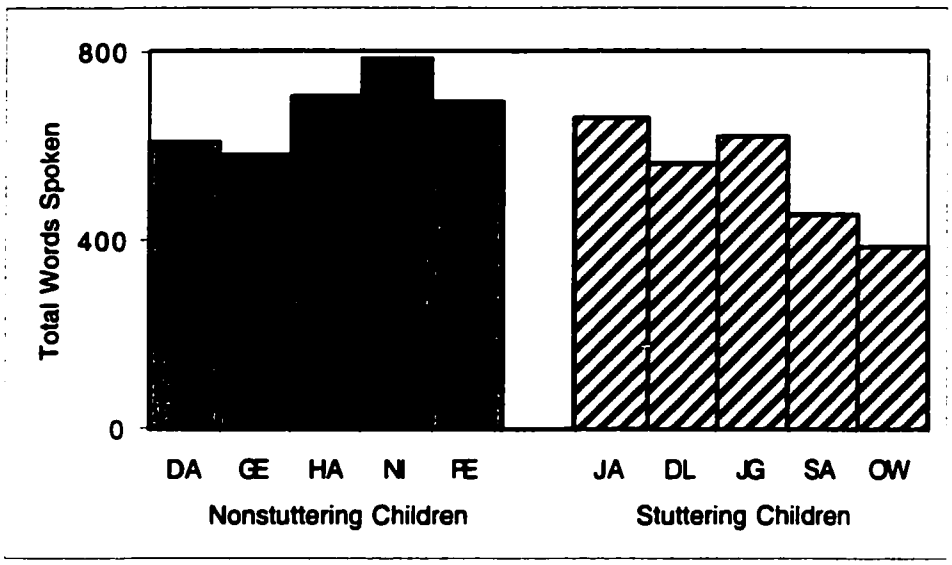


Figure 8. Mean length of utterance (MLU) in words for age-matched pairs of nonstuttering and stuttering children.

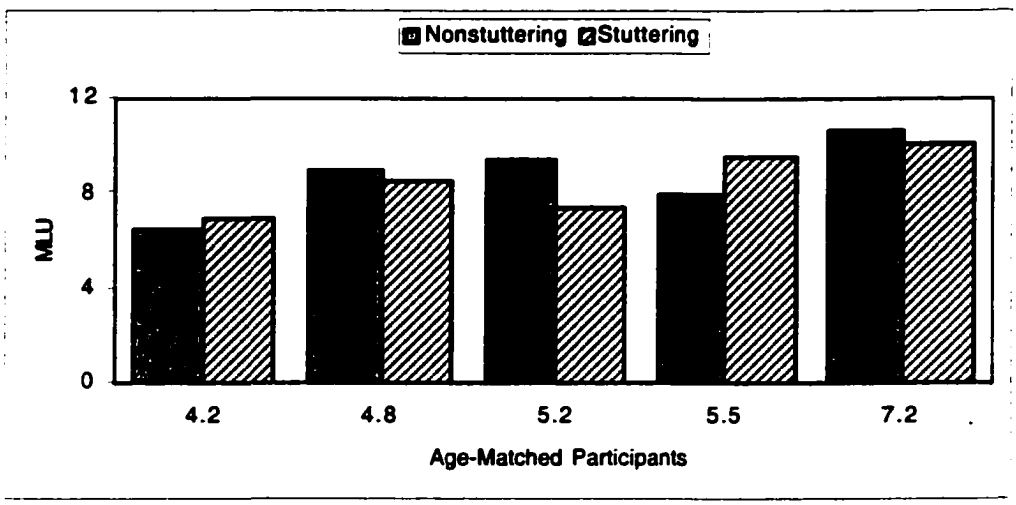


Figure 9. Percentages by group of each child's sentence, clause, and phrase boundaries.

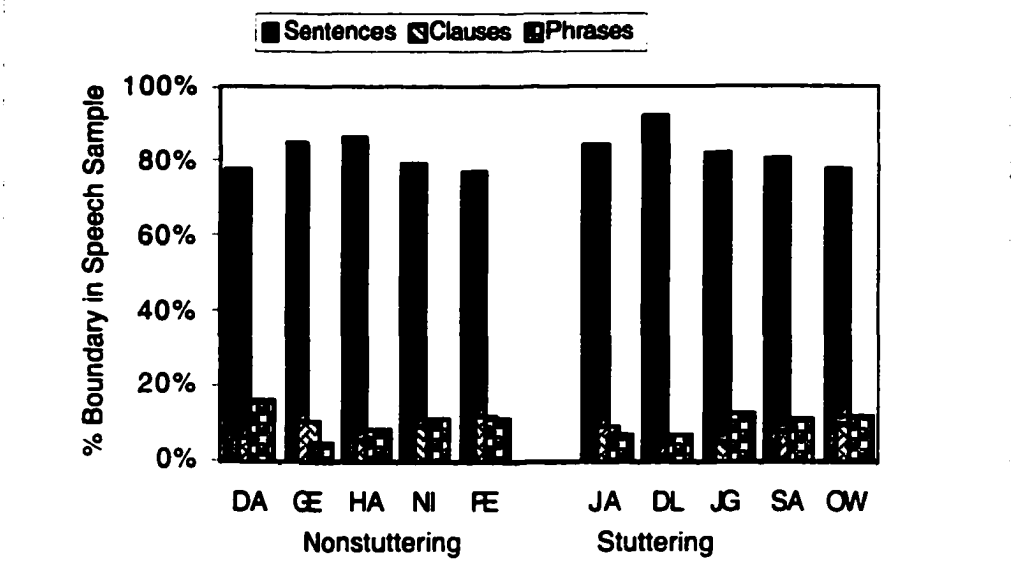


Figure 10. Percentage of total inspirations at grammatical boundaries as a single category.

