UNIVERSITY OF ALBERTA

EFFECTS OF INSERTION OF INTERWORD PAUSES ON THE INTELLIGIBILITY OF DYSARTHRIC SPEECH

by

JOANNE M. GUTEK

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of

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ABSTRACT

This study examined the effects of artificially inserted interword pauses on the intelligibility of selected samples of dysarthric speech. Three dysarthric speakers who exhibited similar prosodic characteristics and sentence intelligibility scores were recorded reading five sentences of similar length. These sentences were digitized and systematically altered by means of silent intervals inserted between words. Altered and unaltered versions of the sentences were played to two groups of thirty listeners each for verbatim transcription. Speech intelligibility scores for the unaltered and the pause-altered sentences were calculated and compared to determine if pause alteration enhanced intelligibility. Pause alteration resulted in a statistically significant improvement in intelligibility of approximately five percent ($p \leq .0001$), although this improvement did not reach an arbitrarily set level of clinical improvement (≥10 percent) established *a priori* by the investigator. Results were discussed with reference to the clinical implications for the use of pause alteration as a strategy in the treatment of dysarthric speakers, the implications of differences in listener ability as a factor in intelligibility assessment, and the implications for the use of digital analyses in similar investigations.

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INTRODUCTION

Improved intelligibility is a primary goal in remediating dysarthric speech (Rosenbek & LaPointe, 1978; Yorkston, Beukelman, & Bell, 1988). In general, dysarthric talkers tend to demonstrate improved intelligibility when speaking rate is reduced (Berry & Goshorn, 1983; Beukelman & Yorkston, 1977; Crow & Enderby, 1989; Hammen, 1990; Hanson & Metter, 1980, 1983; Helm, 1979; Yorkston & Beukelman 1981b; Yorkston, Hammen, Beukelman, & Traynor, 1990). However, investigators remain uncertain about which of the components that influence speaking rate, pauses, articulation, or both may be responsible for the improved intelligibility.

Rate reduction has been shown to result in an increased number of pauses (Beukelman & Yorkston, 1977, 1978; Crow & Enderby, 1989) which may provide more well defined word boundaries for the listener (Crow & Enderby, 1989; Yorkston & Beukelman,1981b: Yorkston et al., 1990). The hypothesis that interword pauses may improve intelligibility was based partially on studies of dysarthric talkers that employed rigid rate control techniques. While such training studies reported improvements with a one-word-at-a-time style (Beukelman & Yorkston, 1977; Crow & Enderby, 1989), a causal relationship between interword pauses and improved intelligibility was not possible to determine. Osberger and Levitt (1979) noted that a problem with studies of this nature was that the training may have resulted in changes in components of the subjects' speech other than those of interest. That is, improved intelligibility could have resulted from changes to speech characteristics other than the pauses. This confounding factor has made it difficult to determine if frequency or duration of changes reported in intelligibility following training were due only to the insertion of pauses.

The effects on intelligibility of changing pausal and speech duration characteristics in a controlled experimental environment have been examined for deaf speakers (Maassen, 1986; Maassen & Povel, 1984, 1985; Osberger & Levitt, 1979; Parkhurst & Levitt, 1978), elderly hearing-impaired listeners (Gordon-Salant, 1986), and most recently for dysarthric talkers (Hammen, 1990). These investigations are unique in that they have employed modern computer processing techniques which enable pauses to be altered systematically and the relationship between pauses and intelligibility to be tested in controlled procedures.

An additional factor of interest in this area is that while the majority of persons with dysarthria tend to benefit from reducing overall rate of speech, there may be a subgroup of dysarthric speakers who need to adjust pause time or articulation time selectively (Yorkston & Beukelman, 1981b). Unfortunately, only one case study has described the deviant perceptual speech features which may characterize the dysarthric talker who benefits from a word-by-word style of speech (Yorkston & Beukelman, 1981c). The development of perceptual profiles of dysarthric speakers who might benefit from selective rate control would thus be valuable from both clinical and research perspectives (Hammen, 1990; Yorkston & Beukelman, 1981b; Yorkston, Beukelman, & Bell, 1988).

If speaking rate reduction is to be used most effectively as a clinical management stratagem with dysarthric individuals, research must provide clearly defined guidelines about which rate control techniques should be used and with whom. Because no interword pause-alteration study has been conducted on the speech of dysarthric persons chosen specifically for the severity of their spoken intelligibility and the profile of their deviant prosodic characteristics, this investigation attempted to provide such information by using digital editing techniques to experimentally manipulate the interword pause characteristics of selected samples of dysarthric speech. The rationale for this study will be developed in the chapter that follows, based on a review of the literature on dysarthric speech, the effects of speaking rate reduction on intelligibility, and the availability of digital techniques for pause alteration of connected speech.

CHAPTER II

REVIEW OF THE LITERATURE

INTELLIGIBILITY OF DYSARTHRIC SPEECH

The assessment of speech is a widely used measurement tool for categorizing the severity of dysarthria (Beukelman & Yorkston,1977; Beukelman & Yorkston,1979; Darley, Aronson & Brown,1969a, 1969b, 1975; FitzGerald, Murdoch, & Chenery; 1987; Hammen,1990; Yorkston & Beukelman, 1981a, 1981b; Yorkston, Hammen, Beukelman, & Traynor, 1990). An unbiased listener's assessment of a speaker's intelligibility has been described as a comprehensive indicator of all components of speech production across all categories of dysarthria and levels of severity (Darley, Aronson, & Brown, 1969a; Sarno, 1968; Yorkston & Beukelman, 1981c; Yorkston, Beukelman, & Bell, 1988).

Intelligibility scores represent the accuracy with which messages are conveyed (Sarno, 1968; Yorkston, Beukelman, & Bell, 1988; Yorkston & Beukelman, 1980). Yorkston and Beukelman (1981a) have provided several reasons for quantifying intelligibility to represent an overall measure of speech performance. They stated that reduced intelligibility is a frequent and perhaps universal characteristic of dysarthric speech. In addition, intelligibility serves as an overall index of severity and represents a functional index of communicative performance (Yorkston & Beukelman, 1981a).

Nevertheless, while speech intelligibility provides such essential information its measurement is not straightforward (Yorkston, Beukelman and Bell, 1988). Intelligibility scores may be influenced by the speaker's task (production of single words, spontaneous speech, sentences), the transmission system (live voice, video-taped or audiorecorded), as well as the listeners' task (verbatim transcription or multiple choice format) and the listeners themselves (familiarity with dysarthric speakers or the testing material). Because measurements of intelligibility can be influenced by so many variables, the Assessment of Intelligibility of Dysarthric Speech (AIDS) (Yorkston & Beukelman, 1981c, 1984) was developed to provide a standardized technique for assessing intelligibility in the clinical setting and across repeated measures if necessary.

One portion of the AIDS in which a listener transcribes verbatim sentences read aloud by a dysarthric speaker and recorded on audio tape, has been reported to be a reliable, objective measure of intelligibility (Yorkston & Beukelman, 1978). An intelligibility score derived from verbatim transcription can be considered an index of the success of communication because it represents the amount of information (reported in percent intelligibility) that is transfered from a speaker to a listener through speech. Therefore, by means of the AIDS it is possible to accomplish the quantitative and comprehensive measure of intelligibility for dysarthric speakers reliably across speakers, listeners and clinical settings.

RATE REDUCTION IN DYSARTHRIC SPEECH

Reducing the rate of dysarthric speech may be both a primary (Yorkston & Beukelman, 1981b) and an essential (Barnes, 1983) step in achieving maximal intelligibility. However, remediation of dysarthric speech has traditionally focused on treating segmental levels of speech, or those distortions related to errors in consonant and vowel articulation. In fact, published accounts of dysarthria treatment protocols suggested that treatment of prosodic features (rate, stress, intonation) tended to occur late, if at all, in a treatment program. Research now suggests that reducing the rate of speech may indeed be the most appropriate starting point in treatment for some dysarthric speakers.

Reducing rate of speech may be appropriate for dysarthric speakers with different motor disorders and varied degrees of intelligibility impairment. For example, rate reduction has been used with a variety of dysarthric talkers who exhibit an inability to coordinate and regulate the activities of several speech structures simultaneously. These talkers include persons with degenerative diseases such as amyotrophic lateral sclerosis, multiple sclerosis and other severe chronic deficits (Netsell, 1986; Yorkston & Beukelman, 1981b). Rate reduction techniques also have been frequently used with those dysarthric speakers who exhibit primarily prosodic disturbances in speech rate, stress, or intonation (Yorkston, Hammen, Beukelman & Traynor, 1990). In particular, persons with ataxic and hypokinetic dysarthrias have been cited as speakers who demonstrate prosodic disturbance that can benefit from rate reduction.

Rate reduction techniques have been used with speakers whose sentence intelligibility scores are as low as 10 percent, and as high as 90 percent. Despite differences among speakers' intelligibility levels at their habitual speaking rates, rate reduction has been shown consistently to improve speech intelligibility (Berry & Goshorn, 1983; Beukelman & Yorkston, 1977; Crow & Enderby, 1989; Hammen, 1990; Hanson & Metter, 1983; Helm, 1979; Yorkston & Beukelman 1981b; Yorkston, Hammen, Beukelman, & Traynor., 1990). In certain cases, improvements as large as 42 percent have been documented with the application of rate reduction strategies (Yorkston, Hammen, Beukelman, Traynor, 1990).

Rate reduction techniques are now being realized as appropriate and effective management strategies for a wide range of dysarthric speakers. However, while rate reduction may work for a great many dysarthric speakers, certain rate control techniques may be more effective for certain speakers. This realization has been reflected in the recent appearance of literature on the application of specific rate control techniques to particular dysarthric speech patterns (Yorkston, Hammen, Beukelman, & Traynor, 1990).

RATE CONTROL TECHNIQUES

A general deceleration in speaking rate is a strategy that may be used by some talkers to clearly emphasize an entire phrase or clause (Kloker, 1975). In a treatment setting however, simply telling a dysarthric speaker to "slow down" is usually an ineffective strategy in achieving rate reduction (Berry & Sanders, 1983; Netsell & Rosenbek, 1986). Yorkston, Beukelman, and Bell (1988) identified two groups of rate control techniques for dysarthric speech. One group consists of techniques which tend to reduce the rate of speech while preserving the natural prosody of the speaker. The other group consists of rigid rate control techniques which tend to rely on some external pacing mechanism to promote a one-word-at-a-time style of speech.

Rate modification techniques that preserve prosody have included oscilloscopic feedback (Berry and Goshorn, 1983; Caliguiri & Murray, 1983), delayed auditory feedback or DAF (Hanson and Metter, 1980, 1983) and rhythmic cueing (Yorkston and Beukelman, 1981). When speaking rate is altered by means of these techniques, naturalness and prosody tend to be maintained because new rates, stress patterns, and pause locations which parallel normal speech are learned. Unfortunately, these techniques require a great deal of training, practice, and attention on the part of the speaker.

Speakers who lack these cognitive or motivational requisites for such efforts might encounter failure and frustration during treatment. Therefore, for those persons with dysarthria who are unable to learn to use the techniques that preserve prosody, rigid rate control techniques may provide a more suitable alternative.

Rigid rate control methods have included metronomes (Allan, 1970), pacing boards (Helm, 1979) and alphabet supplementation boards (Beukelman & Yorkston, 1977; Crow & Enderby, 1989; Yorkston & Beukelman, 1978). With these techniques, the person is taught to speak in time with the beats of the metronome, or to accompany speech with systematic movements along the squares of a pacing board or the letters of an alphabet supplementation chart. Although the one-word-at-a-time style of speech does result in some decreased naturalness due to an increase in the number of pauses and an equalization of syllable stress patterns (Beukelman, 1983), these techniques are inexpensive, portable, and require a small amount of training. Rigid rate control techniques may, in certain cases, be the only practical option for some dysarthric talkers. Indeed, observation has suggested that the word-by-word speaking style may be most appropriate and successful for a group of selected dysarthric speakers (Beukelman & Yorkston, 1977, 1978; Crow & Enderby, 1989). Anecdotal reports also have claimed that those dysarthric talkers who exhibit a severe dysarthria may be the most appropriate candidates for rigid rate control techniques (Beukelman, 1983; Yorkston, Hammen, Beukelman, & Traynor, 1990).

In summary, although a few studies have documented the success of some rate control techniques and have speculated about which may be the most effective, no one has systematically attempted to determine which rate control technique is best suited to a specific constellation of dysarthric features. No doubt researchers have been limited by uncertainties about the temporal modifications which may occur when talkers accomplish rate reduction and improve intelligibility.

COMPONENTS OF SPEAKING RATE

It has been suggested that the exact pattern of durational adjustment may depend on both the speaking rate and the strategy used to obtain it (Hammen, Yorkston, and Beukelman, 1989). Reduced speaking rate may reflect a decrease in articulation rate (Hammen, Yorkston, and Beukelman., 1989), an increase in the number or duration of intra- and interword pauses (Goldman-Eisler, 1961, 1968; Lane & Grosjean, 1973), or a combination of pausal and segmental duration characteristics (Crystal & House, 1982; Hammen, Yorkston, and Beukelman. 1989; Linebaugh & Wolfe, 1984).

The perception of silent pauses has been examined by several investigators (Crystal & House, 1982; Duez, 1985; Goldman-Eisler, 1961; Henderson, Goldman-Eisler & Skarbek, 1966; Hieke, Kowal & O'Connel, 1983). The silent pause has been defined as "a period of vocal inactivity of a certain duration embedded in the stream of speech" (Hieke, Kowal, & O'Connell, 1983, p.203). Kent and Rosenbek (1982) considered pause time to be a suprasegmental feature of speech which interacts with other features of pitch, loudness, and articulation time to form prosodic domains of rhythm, stress and intonation.

The occurrence of pauses in the speech of non-impaired speakers has been studied considerably. The distribution and duration of pauses in particular are important factors in altering overall speaking rate. For example, a continuous flow of speech, rarely broken by periods of silence, is perceived as "fast" speech; spoken utterance halted by frequent pauses of hesitation is perceived as "slow" speech (Goldman-Eisler, 1961). As speaking rate is altered by normal speakers, the number and duration of pauses has been shown to be responsible for the observed changes in speech tempo (Goldman-Eisler, 1968; Lane & Grosjean, 1973; Minifie, 1973).

As overall speaking rate is decreased, the number of pauses increases while articulatory rate remains relatively stable (Goldman-Eisler, 1968). Lane and Grosjean (1973) reported that non-impaired speakers were able to increase their speaking rate by approximately 30 percent. The speakers accomplished this increased rate almost exclusively by reducing the number of pauses in their speech; minimal changes to the rate of articulation were made. In summary, although changes in rate can be accomplished by modifying speech time, the number and duration of pauses are more free to vary than are the speech events (Minifie, 1973).

In spontaneous speech, pauses may occupy as much as 50 percent (Goldman-Eisler, 1961; Henderson, Goldman-Eisler, & Skarbek, 1966) of the total utterance time in a non-impaired speaker and during reading aloud, pauses typically account for 30 percent of the total speaking time (Fonagy & Magdics, 1960; Kelly & Steer, 1949). The distribution of pauses is hypothesized to be related to planning and organization and the syntactic requirements of the material. The length and number of pauses in non-impaired speech may either be consistent or variable depending on the syntactic requirements of the material to be spoken. For example, Fonagy and Magdics (1960) reported that some breath groups were as short as 1.17 seconds, while the longest breath groups produced by non-impaired subjects in their sample exceeded 8 seconds. Ordinary discourse may be interspersed with pauses of such short duration that they are often below the perceptual threshold of a human listener (Hieke, Kowal, O'Connell, 1983).

In contrast to non-impaired speakers, pauses in the speech of dysarthric persons may be more or less frequent (Bellaire, Yorkston, & Beukelman, 1986). Dysarthric speakers may be pausing too often or too little due to poor monitoring associated with reduced cognitive functioning or to a compromised physiological state (Bellaire, Yorkston, & Beukelman, 1986). If cognitive functioning is reduced, a dysarthric speaker may forget to pause at syntactically appropriate places. "If physiological support is severely reduced, breath groups may be extremely short and may not be closely associated with syntactic structure" (Bellaire, Yorkston, & Beukelman, 1986, p.272). Unfortunately, few research reports have focused on the durational characteristics of the speech of dysarthric talkers .