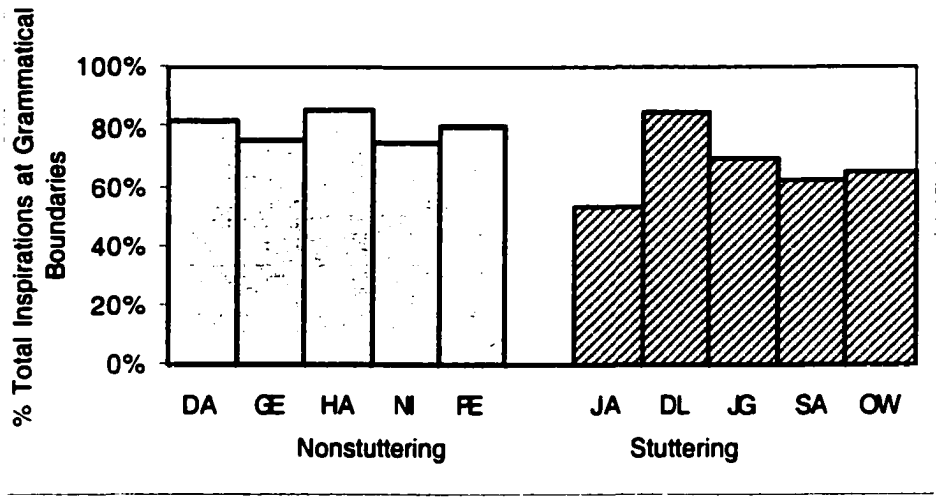


Figure 11. Mean percentage per child of all grammatical boundaries as one category preceded by inspiration.

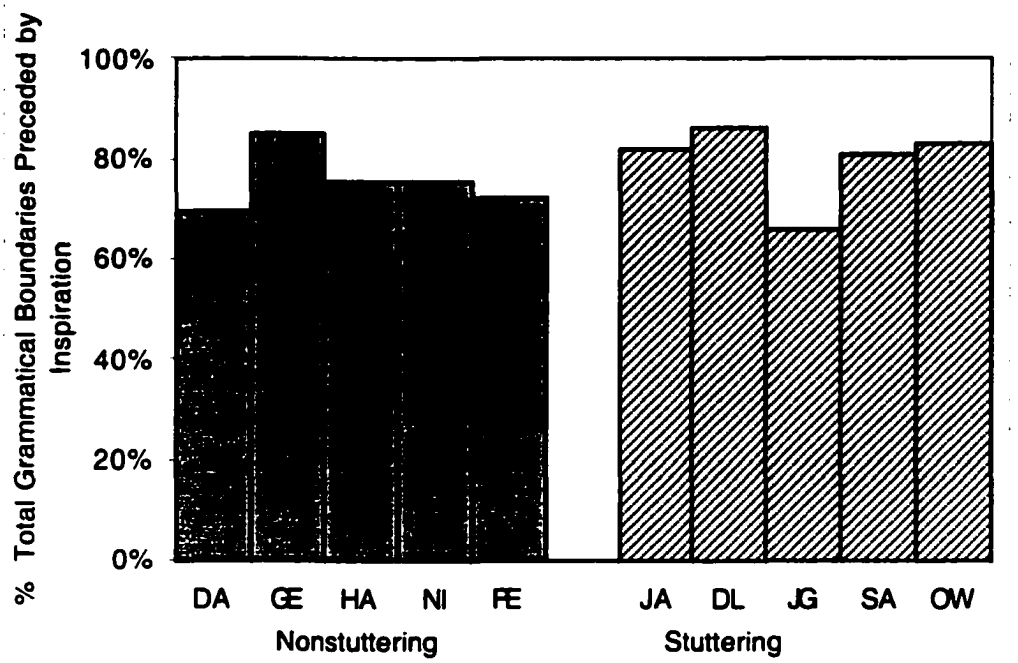


Figure12. Percentages of nonfluency for each child.

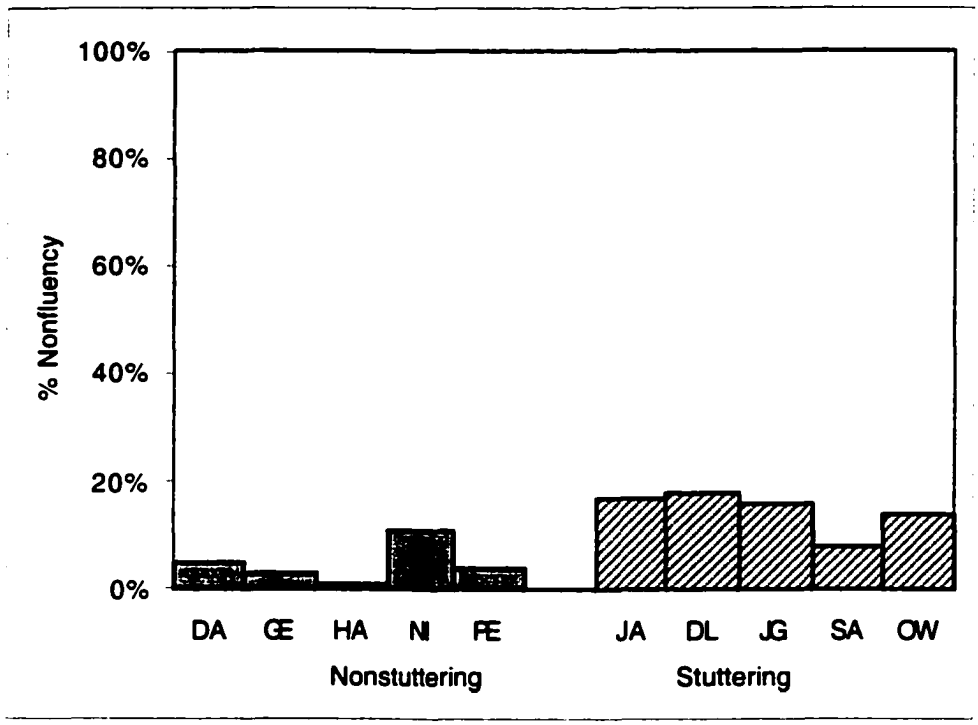


Figure 13. Percentages of sentence, clause, and phrase boundaries as contrastive categories; designated grammatical boundaries as one category; and other non-boundary locations affected by nonfluencies.