Researchers have only recently begun to quantify the durational characteristics of dysarthric speech. Hammen, Yorkston, and Beukelman (1989) collected information on speech duration, pause duration, and number of pauses in a three-sentence sample from the middle of a paragraph read by four speakers with hypokinetic dysarthria. Measures were taken at three different rates: habitual, 80 percent of habitual, and 60 percent of habitual. The habitual rate was defined as the rate at which subjects read a stimulus material when given no instructions regarding speaking rate. At habitual rates, the four hypokinetic dysarthric speakers spoke at a greater overall rate than the normal controls: 200 versus 189 syllables per minute. The dysarthric speakers had a larger proportion of pause time (35 percent) than the normal speakers (22 percent). The number of pauses produced by the dysarthric speakers differed only slightly from the number produced by the normal speakers (2.7 versus 2.5). In addition, when speech rate was calculated exclusive of pauses, the dysarthric speakers had a greater articulation rate

(325 syllables per minute) than the normal controls (280 syllables per minute).

For the dysarthric speakers talking at 80 percent of their habitual rates, increases in overall duration came from moderate (22 percent) increases in speech duration and a slight increase in mean pause duration (13 percent). At 60 percent of the habitual rate, speech duration increased by 44 percent, mean pause duration increased by 56 percent, and a 26 percent increase in the number of pauses was measured. These data represent a marked increase in both speech and mean pause durations for the dysarthric speakers, as well as a moderate increase in the number of pauses. In a subsequent study, Hammen (1990) reported that when dysarthric speakers were paced to speak at 60 percent of habitual rate, speech time increased 28 percent, pause time increased 156 percent and number of pauses increased 125 percent.

The strategy used for rate reduction has been shown to influence the durational characteristics of speech. "Additive" and "cued" presentation styles are two types of rate control strategies. An additive style technique reveals a passage to a reader one word at a time at a selected rate. A cued style presents an entire stimulus passage on a display (paper or computer screen) and the passage is then underlined or pointed to word by word at a selected rate for the reader. Two additional styles, "rhythmic" and "metered" can also be applied to a given passage. A metered style cues a speaker to utter words with equal pausal and articulatory durations; a rhythmic style presents or cues a speaker to produce words with timing patterns that simulate those of normal speech.

Hammen, Yorkston, and Beukelman (1989) reported that rhythmic pacing appeared to have its greatest impact on mean pause duration (dysarthric speakers demonstrated a 49 percent increase), with essentially no change in the number of pauses, and a slight increase in speech duration (24 percent). In contrast, the metered strategy increased mean pause duration moderately (dysarthric speakers demonstrated a 26 percent increase), increased the number of pauses slightly (13 percent), and had the greatest influence on speech duration which increased 41 percent. Hammen, Yorkston, and Beukelman (1989) provided an explanation for why the rhythmic pacing style produced greater increases in pause duration than the metered pacing style: since the metered pacing presented words with equal duration, even short words like articles were alloted the same duration as the longer words ... "this may have caused the speakers to extend the short words to accommodate the pacing program, resulting in somewhat inflated speech duration measures" (p.221). In summary, Hammen, Yorkston, and Beukelman (1989) reported that when large reductions in speaking rate are required, speakers tend to increase pausal characteristics primarily, expanding speech time only somewhat.

It has been hypothesized that changes in primarily pausal characteristics accompany rigid rate control techniques (Yorkston & Beukelman, 1981b). However, no studies have formally documented the temporal changes which occur with rigid rate control techniques.

HYPOTHESES FOR IMPROVED INTELLIGIBILITY WITH RATE REDUCTION

Two theories have been put forth to explain the increases in intelligibility resulting from speaking rate reduction. One theory proposes that reducing speaking rate helps the dysarthric speakers. When they slow down, dysarthric speakers have more time to achieve articulatory targets accurately and greater time for intercomponent coordination (Barnes, 1983; Berry and Goshorn, 1983; Kent and Netsell, 1972; Rosenbek & LaPointe, 1978). The other theory states that it is primarily the listeners who benefit from reduced rate. The listener is given more time to process a distorted or ambiguous signal. Certain investigators suggest improved intelligibility from a reduction in speaking rate could be associated with both listener and speaker variables (Crow & Enderby, 1990; Hanson & Metter, 1983).

Slowing the speaker's rate may give the listener extra processing time to extract the general content of meaning of the sentence and thus facilitate "filling in the missing pieces." (Beukelman & Yorkston, 1977; Crow & Enderby, 1989; Osberger & Levitt, 1979; Parkhurst & Levitt, 1978; Yorkston & Beukelman, 1981; Yorkston et al. 1990). It appears that a listener requires a longer period of time to understand what is said when the speech is distorted than when it is not (Osberger and Levitt, 1979). The occurrence of any type of pause may therefore improve intelligibility by providing the listener with that additional time to process the distorted speech that has been heard (Parkhurst and Levitt, 1978).

Increases in intelligibility with the use of an alphabet chart might occur by providing the listener with knowledge of the first letter of each word, more processing time while the speaker searches for the first letter of each subsequent word, or both, together with the putative improvement in the speaking performance of the subject due to a slower rate of delivery (Beukelman & Yorkston, 1977; Yorkston & Beukelman, 1981b). A reduction in speaking rate using the alphabet chart approach is frequently achieved naturally because the speaker's search time accomplishes the insertion of pauses between the words of a continuous speech passage. An increase in the number of pauses that may occur as the result of slowing the speaking rate also may help the listener to identify word boundaries which might aid in segmenting the message (Crow & Enderby, 1989; Maassen, 1986; Yorkston & Beukelman, 1981b; Yorkston, Hammen, Beukelman, & Traynor, 1990). Research tends to support the claim that such highly structured rate reduction techniques appear to encourage the relative lengthening of pause time rather than temporal adjustments to other aspects of the speech signal (Yorkston & Beukelman, 1981b).

Yorkston and Beukelman (1981b) described a subject with compromised intelligibility for whom an occasional word could be recognized if a pause preceded it. In addition, Yorkston and Beukelman (1981b) found that forcing marginally intelligible speakers into specific stress patterns tended to increase intelligibility and reduce bizarreness. In light of these reports, and those reviewed above in which pauses have been hypothesized potentially to play a major role in improving intelligibility of selected dysarthric speakers, there may be particular dysarthric speech patterns that benefit especially from pauses.

IMPORTANCE OF PAUSES FOR SELECTED DYSARTHRIC SPEAKERS

Yorkston and Beukelman (1981b) suggested that there may be a subgroup of dysarthric speakers who need to adjust pause time selectively and that research in this area is needed. Those dysarthric speakers who have demonstrated improvements in speech intelligibility in response to rigid rate control techniques appear to benefit especially from the deliberate use of interword pauses. The dysarthric speakers studied with respect to this issue have included persons with speech disorders secondary to cerebral palsy (Yorkston & Beukelman, 1981b), motor neuron disease (Crow & Enderby, 1989), cerebellar degenerative disease, bilateral cerebral vascular accidents, Parkinson's disease, brainstem vascular accidents, and traumatic brain injuries from motor vehicle accidents (Yorkston & Beukelman, 1977, 1978). Knowledge of disease etiology therefore becomes important because certain perceptual speech characteristics have been found to co-occur with disease etiology and dysarthria type.

Darley, Aronson and Brown (1969a, 1969b, 1975) studied the perceptual speech characteristics associated with a wide variety of neurological conditions. Speech samples obtained from men and women representing seven categories of neurological disorder were rated by Darley and his colleagues on a seven-point equal-appearing interval scale for 38 speech dimensions. Distinct groupings of perceptual characteristics of speech were found to relate to particular disorder etiologies (Darley, Aronson, & Brown, 1969a, 1969b). Several other studies have also rated perceptual characteristics of the speech of persons representing various categories of dysarthria (Brown, Darley & Aronson, 1970; FitzGerald et al., 1987; Forrest, Weismer, & Turner, 1989; Kearns & Simmons, 1988; Ludlow & Bassich, 1983, 1984; Sheard, Adams, & Davis, 1991). However, although dysarthric speakers with the same disorder etiology tend to have similar perceptual speech characteristics (Darley, Aronson, & Brown, 1969b), each dysarthric speaker's utterance exhibits a unique perceptual profile. Indeed, Metter and Hanson (1986) have noted that patients within the same type of dysarthria category may have markedly dissimilar speech profiles. Therefore, detailed description of deviant perceptual features is warranted, especially when experimental treatment techniques are to be applied to a dysarthric speaker.

Crow and Enderby (1989) found that for six dysarthric subjects representing a range of severity (mild to severe) and a variety of etiologies (including motor neuron disease, cerebellar degeneration, Parkinson's disease, bilateral strokes) average intelligibility was improved with the aid of a rigid rate reduction tool. Average intelligibility scores for predictable sentences improved from 59.3 percent (unaided) to 74.5 percent (aided).

Individual perceptual profiles of the speakers in the Crow and Enderby report would have been valuable in determining which among the dysarthric speech patterns represented by their speakers benefitted from a one-word-at-a-time style.

Yorkston and Beukelman (1981c) attempted to describe the speech characteristics of an individual who showed dramatic improvement using a rigid rate control technique. They characterized the speech of their dysarthric talker as marked by rapid rate, rushes of speech, monoloudness, reduced loudness levels, monopitch, little articulatory excursion, and reduced stress patterning. In addition, they reported a large discrepancy between single-word (76 percent) and sentence (24 percent) intelligibility for the speaker, and it was suggested that rigid rate control, which would promote a one-word-at-a-time style, might therefore be an appropriate treatment strategy.

In addition, Yorkston, Hammen, Beukelman, and Traynor (1990) applied rate control techniques to four individuals with severe ataxic dysarthria and four individuals with severe hypokinetic dysarthria. Sentence intelligibility improved for both groups, with the metered pacing condition (a one-word-at-a-time style of rate control) and slow rate (60 percent of habitual) associated with the largest improvement in scores. For the ataxic group, mean sentence intelligibility improved by 32.8 percentage points (from 40.9 percent at habitual rates to 73.7 percent at 60 percent of habitual). For the hypokinetic group, mean sentence intelligibility improved 20.5 percentage points (from 60.7 percent at habitual speaking rates to 81.2 percent at 60 percent of habitual). These studies suggest that specific profiles of dysarthric features (perceptual characteristics as well as intelligibility scores) might help designate the dysarthric speaker who could especially benefit from the addition of interword pauses in connected speech.

PAUSAL ALTERATION STUDIES

The use of new commercially available computer digital speech processing techniques offer researchers in the area of dysarthria an opportunity to experiment with dysarthric speech patterns to determine the exact effect of pauses in connected speech. This technology has already been used to study the effects on spoken intelligibility of changing pausal characteristics in a controlled experimental environment for deaf speakers and most recently for dysarthric talkers. These studies aimed to determine the causal relationship between timing errors and intelligibility without the confounding variables that are inherent in training studies.

Several studies have examined the effects of changing pausal and speech duration characteristics on speech intelligibility of deaf individuals (Maassen, 1986; Maassen & Povel, 1984; Osberger & Levitt, 1979; Parkhurst & Levitt, 1978). Parkhurst and Levitt (1978) were the first to report that pausal characteristics may influence the intelligibility of deaf speakers. They reported that short pauses at syntactically appropriate boundaries may have aided the intelligibility in deaf talkers' utterance. They went on to interpret that even excessive and/or prolonged pauses (over one second) provide the listener with additional time to process the distorted speech that has been heard. Overall, Parkhurst and Levitt (1978) reported a positive correlation between the number of pauses in sentences spoken by deaf children and the intelligibility scores for listeners' transcription of those sentences.

In 1979, Osberger and Levitt removed pauses from deaf speech, and reported a 10 percent reduction in mean intelligibility scores. Later, Maassen and Povel (1984) confirmed the finding that pause removal decreased speech intelligibility. Maassen (1986) artificially inserted silent pauses between words in sentences spoken by ten deaf children so that word boundaries became perceptually more distinct. The spoken sentences were digitized using Linear Predictive Coding (LPC) and resynthesised with silent pauses of 160ms inserted between words. This procedure caused a small significant improvement in intelligibility (4 percent). However, the improvement was larger (7 percent) for sentences containing few pauses than for sentences that already contained many pauses between words. Perhaps had Maassen attempted to select his speakers specifically on the basis of deviant speech production characteristics (e.g., few pauses in habitual speech) a more consistent improvement may have resulted. However, it was determined that pauses, especially those between words, proved to be beneficial to listeners in understanding the speech of deaf persons (Maassen, 1986; Parkhurst & Levitt, 1978).

Hammen (1990) investigated the effect of alterations of speech duration and pausal characteristics on the speech intelligibility of six talkers with parkinsonian dysarthria. One type of temporal alteration used in her investigation involved alteration of pausal characteristics in spoken sentences such that existing pauses were lengthened, and additional pauses were inserted at predetermined locations to achieve a total target duration (60 percent of habitual speaking rate). No more than three pauses were lengthened or inserted within each sentence. The average improvement in intelligibility of speech in the pausal condition over that in the habitual condition was only 1 percent (56 percent habitual intelligibility and 57 percent pause-altered intelligibility).

Several things may have accounted for this absence of change. Two of the characteristics of parkinsonian dysarthria, reduced loudness and breathy vocal quality, may have affected the quality of the speech samples. The distortion created by the computer re-synthesis process itself may have served to mask some of the differences between the digitally altered conditions accounting for the absence of a differences. The re-synthesis process has been reported to degrade the speech signal (Maassen & Povel, 1984). And in fact Hammen suggests that "methods to alter speech samples that do not require analysis and re-synthesis need to be developed if this approach is to be used effectively" (Hammen, 1990, p.102).

The insertion of pauses into a very rapid stream of speech, which was present for a number of subjects in the Hammen study (1990), may have served only to increase the bizarreness of their speech. In addition, the decisions made regarding placement and distribution of pauses may have created speech samples which were unusual sounding to the listeners. Hammen also used sentences which were considerably longer than those used in other sentence intelligibility tasks such as the AIDS and may have provoked fatigue effects in the dysarthric speakers in her study. Although speech pathologists listened to samples for each subject's speech to confirm perceptually the presence of hypokinetic dysarthria, no perceptual rating form was used to describe each speaker. Further examination of Hammen's data reveals that one subject in the study was reported to have an increase in intelligibility of 12 percentage points when pauses were inserted. An individual perceptual profile of this subject's speech may have been valuable in determining the reason why pause insertion was so successful in this speaker's case.

Studies that have used computers to manipulate pauses have attempted to determine the relationship between timing errors and intelligibility. Pauses, especially those between words, proved to be beneficial to listeners in understanding the speech of deaf persons (Maassen, 1986; Parkhurst & Levitt, 1978). Pause removal has been reported to result in decreased speech intelligibility scores of deaf speakers (Maassen & Povel, 1984; Osberger & Levitt, 1979). In contrast, Hammen (1990), reported that digital manipulation of syntactic pauses in samples of hypokinetic dysarthric speech did not appear to show a significant difference in intelligibility scores. However, certain instrumental and methodological flaws in her study may have confounded the results. Therefore, while these studies have provided valuable information about the type of temporal manipulation which may be useful, each study lacked specified perceptual descriptors which characterized the speech of those talkers who improved from pause alteration.

RATIONALE

Reduced intelligibility is a frequent if not universal characteristic of dysarthric speech (Yorkston & Beukelman, 1981a). Various deviant speech characteristics have been reported to contribute to a reduction in speech intelligibility. Prosodic disturbance is one such deviant characteristic which may compromise the speech intelligibility of some dysarthric talkers. Reduction of the rate of speech has been reported as one effective mode of treatment which improves intelligibility of those speakers (Berry & Goshorn, 1983; Beukelman & Yorkston, 1977; Crow & Enderby, 1989; Hammen, 1990; Hanson & Metter, 1983; Helm, 1979).

The effects on spoken intelligibility of changing pausal characteristics in a controlled experimental environment have been examined for deaf speakers (Maassen, 1986; Maassen & Povel, 1984; Osberger & Levitt, 1979; Parkhurst & Levitt, 1978) and most recently for dysarthric talkers (Hammen, 1990). These studies aimed to determine the causal relationship between timing errors and intelligibility without the confounding variables that are inherent in training studies.