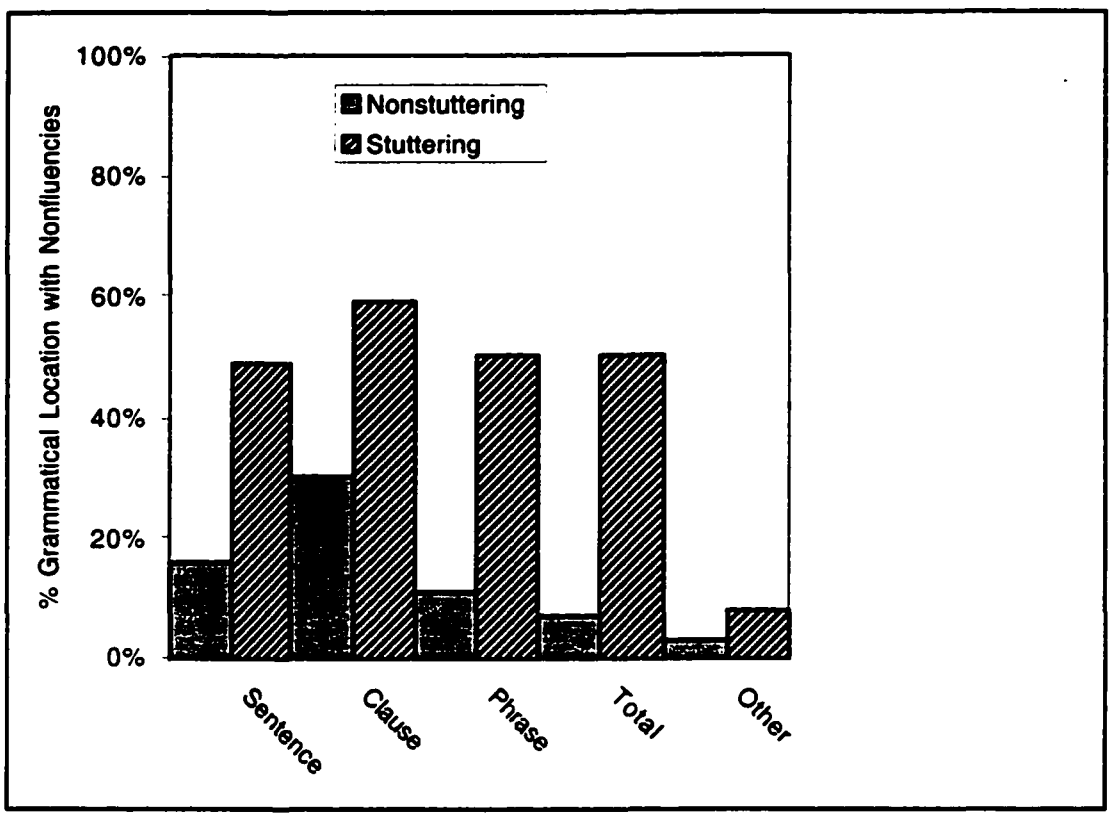


Figure 14. Percentages of total nonfluencies at sentence, clause, and phrase boundaries; at grammatical boundaries as a single category; and at non-boundary locations.

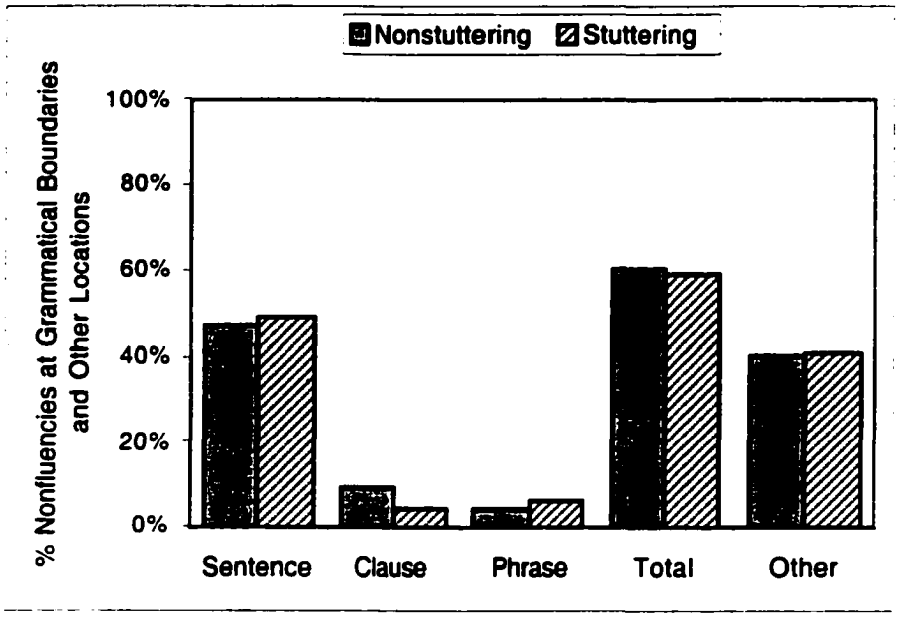


Figure 15. For each nonstuttering child, percentages of nonfluencies at grammatical boundaries and non-boundary locations with and without preceding inspiration.