The type of rate control technique used can produce more noted changes in the pausal domain of speech or more changes in the segmental domain of speech (Crystal & House, 1982; Goldman-Eisler, 1961, 1968; Hammen et al., 1989; Linebaugh & Wolfe, 1984). Preliminary research on which rate control techniques should be used and with whom has suggested that rigid rate control techniques which promote a one-word-at-a-time style encourage the lengthening of pause time and number of pauses, and may be especially beneficial for some dysarthric talkers (Crow & Enderby, 1989; Yorkston & Beukelman, 1981b; Yorkston, Beukelman, & Bell, 1981c). To date, however, no studies have been conducted which aim specifically to determine the speech profile of the dysarthric speaker who is best suited to a treatment that encourages a one-word-at-a-time style of speech. In addition, no interword pause alteration study that experimentally controls extraneous variables, which may confound results in treatment studies, has been conducted.

STATEMENT OF THE PROBLEM

Whereas the effect of pause-alterations has not been demonstrated unequivocally on the intelligibility of dysarthric speech, and whereas the characteristics of dysarthric speech and the techniques used to effect pause alterations in such speech have been confounded in previous research, this investigation will attempt to provide such information and control confounding variables by experimentally manipulating the interword pause characteristics of selected samples of dysarthric speech in order to test the following hypothesis:

> The mean intelligibility scores for sentences spoken by dysarthric talkers that have been digitally altered by the addition of pauses will be higher than the scores for those same sentences unaltered by pauses.

METHOD

This study of the effects of insertion of interword pauses on the sentence intelligibility of selected dysarthric speech involved four stages. First, the actual samples of the dysarthric speech were obtained; several dysarthric speakers were identified, their speech recorded, and rated with respect to level of intelligibility and prosodic features. The second stage involved the digital manipulation of those experimental samples of dysarthric speech to create pause-altered versions of the samples. Two groups of listeners were then accessed to transcribe word-for-word the altered and unaltered sentences. Finally, intelligibility scores based on these transcriptions for unaltered and pause-altered sentences of dysarthric talkers were computed and compared statistically.

ACQUISITION OF EXPERIMENTAL SAMPLES OF DYSARTHRIC SPEECH

Initial Subject Selection — Speakers with Dysarthria

Dysarthric speakers were recruited by means of personal contacts with speech-language pathologists working at the Alberta Hospital Ponoka Brain Injury Unit in Ponoka, Alberta. All speakers selected for this study met the following initial selection criteria:

1. Dysarthric with notable problems in connected speech.
2. Adequate vision (including use of corrective lenses) to complete reading tasks as documented by hospital chart.
3. No history of hearing loss as documented by hospital chart.
4. Native speaker of English.
5. Sentence intelligibility that was moderately impaired based on subjective judgment by a speech-language pathologist.

Ten speakers (eight male and two female) who satisfied these criteria were selected. They ranged in age from 17 to 68 years (M = 35 years), and in time post brain-injury from 1 to 13 years (M = 5 years). Three subjects had suffered head injuries due to falls, and the remaining seven subjects had suffered head injuries as the result of motor vehicle accidents. This information is summarized and displayed below in Table 1.

TABLE 1. Demographic information for the dysarthric speakers. (TBI=Traumatic Brain Injury; MVA=Motor Vehicle Accident)

Speaker	Gender	Age in Years	Primary Etiology	Years Post Injury
A	Male	37	TBI/fall	13
B	Female	42	TBI/fall	3
C	Male	47	TBI/fall	5
D	Male	23	TBI/MVA	4
E	Female	29	TBI/MVA	3
F	Male	68	TBI/MVA	1
G	Male	38	TBI/MVA	15
H	Male	29	TBI/MVA	2
I	Male	22	TBI/MVA	1
J	Male	17	TBI/MVA	1

Dysarthric Speech Sample Recording

The ten dysarthric speakers read and signed an information/consent form (Appendix A) to indicate informed agreement to participate in the study. Separate information/consent forms (Appendix B) were sent to parents or legal guardians of speakers who were deemed dependent. Historical information (speaker's name, birthdate, disease etiology, visual status, hearing status, and native language) was obtained from each speaker's hospital chart and summarized on a speaker history form (Appendix C).

Each speaker was recorded using the sentence portion of the Assessment of Intelligibility of Dysarthric Speech (AIDS) (Yorkston & Beukelman, 1981c) from which a sentence intelligibility score was obtained according to the authors' protocol. Because the recording length of the standard sentence protocol was long (22 sentences), an effort was made to reduce the impact of fatigue on participants by recording a shortened (11 sentence) version of the AIDS. Yorkston, Hammen, Beukelman and Traynor (1990) reported no difference between intelligibility scores from the shortened version and the full version of the sentence section of the AIDS. In the shortened version, one rather than two representations of each sentence length (5 - 15 words) was recorded. Yorkston et al. (1990) verified that the scores for the shortened version were similar to those for the standard version; the difference between the shortened and total sample averaged 3.2 percent with a standard deviation of 2.8 percent. A t-test comparison indicated that the intelligibility scores for the shortened samples were not different from those for the total sample ($p > .01$).

Four additional 8-word sentences also were recorded by each dysarthric speaker to provide an experimental sample of five 8-word sentences (the one 8-word sentence obtained during the shortened AIDS administration plus four extra) per speaker. The investigator planned to use these later in the experiment as targets for pause manipulation. It should be noted that all 8-word sentences drawn from the AIDS sentence pool can be considered equivalent because research has shown that intelligibility scores on different utterance samples drawn from the same pool and produced by the same speaker revealed intersample correlation coefficients which ranged from .92 to .99 (Yorkston & Beukelman, 1981c).

Sentence intelligibility recording procedures followed the protocol outlined in the AIDS manual (Yorkston & Beukelman, 1981c). Sentences were presented in a typed format, one sentence at a time. The investigator read the sentence aloud once, asking the dysarthric speaker to read along silently as the sentence was read. This procedure was used to ensure that intelligibility was not compromised by misreading and that speaking rate was not altered by reading difficulties (Yorkston & Beukelman, 1981c). Specifically, the examiner's instructions were as follows:

> Follow along as I read these sentences.
> When I am finished I want you to read each sentence as clearly as possible.

Each sentence was therefore read once by the examiner and then read aloud by the dysarthric speaker whose performance was tape-recorded.

High-quality tape recordings of the sentences were obtained using an audiocassette tape-recorder (Marantz model PMD221) in a quiet room at the Alberta Hospital Ponoka during after-work hours. A close-talk, head-mounted, unidirectional microphone (Shure SM10A) was positioned 2.5 cm from the talker's lips at the left corner of the mouth, at an angle approximately 90 degrees to the direction of airflow from the mouth throughout the recording session. Mouth-to-microphone distance and position were held constant within and across all ten subjects. Recording sessions lasted approximately thirty minutes.

Speech Intelligibility Measurement

The next step in the acquisition of the experimental samples of dysarthric speech was to obtain intelligibility scores for the sentences recorded by the ten speakers. Yorkston and Beukelman (1981c) reported that any literate adult with normal hearing may serve as an intelligibility judge and that the number of listeners required for reliable results depends on the purposes of the intelligibility measurements. Because intelligibility scores were used to compare dysarthric individuals, multiple listeners were needed (Yorkston & Beukelman, 1981c). Three adults who had normal hearing, were native speakers of English, and were not speech-language pathologists, were recruited to transcribe the sentences of the shortened version of the AIDS that had been recorded for each of the ten subjects with dysarthria. These listeners were obtained from the Faculty of Rehabilitation Medicine at the University of Alberta and consisted of two male third-year physiotherapy students and one female third-year physiotherapy student. Listeners were asked to complete an information/consent form (Appendix D) and a history form (Appendix E).

The transcription task included a total of 110 sentences (11 sentences from each of the 10 dysarthric subjects). Prior to the listeners' performance of the task, the audio records of all the sentences were replayed on the same audiocassette recorder on which they had been recorded, low-pass filtered at 8.6 kHz (Frequency Devices 901) and digitized at 22 kHz via a MacRecorder (Farallon Computing, Inc.) at 8-bit resolution on a Macintosh SE/30 computer (Apple Computer, Inc.). The computer was then programmed to replay the sentences in random order through a low-pass filter at 8.6 kHz (Frequency Devices 901) and loudspeaker (Pro III JBL) by means of software written by the principal investigator using Hypercard (version 2.0). The three listeners interacted individually with the investigator who operated the computer/loudspeaker in a quiet room; each listener heard all 110 sentences and transcribed them word-for-word on a formal record sheet (Appendix F) according to transcription standards for the AIDS.

For this transcription task, each listener was seated at a table in a comfortable writing position 1.5m from the computer and 1m from the loudspeaker. The ambient noise level of the room in which the listeners transcribed was monitored with a sound level meter (Realistic 33-2050). The average ambient noise level for the situations in which the three listeners transcribed was 55dB(C). The judges were not allowed to listen to any sentence more than two times. They were encouraged to guess at words they did not completely understand. The following instructions were given:

> You will be listening to someone saying sentences and writing down what you think the person said.
> Some of the sentences will be short and others will be long.
> You will be able to hear each sentence only two times.
> You will be allowed to set the volume output of the speaker to a comfortable loudness level.
> When you are ready to begin, you will signal me to play a sentence for the first time.
> When you are ready, you may then signal me to play the sentence for a second time.
> At any time you may signal me to pause the sentence to allow you to transcribe the sentence.
> You may not listen to a sentence more than two times.
> If you encounter a word which you do not understand, you should guess at the word.
> If you cannot guess at the word, you may leave a blank space (indicated by a line) on the transcription form.
> You will transcribe what you hear on these forms.
> Please print clearly in pencil.
> Once you have completed transcribing a sentence, and have moved on to a new sentence, you will not be permitted to go back and change any of the words in a previously completed sentence.
> You will be given a 10 minute break after every 22 sentences you listen to.
> At the end, a short speech perception test will be given.
> Do you have any questions?

Following the transcription task, listeners were given a short hearing perception test to confirm the adequacy of their hearing at the listening levels they had used for the sentence transcription. Hearing perception was tested by having listeners complete the Ling Five-Sound test (Ling, 1978). The phonemes /u/, /a/, /i/,/ʃ/, and /s/ were played to listeners via the Macintosh computer at the same loudness at which they had set the loudspeaker for the sentences. Listeners were required to repeat aloud the sounds they heard. The following directions were given:

> You will be listening to five speech sounds, one at a time.
> You will be asked to say aloud the sound you heard.
> You may hear each sound only two times.

This test was considered a reliable check of the range of the listeners hearing sensitivity because the five sounds employed "encompass the frequency range of all phonemes, and the voiced sounds contain sufficient harmonics to convey suprasegmental information" (Ling, 1978, pp. 195-196). Each of the three judges repeated all five sounds with 100 percent accuracy.

Each dysarthric talker's sentence intelligibility score (in percent) was determined from each judge's transcription by dividing the number of words correctly transcribed by that judge by the total number of words spoken (110) and multiplying this dividend by 100. Average sentence intelligibility scores were determined for each speaker from the results of the three judges and are displayed in Table 2. Intelligibility measures were then used to estimate functional communication levels for comparison among speakers. Speakers whose intelligibility scores fell between 40 percent and 75 percent (speakers A, C, D, F, and H) were accepted for further perceptual evaluation. The intelligibility scores of those five speakers are shown on the next page in Table 2 and are marked with stars (**).

TABLE 2. Initial intelligibility scores in percentages for the dysarthric speakers.

Speaker	Gender	Age	Listener 1 Intelligibility	Listener 2 Intelligibility	Listener 3 Intelligibility	Average % Intelligibility
A	Male	37	38%	47%	44%	43%
B	Female	42	87%	89%	93%	90%
C	Male	47	54%	59%	58%	57%
D	Male	23	65%	74%	75%	71%
E	Female	29	94%	94%	98%	95%
F	Male	68	71%	62%	73%	69%
G	Male	38	3%	22%	1%	9%
H	Male	29	55%	57%	67%	60%
I	Male	22	90%	87%	85%	87%
J	Male	17	93%	81%	93%	89%

Sentence intelligibility has been reported to rank that portion of the dysarthric population whose scores are between 10 and 90 percent. Therefore, the range of sentence intelligibility scores from 40 to 75 percent was chosen because it represented the middle of that range. In addition, by choosing those five speakers whose scores fell in the middle portion of the intelligibility curve, the investigator hoped that potential floor and ceiling effects on subsequent portions of this investigation could be avoided. An example of the impact of such effects on subsequent data collection is described below.

The reader will recall that an extra sample of 8-word sentences had been recorded originally from each of the dysarthric speakers. This pool of 8-word sentences was to be tapped for the experimental manipulation of pauses once the field of speakers had been narrowed systematically; that is, five 8-word sentences would serve as the experimental sample for each subject chosen for the final stage of the data acquisition process. However, inspection of several of the 8-word sentences produced by the five subjects in the 40 to 75 percent intelligibility range revealed average intelligibility of 100 percent, an obvious ceiling that would preclude observation of improvement in intelligibility as a result of pause alteration. Individual sentence intelligibility scores for the chosen five dysarthric speakers are outlined in Table 3. The intelligibility scores reflecting the ceiling appear for the first 8-word sentences listed for speaker C (100 percent) and speaker D (100 percent). Because the four additional 8-word sentences that had been recorded from each speaker but had not yet been rated could have also exhibited such ceiling effects, the three listeners were invited back to listen to those additional 8-word sentences for each of the five speakers. The results of this additional transcription analysis are incorporated in Table 3 as sentences 8B,8C,8D,and 8E.

TABLE 3. Intelligibility scores of individual sentences in percentages for the five dysarthric speakers including the extra eight-word sentences.

Sentence Length (# of Words)	Intelligibility Score for Speaker A	Intelligibility Score for Speaker C	Intelligibility Score for Speaker D	Intelligibility Score for Speaker G	Intelligibility Score for Speaker H
5	27%	53%	60%	80%	40%
6	83%	72%	50%	61%	72%
7	48%	100%	29%	24%	34%
8	50%	100%	100%	84%	71%
8B	4%	59%	54%	96%	42%
8C	25%	71%	79%	21%	42%
8D	21%	63%	75%	100%	54%
8E	54%	75%	83%	46%	50%
9	33%	37%	89%	93%	26%
10	30%	43%	100%	67%	87%
11	15%	82%	56%	91%	58%
12	70%	67%	67%	50%	58%
13	84%	64%	57%	80%	79%
14	19%	31%	79%	74%	76%
15	33%	20%	69%	51%	38%

Additional transcriptions of sentences 8B,8C,8D, and 8E for each of the five speakers yielded several intelligibility scores which did not fall into the desired intelligibility range of 40 to 75 percent. Intelligibility scores from sentence 8B (4 percent), 8C (25 percent) and 8D (21 percent) for speaker A fell below the desired value of 40 percent. For speaker D, two sentences (8C=79 percent and 8E=83 percent) exceeded the original 75 percent ceiling which was set. For speaker F, two sentences (8B=96 percent and 8D=100 percent) exceeded the ceiling, and one sentence (8C=21 percent) fell below the floor of 40 percent.

After consideration of the additional intelligibility data and the implications of ceiling effects for subsequent portions of the experiment, the investigator changed the criteria for selection of experimental sentences from five 8-word sentences to five 8 ± 2-word sentences which fell between 20 and 80 percent intelligibility to allow a greater number of scored sentences to be eligible for pause manipulation. The new ceiling (80 percent) allowed one additional 8-word sentence (speaker D, sentence 8C) to be included as a potential experimental sentence. The new floor value (20 percent) permitted five additional 8-word sentences to be included as potential experimental material. Expansion of the limit on the number of words per experimental sentence from only 8 words to 6-10 words allowed for greater flexibility in choosing sentences which fell between the range of 20 and 80 percent.

Selection of Subjects Based on Prosodic Profile Ratings

Ratings were required to profile the prosodic characteristics of the five dysarthric speakers to satisfy another potentially confounding variable in this research: homogeneity of subjects with respect to prosodic disturbance. In addition, it was hoped that specific profiles of the dysarthric speakers ultimately selected for the experimental speech sample might shed more light on the feature or constellation of prosodic features of dysarthric speech that could especially benefit from the addition of interword pauses in connected utterance. Those speakers whose abnormal prosodic characteristics included 1) reduced stress 2) monopitch 3) monoloudness and 4) abnormal rate as the four most deviant features were to be considered for further study. These features were chosen based on Yorkston and Beukelman's (1981b) report of perceptual characteristics which identified a speaker who benefited from treatment that encouraged a word-by-word style of speech.