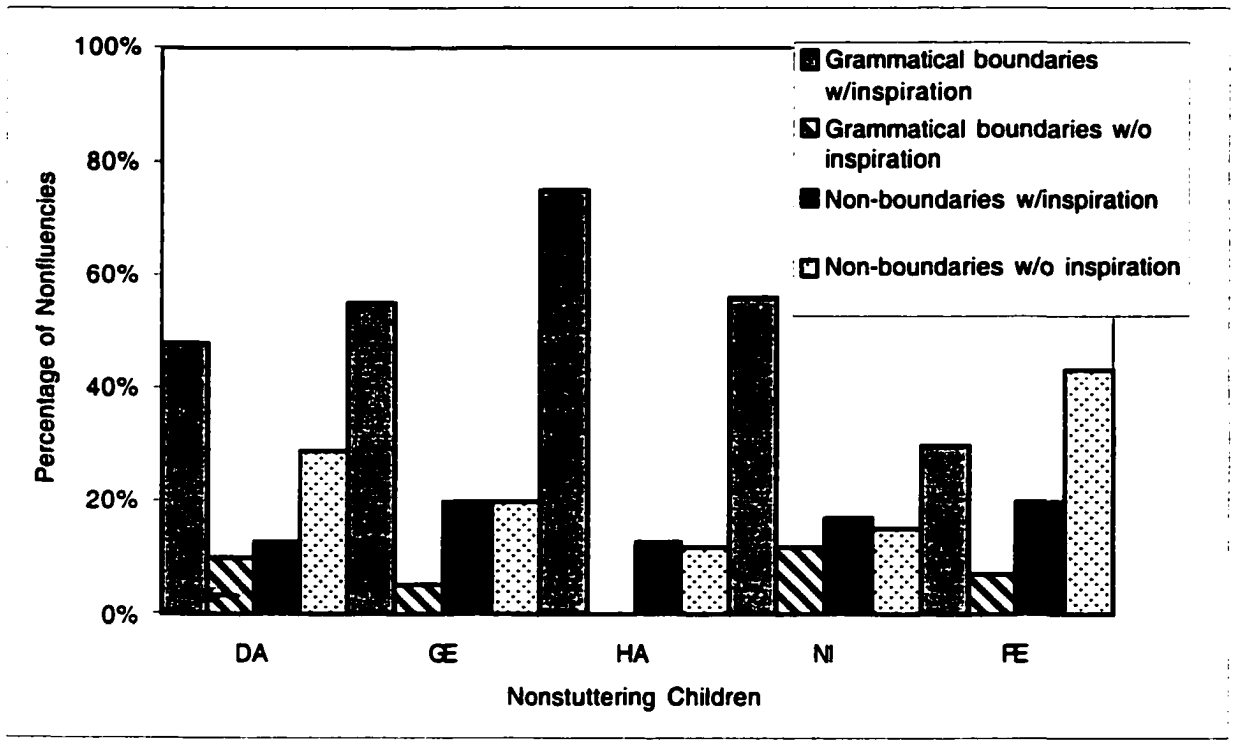


Figure 16. For each stuttering child, percentages of nonfluencies at grammatical boundaries and non-boundary locations with and without preceding inspiration.

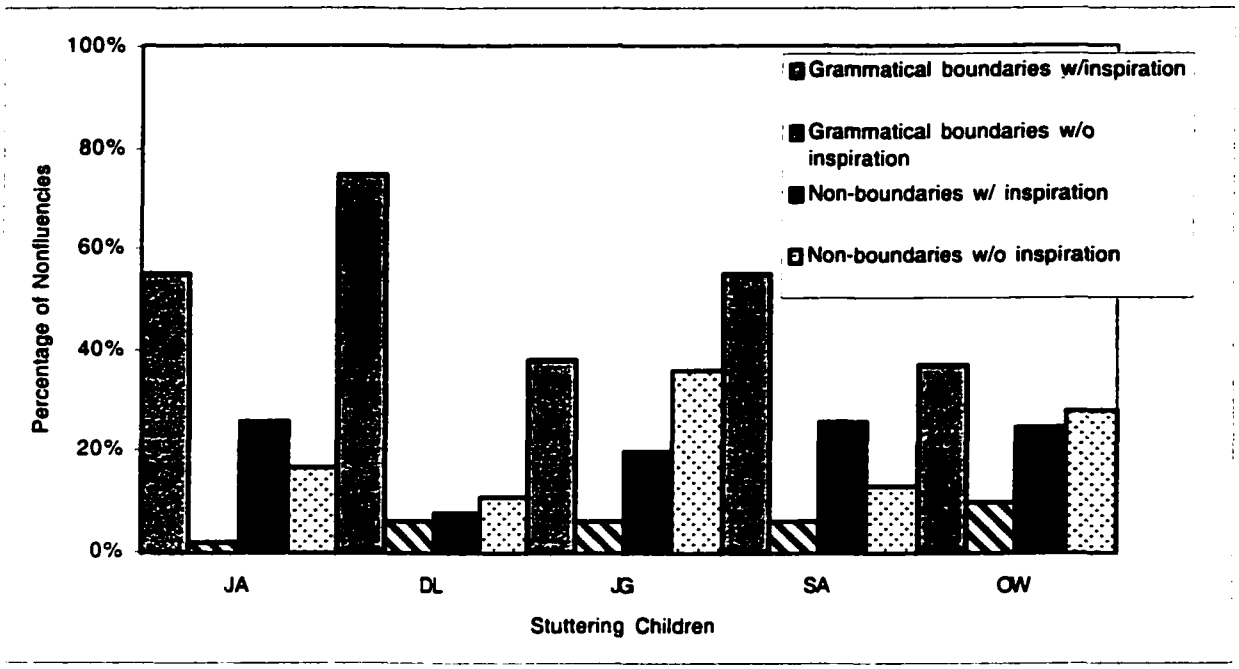


Figure 17. Change in chi square, for nonstuttering children, when syntax [BS] in relation to inspiration [BR] was eliminated from the log-linear base model [BR] [BS] [RS].

Change in Chi Square When Eliminating Syntax [BS] versus Inspiration [BR] from the Log-Linear Base Model [BR] [BS] [RS]

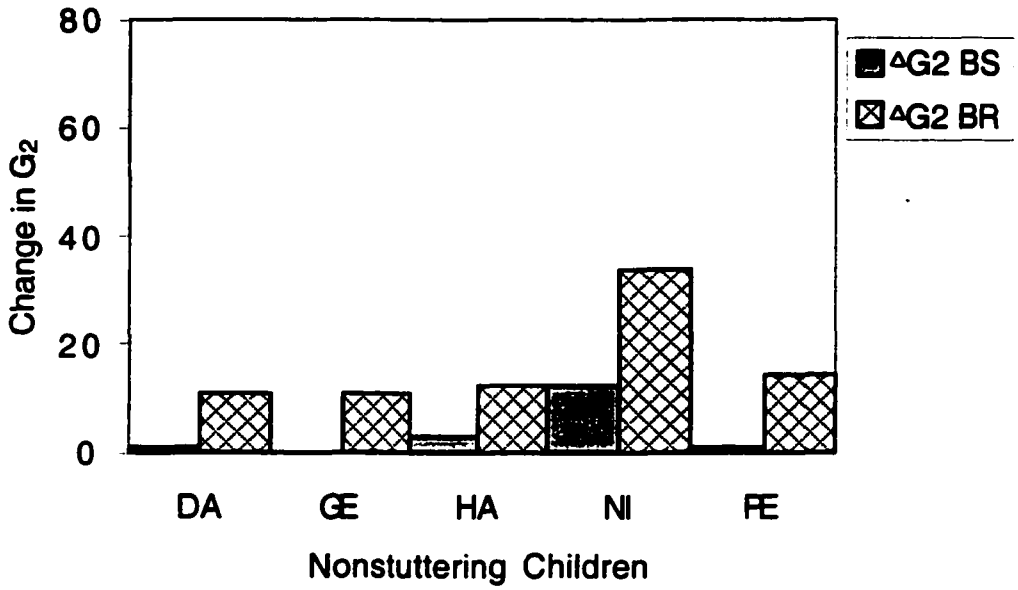
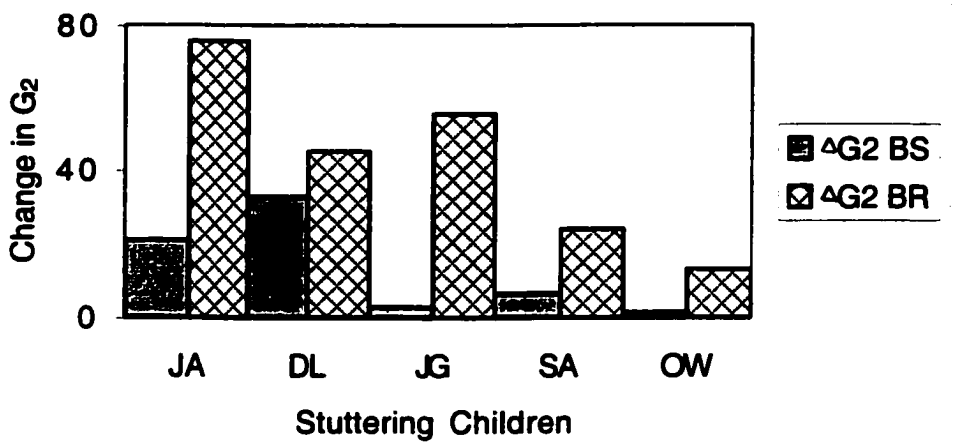


Figure 18. Change in chi square, for stuttering children, when syntax [BS] versus inspiration [BR] was eliminated from the log-linear base model [BR] [BS] [RS].

Change in Chi Square When Eliminating Syntax [BS] versus Inspiration [BR] from the Log-Linear Base Model [BR] [BS] [RS]



APPENDIX A

Child Consent Procedure

Once the parents agreed to have their child participate in the study, the procedures were explained to the child as follows:

"I would like you to help me with a project I am doing. It is like some of the projects you do at home with Mom and Dad or at school. You will come to see me here, in my school, a few times and then we will take a trip to another place to complete the project. When you are here, you will look at pictures for me, answer some questions and tell me about some things. It will be fun and you will be helping me know what is interesting for children like you to do and what isn't so interesting to do. Mom will be with us all the time.

Each time you come to see me, you will get treats, like lollipops and stickers, and you can pick out a toy from my toy basket to take home. When you, Mom and I go to New Haven to finish the project, you will get a special treat for completing the project. (Here, we talk about what would be a special treat - a video, a toy, etc.) We'll do lots of fun things in New Haven and you will meet some of my grownup friends who are also helping me with this project. You will get to blow through a cardboard tube like this (show tube and have child blow through it while holding his nose closed). When you blow through the tube without letting any air out around the sides of the tube or through your nose, you will make a toy rocket take off from a pretend moon. By blowing air in and out of your mouth, you can make the rocket take off or land on the moon. You will wear these soft bands around your tummy and your chest while you are sending up the rockets and while you are talking to me. (A big Mickey Mouse doll is shown wearing the same bands the child wears during the experiment.

The child tries on a similar set of bands.) You and Mom will also have cupcakes and a juice drink after the project is done. (Discuss the type of cupcake the child would like to have and the type of juice.) Will you help me out with my project? (Depending on what the child says, we go forward, give him time to think about it, or decide not to proceed with the project for this subject.)

APPENDIX B

PARENT CONSENT FORM

Consent to Act as a Research Subject

Project: Research on children's respiratory activity during conversational speech.

Dear Parent,

Your child is invited to participate in a speech breathing study. S/he has been chosen because respiratory behavior in young talkers, between the ages of 4 and 7 years, is of interest to the investigators.

The procedure will involve the placing of expandable cloth belts on the child, one goes around the chest and the other around the tummy, to record changes in chest and stomach movement while the child is breathing and talking.

There are no known risks of physical or psychological damage associated with this procedure. It will not impair your child's breathing nor cause any bodily discomfort, aside from the novelty of wearing the cloth bands. This judgement is based on a large body of knowledge about the effects of this procedure with young children.

Video-recordings of the child will be made during the experimental study using standard video-camera equipment. The videotape will be used for experimental purposes only and will never be shown publicly.

This study will provide information that will add to our understanding of the respiratory patterns in young talkers, which may lead to the future benefit of others. No personal information gathered in this study will be disclosed to any persons other than the investigators and their collaborators unless it is rendered anonymous. If the data is published, your anonymity will be maintained.

The experiment requires approximately three (3) visits with your child. The first one will be in my office or in your home. This first visit will be videotaped, and will be a play-and-talk, get acquainted meeting. At that time, signed consent for your child's participation in the research project, as well as verbal consent from your child, will be obtained. You will be given a form to fill out on your child's medical, developmental, educational, and social development.

The second visit will be in my office or your home, to conduct speech and language testing and a hearing screening. At that time, we will review the case history form together, and you will have an opportunity to ask questions. The second visit should last approximately one and one half (1 1/2) hours. If the child becomes tired during the testing, another meeting will be arranged.

The final visit is the experimental procedure described to you, and will be conducted at Haskins Laboratories in New Haven, Connecticut. Transportation will be provided if you need it. Free parking will be provided in the parking garage next to Haskins.

At the last visit, your child's height and weight will be measured. Your child will be rewarded his pre-determined toy at the end of the experiment, and you will be given an additional $25.00 to be used for his benefit. Of course, you are free to withdraw from the experiment at any time. You will be present with your child at all times.

I will be happy to answer your questions at any time. The experience should be a pleasant and interesting one for you and your child, and the findings may help other children in the future.

Authorization: I have read this form and have decided that my child, _____, will participate in the project described in

this letter. I understand the general purpose of the study and the noninvasive but novel aspects of the experimental procedure to be conducted with my child. My signature also indicates that I have received a copy of this consent form.

_____

Today's date: _____

APPENDIX C

CASE HISTORY FORM FOR STUTTERING SUBJECTS.

(Nonstuttering subjects received the same form without the stuttering section.)