Three speech-language pathology students with similar experience in the assessment and treatment of motor speech disorders were invited to participate in the perceptual judgement section of the study. Each of the three students completed an information/consent form (Appendix G) and a history form (Appendix H). Digital versions of 10 sentences (two $8^{\pm}2$-word sentences produced by each of the five dysarthric speakers who fit the speech intelligibility criteria) were played to the three listeners by means of the same computer/loudspeaker system that had supported the intelligibility ratings. The three prosodic judges interacted as a group with the investigator who operated the computer/loudspeaker in a quiet room; the judges listened to the sample sentences and rated them independently of each other on a formal record sheet according to a protocol. For this judgement task, the listeners were seated at a table in a comfortable writing position 1.2 to 1.5 m from the computer and 1.2 to 1.5 m from the loudspeaker. The ambient noise level of the room in which the judges made their ratings was monitored with a sound level meter (Realistic 33-2050) and averaged 54dB(C). The average sound level of the sentences as they were presented by the computer was 75dB(C) as measured by a sound level meter placed where the judges had been seated. The judges were allowed to listen to each sentence as many times as required to make their ratings.

The judges rated each speech sample on perceptual dimensions derived from those used in the Mayo Clinic Dysarthria Study (Darley, Aronson, & Brown, 1975) and modified by the investigator for this project. The series comprised ten dimensions of prosody (Appendix I). The speech samples were judged using a seven-point equal-interval scale. The ten attributes were rated between 1 and 7, with 1 representing no abnormality, 2 representing mild and inconsistent occurrence (occurring less than 75 percent of the time), 3 representing moderate and inconsistent occurrence, 4 representing mild and consistent occurrence (occurring more than 75 percent of the time), 5 representing moderate and consistent occurrence, 6 representing severe and consistent occurrence, and 7 representing complete dysfunction (Appendix J). The statistical analysis of inter- and intrajudge reliability by Darley, Aronson and Brown (1969) demonstrated adequate inter- and intrajudge reliability on the subjective judgements using such a scale.

Although perceptual rating scales have high content validity because they are able to measure the multiple facets of speech, the value of using such measures in rating dysarthria depends on how well clinicians can agree on scale values and make reliable judgements (Kearns & Simmons, 1988; Sheard, Adams & Davis, 1991). Therefore, prior to the task, the judges were trained to identify the perceptual characteristics using samples of the Motor Speech Disorders tapes published by Darley, Aronson, and Brown (1975). Following this training, judges were tested to determine their level of agreement on the various dimensions before judging of the experimental speech samples took place. Interrater agreement was calculated to be 90 percent (agreement within ±1 point on the rating scale) on two practice tests.

When interrater agreement was judged to be adequate, judges performed the actual (non-practice) prosodic rating on the 10 representative sentence samples for the five dysarthric speakers. The following instructions were given:

> You will be listening to speech samples of five dysarthric speakers who have moderately impaired intelligibility.
> Your task will be to judge the <u>*prosodic characteristics*</u> of each speech sample, as you did in the training session.
> The same prosodic characteristics as well as the same scaling method will be used as in the training session.
> You will be permitted to hear each sample as many times as you want.
> You will focus on and rate one prosodic characteristic at a time.
> You will not be permitted to compare your rating with anyone else.
> You will be given as much time as you need to make a rating you feel comfortable with.
> Do you have any questions?

After the judges completed the ratings of all 10 sentences, they were given a short break (30 minutes) and asked to re-rate 20 percent of the sample (2 sentences). Percentages of intrajudge agreement (agreement within ±1 point on the rating scale) were calculated for the repeated ratings and are shown in Table 4. Judges demonstrated adequate intrarater agreement which ranged from 80 to 100 percent.

TABLE 4. Intrajudge agreement for the prosodic profile ratings.

Judge	Speaker C Sentence 8B	Speaker F Sentence 8E	Average Intra-reliability
1	100%	90%	95%
2	80%	90%	85%
3	100%	90%	95%

Interjudge agreement (agreement within ±1 point on the rating scale) among the three judge was calculated for all the sentences they rated (N=20) for all 10 prosodic attributes. Furthermore, interjudge agreement was calculated not only for the seven-point equal interval scale but also for the perceptual ratings collapsed onto a five-point scale. The reduction of the data from the seven-point scale (Appendix K) to a five-point scale (Appendix L) was performed after one of the judges reported difficulty rating sentences using the larger scale. The scale values of 1 (representing no abnormality) and 5 (representing complete dysfunction) became the extremes on the five-point scale. Points 2 and 3 on the seven-point scale were collapsed so that a 2 on the five-point scale represented mild dysfunction. Points 4 and 5 on the seven-point scale were collapsed so that a 3 represented moderate dysfunction. Point 6 on the seven-point scale was represented by a 4 on the five-point scale which represented severe dysfunction. A comparison of the seven-point scale to the five-point scale is illustrated below in Table 5.

TABLE 5. Comparison of the seven-point scale to the five point scale for severity rating of the prosodic characteristics.

Seven-point Scale	Five-point Scale
1 no abnormality	1 no abnormality
2 mild and inconsistent 3 mild and consistent	2 mild
4 moderate and inconsistent 5 moderate and consistent	3 moderate
6 severe and consistent	4 severe
7 complete dysfunction	5 complete dysfunction

Interjudge agreement for the both the five-point and seven-point scale samples is reported in Table 6. Interjudge agreement on the seven-point scale ranged from 65 to 85 percent (M= 76 percent). On the five-point scale, agreement ranged from 78 to 100 percent (M=89 percent). Examination of Table 6 reveals that the five-point scale average listener agreements are consistently higher across all five speakers than those agreements obtained using the seven-point scale. Although the improved percent agreements accomplished by the five-point scale might be interpreted as inflated values, the agreements present a clearer profile of each speaker by reducing the variance which was present in the data on the seven-point scale.

TABLE 6. Interjudge agreement for the prosodic rating.

Speaker	Scale	Judge 1&2	Judge 2&3	Judge 1&3	Average
A	5 Point Scale	16/20=80%	16/20=80%	15/20=75%	78%
	7 Point Scale	13/20=65%	13/20=65%	13/20=65%	65%
C	5 Point Scale	20/20=100%	20/20=100%	20/20=100%	100%
	7 Point Scale	18/20=90%	17/20=85%	16/20=80%	85%
D	5 Point Scale	18/20=90%	20/20=100%	18/20=90%	93%
	7 Point Scale	18/20=90%	14/20=70%	13/20=65%	75%
G	5 Point Scale	19/20= 90%	16/20=80%	17/20=85%	85%
	7 Point Scale	16/20=80%	13/20=65%	13/20=65%	70%
H	5 Point Scale	19/20=90%	17/20=85%	18/20=90%	88%
	7 Point Scale	17/20=85%	16/20=80%	17/20=85%	83%

Three dysarthric speakers on whom the best interjudge agreement occurred for the prosodic features of interest were chosen from those whose prosody rating profiles included high scores on the primary prosodic characteristics (reduced stress, monopitch, monoloudness, and abnormal rate). Final speaker selection was therefore based on two variables:

1. A speaker's intelligibility score between 20 and 80 percent on 8±2-word sentences, and

2. A speaker's prosodic feature profile obtained from listeners' ratings (identifying primary abnormalities of reduced stress, monopitch, monoloudness, and abnormal rate) on which listeners agreed most often.

<u>Final Subject Selection: Dysarthric Speakers</u>

Three male dysarthric speakers from among the five rated who were similar in overall dysarthric severity and prosodic profile were selected: they were 47 (speaker C), 23 (speaker D) and 29 (speaker H) years of age ($\underline{M}$ = 33 years). For each speaker, five sentences consisting of 8±2 words were chosen as the experimental stimuli to be digitally manipulated; these sentences are indicated by a star (*) in Table 7. Individual sentences across the three speakers ranged in percent intelligibility from 29 to 79 percent. These fifteen sentences were designated as the experimental material which would undergo computer pause alteration (Appendix M).

TABLE 7. Intelligibility scores of the experimental sentences for the final three dysarthric speakers.