Child's name:_____

Sex:_____ Birthdate:_____

Place of Birth:_____

Address:_____

Phone: _____

Language(s) spoken at home:_____

Father's name:_____ Birthdate:_____

Occupation:_____ Grade last completed:_____

List father's health, speech and/or hearing problems:

_____

_____

Mother's name:_____ Birthdate:_____

Occupation:_____ Grade last completed:_____

List mother's health, speech and/or hearing problems:

_____

_____

Siblings' names and ages: _____

_____

List speech problem(s) for the following family members: siblings, grandparents, aunts, uncles, cousins: _____

_____

_____

BIRTH INFORMATION

Length of pregnancy:_____

Birth weight:_____ List health, feeding, breathing and/or sleep problems from birth through the first three (3) months of life:

_____

_____

GENERAL DEVELOPMENT

List ages achieved following developmental milestones:

Walked unassisted_____

Spoke first words_____

Spoke first sentences_____

List any eating, sleeping, and/or behavioral problems past and present.

_____

_____

MEDICAL INFORMATION

Ear infections: Starting age _____ Ending age_____ Dates and types of surgical procedures associated with ear problems:

_____

_____

Date and results of last hearing test/screening (give your opinion of your child's hearing ability if s/he has not been tested):

_____

_____

Date and results of last vision test/screening (give your opinion if no test):

_____

_____

List illnesses, including known or suspected allergies or asthma:

_____

_____

_____

List hospitalizations, operations, and injuries including dates of occurrence:

_____

_____

List medications past and present and explain:

_____

_____

SCHOOL INFORMATION

School name: _____

Grade: _____

Rate your child's performance in the following areas as above average, average, below average: (Ask your child's teacher if you are unsure how s/he is doing in these areas.)

1. Social skills (getting along with teachers/classmates):

_____

_____

2. Communication skills (being understood):

_____

_____

3. Listening skills (paying attention):

_____

_____

4. Following directions (for games, group activities and classwork):

_____

STUTTERING INFORMATION

Age stuttering was first noticed _____

Who first noticed the stuttering? _____

Did stuttering develop gradually or suddenly?_____

Explain:_____

_____

_____

Does your child's stuttering occur every day, come and go from day to day, disappear for weeks and return suddenly? Explain:

_____

_____

Which of the following characterizes your child's stuttering? (check all that apply):

1. Repeats whole words: but but but but I want _____

2. Repeats sounds from a word: b b b but I want _____

3. Repeats syllables from a word: they we-we-we-went away_____

4. Struggles to start a word: b-----ut I want _____

5. Struggles to complete a word by breaking the word in the middle: we went to the st - ore

6. Prolong sounds at the beginning or end of a word: sssssssee the car_____; I waaaaaant that _____

7. Moves a part of the body, e.g., head, arm, feet or eyes, when trying to say a word. Explain: _____

_____

_____

Is stuttering worse: Now?____ When first noticed?____ No Change? _____

Explain:_____

_____

Have you ever sought help for your child's stuttering?_____

With whom?_____

_____

What was recommended?_____

_____

_____

Is your child aware of his/her stuttering? _____

Explain:_____

_____

Does s/he give up trying to speak when stuttering occurs?

_____

Does s/he express anger or frustration when stuttering occurs?

_____

Attitudes of others about your child's stuttering:

_____

_____

Does your child stutter (yes/no) with family members? _____ in school?_____

in stores or restaurants?_____

Explain:_____

_____

What do you say to your child when s/he stutters?

_____

_____

What do you say to your child when s/he is speaking without stuttering?

_____

_____

Name of the person who completed this form:

_____

Relationship to child: _____

Today's Date: _____

THANK YOU.

APPENDIX D

STANDARDIZED TESTS GIVEN TO ALL CHILDREN.

Articulation

[AAPS] Arizona Articulation Proficiency Scale: Revised (1982). Fudala, J.B. Los Angeles, CA: Western Psychological Services.

Language

[PPVT] Peabody Picture Vocabulary Test - Revised, Form M (1981). Dunn, L.M. and Dunn, L.M. Circle Pines, Minnesota: American Guidance Service.

[TOLD] Test of Language Development - Primary (1991-Second Edition). Newcomer, P.L. & Hammill, D.D. Austin, TX: PRO-ED.

[SALT] Systematic Analysis of Language Transcripts (SALT) Miller, J. & Chapman, R. (1984-1991). Madison: University of Wisconsin.

Intelligence

[K-BIT] Kaufman Brief Intelligence Test - KBIT (1990). Kaufman, A.S. & Kaufman, N.L. Circle Pines, MN: American Guidance Service Inc.

APPENDIX E

HASKINS CONSENT FORM FOR RESPITRACE EXPERIMENT

RESPITRACE - CHILD

HASKINS LABORATORIES
270 Crown Street, New Haven, Connecticut 06511

Consent to Act as a Research Subject

Project: "Research Program on the Dynamics of Speech Articulation."
NIH Grant DC00121

Your child is invited to participate in a speech production study involving the use of a technique called Respitrace. You are, of course, free to decline if you wish. Your child has been chosen because his/her speech and respiratory behavior are of interest to the investigators.

You should understand that the procedure will involve the use of a respiration sensing device called Respitrace. An expandable, soft, cloth band with movement sensors sewn into the cloth, will be placed around your child's chest and around his stomach. These bands record changes in chest and stomach movement during breathing for speech. While wearing the bands, your child will be asked to recite a nursery rhyme and to simply converse with the experimenter. We will also make videotape recordings for experimental study. The videotape will be used for experimental purposes only and will never be shown publically.

There are no known risks of physical or psychological damage associated with the procedure. It will not impair your child's breathing, nor cause any bodily discomfort, aside from the novelty of wearing the cloth bands. This judgement is based on a large body of knowledge about the effects of this procedure with young children.

This study will provide information that will add to our understanding of the respiratory dynamics of stuttering in young children, which may lead to the future benefit of others.

No personal information gathered in this study will be disclosed to any persons other than the investigators and their collaborators unless it is rendered anonymous.

The experimental procedure will require a commitment of approximately a 2-hour session with your child. At the end of the experiment, s/he will recieve a toy, and you will be paid $25.00 dollars to be used to buy an additional treat for your child for completing the experiment. Of course, you are free to withdraw from the experiment at any time. You always will be with your child throughout the experimental procedure. I will be happy to answer any questions you may have at any time. The experience should be a pleasant and interesting one for both you and your child.

RESPITRACE - CHILD

Authorization: I have read this form and decided that my son/daughter _____, will participate in the project described above. My signature also indicates that I have received a copy of this consent form.

Signature: _____

Relationship: _____

Date: _____

_____ _____

Signature of Principal Investigator Phone

_____ _____

Signature of Person Obtaining Consent Phone

If you have further questions about this project or your child's rights as a research subject or if your child has a research related injury, please contact the principal investigator, Vincent L. Gracco, (telephone 865-6163 or 764-9353).

THIS FORM IS NOT VALID UNLESS THE FOLLOWING BOX HAS BEEN COMPLETED IN THE HIC OFFICE.

THIS FORM IS VALID ONLY UNTIL

JAN 29 1998 (date)

HIC PROTOCOL NO. 2397

INITIALED: SVK

APPENDIX F

EQUIPMENT USED DURING DATA RECORDING PROCEDURE

1) Avalon data recording system
   Model AE5330-32

2) Respitrace Plus monitoring system
   Model SY07

3) JVC Camera
   Model GR-S505U/AA-V6U

4) JVC - VCR
   Model HR-S7100U

5) Mitsubishi - TV/Monitor
   Model CS 20201

6) Spirometer
   Model Collins Survey III
   Cat. No. 002900

7) Power Supply
   Model 6201A

8) Sennheiser Microphone
   Model MKH 816T

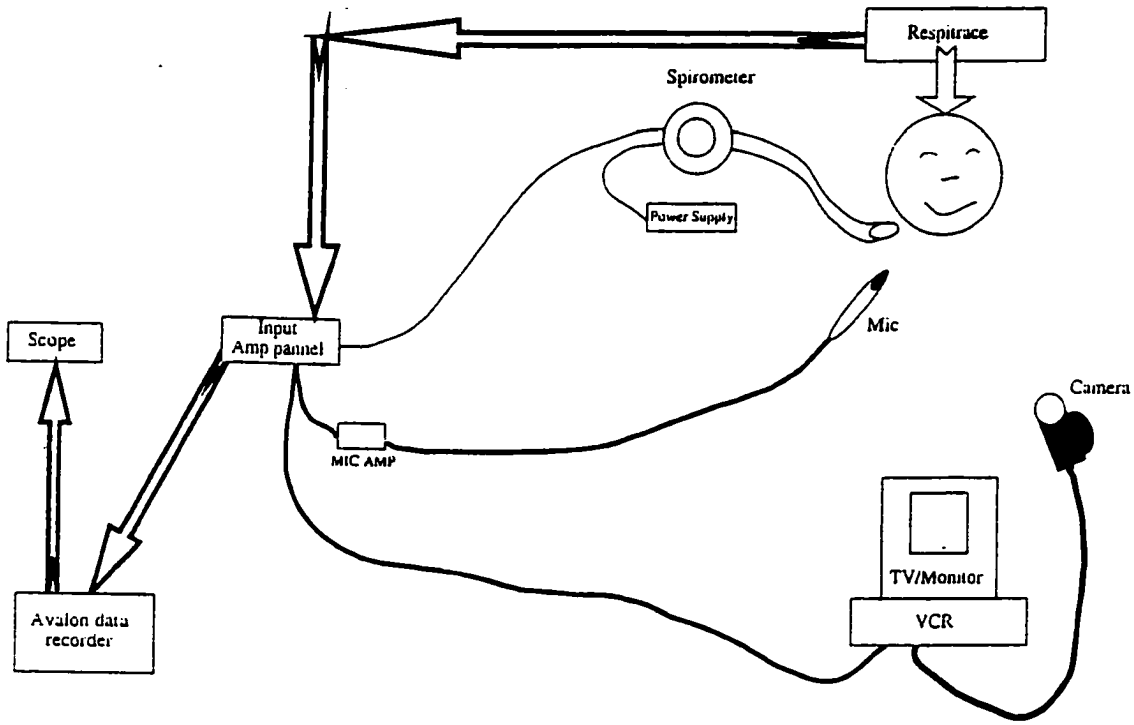
8) Sennheiser Mic Amplifier
   Model MZN 16T

10) Input Amplifier
   HART panel

11) Iwatsu Oscilloscope
   Model SS5802

APPENDIX G

Schematic Diagram of Equipment Placement Relative to Seated Subject.



APPENDIX H

SALT program codes and SALT accepted user-created codes for transcript analysis of disfluency and stuttering.

1. Codes created for identifying stuttering in the SALT program.
   - SBW = broken word following an inspiration
   - SBWX = broken word with no prior inspiration
   - SW = whole word repetition following an inspiration
   - SWX = whole word repetition with no prior inspiration
   - SP = sound prolongation following an inspiration
   - SPX = sound prolongation with no prior inspiration
   - SR = sound/syllable repetition following an inspiration
   - SRX = sound/syllable repetition with no prior inspiration
   - SRP = phrase repetition following an inspiration
   - SRPX = phrase repetition with no prior inspiration
   - SS = struggle following an inspiration
   - SSX = struggle with no prior inspiration

2. Codes used in the SALT program for identifying nonstuttered disfluency.

([M:REF]) = reformulation. Example - Goldilocks sat on the bed (the chair [M:REF]).

([M:FIL]) = filler. Example - He (like [M:FIL]) went to the store in his (like [M:FIL]) new car.

([M:SREP]) = single-unit sound or syllable repetition. Examples: She tasted (s* some [M:SREP]) in the big bowl; Then (da* daddybear [M:SREP]) said...

([M:WREP]) = single-unit word repetition. Example - He (he [M:WREP]) came to the door.

([M:PREP]) = single-unit phrase repetition. Example - He said (He said [M:REP]) we should go.

> = abandoned utterance. Example - We sang> I forgot what we sang.

APPENDIX I

Special code legend developed for use in the SALT program for identifying grammatical boundary and non-boundary locations, nonfluency, and presence or absence of inspiration.

B = Beginning of a sentence I = Inspiration N = No stuttering or disfluency
C = Beginning of a clause X = No inspiration
P = Beginning of a phrase S = Stuttering
G = Other location D = Disfluency

Combination codes for events at the beginning of a sentence.

[BIN] = sentence/ inspiration/ no stuttering
[BIS] = sentence/ inspiration/ stuttering
[BID] = sentence/ inspiration/ disfluency
[BXN] = sentence/ no inspiration/ no stuttering
[BXS] = sentence/ no inspiration/ stuttering
[BXD] = sentence/ no inspiration/ disfluency

Combination codes for events at the beginning of a clause.

[CIN] = clause/ inspiration/ no stuttering
[CIS] = clause/ inspiration/ stuttering
[CID] = clause/ inspiration/ disfluency
[CXN] = clause/ no inspiration/ no stuttering
[CXS] = clause/ no inspiration/ stuttering
[CXD] = clause/ no inspiration/ disfluency

Combination codes for events at the beginning of a phrase.

[PIN] = phrase/ inspiration/ no stuttering
[PIS] = phrase/ inspiration/ stuttering
[PID] = phrase/ inspiration/ disfluency
[PXN] = phrase/ no inspiration/ no stuttering
[PXS] = phrase/ no inspiration/ stuttering
[PXD] = phrase/ no inspiration/ disfluency

Combination codes for events at other locations.

[GIN] = other location/ inspiration/ no stuttering
[GIS] = other location/ inspiration/ stuttering
[GID] = other location/ inspiration/ disfluency
[GXN] = other location/ no inspiration/ no stuttering
[GXS] = other location/ no inspiration/ stuttering
[GXD] = other location/ no inspiration/ disfluency

APPENDIX I

Sample SALT transcript with SALT and special codes for stuttering subject JA.

E = Experimenter
C = Subject
= Goldilocks and The Three Bears
E Start with once upon a time.
C [BIN] Once upon a time [CID] Once upon a time [CXS] there[SPX] [GIN] was three bear/s.
C [BIN] One was[SSX] the great [GIN] huge bear [CIN] one was the mediumsize bear [CIN] and one was the [GIS] tiny/est[SR] bear.
C [BIS] They[SS] went [GXS] for[SRX] a walk [CIS] when[SS] their porridge was cool/ing.
C [BIN] A little girl came in their [GIS] house[SR].
C [BXN] First [CIN] she taste/ed [GIS] the[SR] great [GIN] huge bear.
C [BIN] It was too hot.
C [BIN] Then she taste/ed [GIN] the little [GXS] small[SSX] [GXDREF] mediumsize [GIN] bear.
C [BIN] It was too cold.
C [BXN] Then she taste/ed [GIN] the teeny [GIN] tiny bear/z [CIS] and[SR] it was [PXS] neither[SSX] too hot [GXS] neither[SPX] too cold [GIN] just right [CXN] so she ate it all up.
C [BIS] She[SP] [GIS] went[SS] >
C [PIN] Into the [GXS] livingroom[SSX].
C [BIS] First[SS] [CIS] she[SP] (uh) [GXS] sat[SPX] [GIN] in the great huge bear [CIS] and[SP] [GIS] it[SS] [GIS] was[SS] [GIN] too hard.
C [BIN] Then [CXS] she[SPX] [GXS] sat[SPX] [GIN] in the [GXS] middlesize[SSX] bear.
C [BIN] It was too soft.
C [BIN] Then she [GIN] sat [GIN] in the [GIN] tinybear/z [GIN] chair.
C [BIN] It was [PXS] neither[SSX] too hard [GXS] neither[SSX] [GIN] too soft [GIN] just right.
C [BIS] While[SS] [GXS] she[SPX] (while she) was [GXS] sat/ing[SPX] [CIN] the bottom of the chair broke.
E And then where did she go?
C [BIN] To the bedroom.
C [BIS] First[SS] [CXN] she sat [CIS] first[SS] she went [GIN] in the papa [GIN] bed.
C [BIN] It was too [CIS] the[SR] bed [GIN] was too high.
C [BIN] Then [CIN] she [GIN] went to the motherbear/z [GIN] bed.
C [BIN] It was too [GIS] soft[SP].
C [BIN] Then she went [GIN] to the [GIN] tinybear/z [CIS] and[SR] (and) it was [GIN] just [GIN] right.
E Okay who came home?
C [BIN] The three [GXS] bear/s[SRX] [CIN] and the [GIS] papabear[SR] said [CIN] somebody was eat/ing ^
E Whoops sit still.
C [BIN] Somebody was eat/ing my porridge.

E And the mama bear?
C [BIN] Said somebody eat/ing my porridge.
C [BIN] And the babybear said [CIN] somebody was eat/ing my porridge [CIS] and[SR] she [CIS] and[SR] it/'s all gone.
E And then they went into the livingroom.
C [BIS] Somebody[SP] was [GXS] sit/ing[SPX] in my chair.
C [BIN] Somebody was sit/ing in my chair.
C [BIN] And somebody was sit/ing in my chair and she [CIDREF] and it/'s all brok/en{ed}.
C [BIN] Then they went [GXS] upstairs[SSX].
C [BIN] Somebody was sleep/ing in my bed.
C [BIN] Somebody was sleep/ing in my bed.
C [BIN] Somebody was sleep/ing in my bed and [CIN] here she is.
C [BIN] She open/ed her eye/s [CIN] and open/ed the [GXS] shutter/s[SPX] [CXN] and ran out [CIN] and nobody see her again.

APPENDIX K

Data Collected from Codes in Sample SALT Transcript Shown in APPENDIX J.

Codes	Number		Results
			Total Words in conversation sample = 291 (count)
BIN	26		Words with Codes = 110 (add codes - GXN)
BXN	2		Appropriate Grammatical Boundary Locations = 53
BIS	6		(Add codes beginning with B C P)
BXS	0		Appropriate Locations with Inspiration = 50
CIN	11		(Codes beginning with B C P + I)
CXN	3		Appropriate Locations w/o Inspiration = 9
CIS	9		(Codes beginning with B C P + X)
CXS	2		Other Locations = 236
PIN	1		(Codes beginning with G)
PXN	0		Other Locations with Inspiration = 34
PIS	0		(GIN + GIS)
PXS	2		Stutters at Appropriate Locations = 19
GIN	26		(Codes beginning with B C P + IS and XS)
GXN	181	=	Total Words minus Words with Codes
GIS	8		Stutters at Appropriate Locations w/Inspiration = 15
GXS	14		(Codes beginning with B C P + IS)
			Stutters at Appropriate Locations w/o Inspiration = 4
			(Codes beginning with B C P + XS)
			Stutters at Other Locations = 22
			(GIS + GXS)
			Stutters At Other Locations with Inspiration = 8
			(GIS)
			Stutters at Other Locations w/o Inspiration = 14
			(GXS)

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