# Words	Speaker C	Speaker D	Speaker H
6	72%	* 50%	72%
7	100%	* 29%	34%
8	100%.	100%	* 71%
8B	* 59%	* 54%	* 42%
8C	* 71%	* 79%	* 42%
8D	* 63%	* 75%	* 54%
8E	* 75%	83%	* 50%
9	* 37%	89%	26%

DIGITAL MANIPULATION OF EXPERIMENTAL SAMPLES OF DYSARTHRIC SPEECH

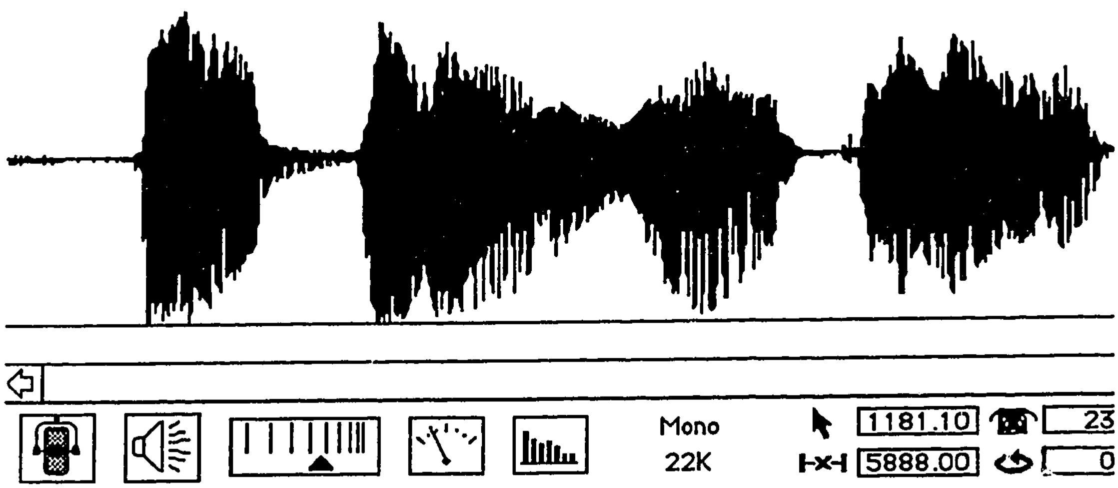
Digital Processing Procedure for Speech Signals

Tape-recordings of the five 8 ± 2 word sentences obtained from each of the three dysarthric subjects were accessed from a cassette tape using the audio-tape recorder on which they had been recorded (Marantz model PMD221), low-pass filtered at 8.6 kHz (Frequency Devices 901 filter) and digitized at 22 kHz via MacRecorder (Farallon Computing, Inc.) at 8-bit resolution on a Macintosh SE/30 computer (Apple Computer, Inc.).

Digital Editing Procedure for Pause Alterations

Pause-altered versions of these fifteen original experimental sentences (five sentences from each of three speakers) were then created systematically by the investigator by means of SoundEdit software (Farrallon Computing, Inc.). SoundEdit is a commercially available sound processing application program that displays a digitized acoustical signal on the computer monitor as a wave form accessible to the operator for editing (cutting, pasting, etc.), manipulation in the temporal domain, and playback. Figure 1 shows an example of a SoundEdit waveform display.

FIGURE 1. Example of SoundEdit waveform display.



The following rules were employed in creating the pause-altered sentences:

1. All editing measurements were made by the investigator.

2. Word boundaries were determined by alternately visually marking segment boundaries and listening to the enclosed fragments.

Osberger and Levitt (1979) established the majority (80 percent) of the phoneme boundaries in their experimental signals by ear, playing a digitized segment of speech repeatedly and systematically adjusting the start time until the last evidence of the phoneme of interest was heard. Twenty percent of the edits were determined by visual inspection of the wave form.

3. Pauses of 160 ms were inserted between all words.

Maassen (1986) found that pauses of this length were just long enough to give the impression of a word boundary.

4. Pauses consisted of background tape noise .

Pure "silent" pauses which resulted in abrupt signal-to-silence and silence-to-signal transitions were found to introduce undesired audible clicks, onsets and offsets. Therefore a 160 ms segment of silence between utterances on the audiotape for each speaker was digitized as the "pause" for insertion. It was less obtrusive as an insert because it contained the "background noise" that occurred naturally on the tape recordings between segments of speech.

5. When two words were already separated by a long pause (greater than 160msec), that part of the signal was not altered by the addition of any more pause material.

6. The accuracy of the pause adjustments was determined by re-measuring thirty randomly chosen pause placements and calculating the reliability of these measurements.

The values of the first pause placement, the second pause placement, and the difference between the two measures are reported in milliseconds in Appendix Q. Average measurement error was calculated to be 23.30 ms with a range of 174.54 ms.

7. Both the unaltered and pause-altered sentences were D/A converted, filtered at 8.6kHz, and played via a loudspeaker to listeners for intelligibility judgements.

By virtue of the digitization and editing process, each speaker was represented by ten 8±2 word sentences (five pause-altered and the same five unaltered). The total test corpus for all three speakers therefore included thirty 8±2 word sentences (fifteen altered and fifteen unaltered).

Subject Selection: Listeners

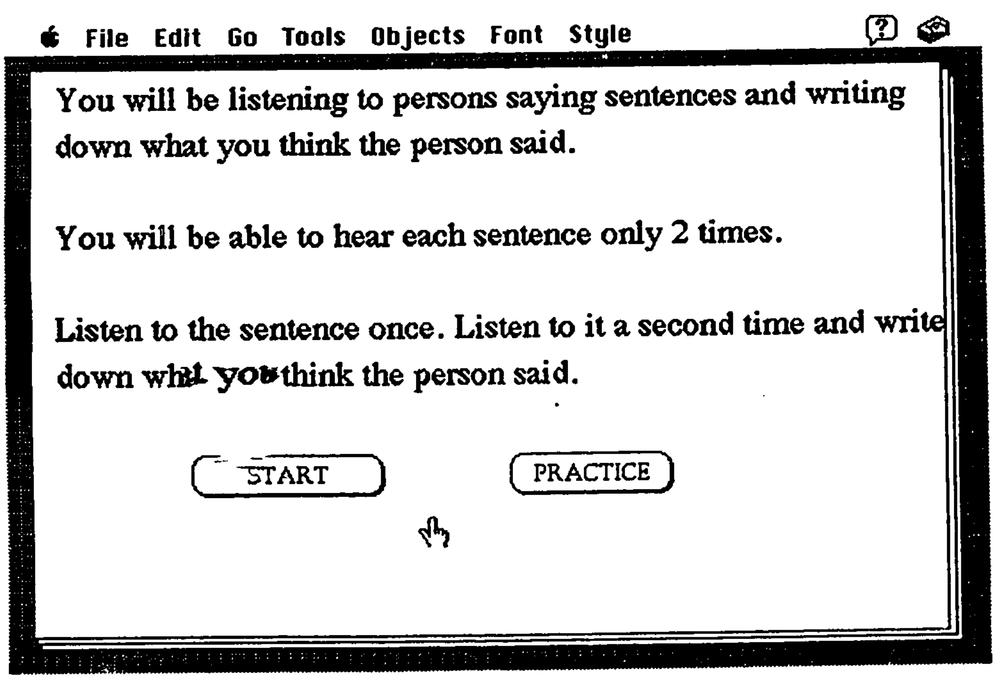
Two large groups of 30 listeners each were required to hear and transcribe word-for-word a version of the 15 sentences. Listeners were students, between the ages of 18 and 33 years, who were native speakers of English with no history of hearing loss, and were enrolled in rehabilitation medicine studies at the University of Alberta, Edmonton. Each listener was required to fill out a consent form (Appendix N) as well as a history form (Appendix O). The sixty individuals who served as listeners were randomly assigned to one of two groups; one group (control group) transcribed the 15 unaltered sentences and the other (experimental group) the 15 pause-altered versions. For the control group, mean age was calculated to be 23 years, ranging from 18 to 30 years, with a male-to-female ratio of 10 males to 20 females. For the experimental group, mean age was calculated to be 22 years, ranging from 19 to 33 years, with a male-to-female ratio of 4 males to 26 females.

Speech intelligibility listening tasks pose a unique problem; listeners must not have precise foreknowledge of what the speaker is saying (Yorkston & Beukelman, 1981c). Furthermore, results may be confounded by the differences among listeners' proficiencies at comprehending and transcribing dysarthric speech (Yorkston & Beukelman, 1980). In an attempt to control for this factor, the investigator recruited rehabilitation students who were not in the Department of Speech Pathology and Audiology. In addition, any students who had substantial exposure to individuals with a motor speech disorder (e.g., students who lived or worked closely with a dysarthric speaker) were not eligible to serve as listeners. Information from potential listeners about their department of study and exposure to dysarthric speakers was obtained from the listener history form (Appendix O).

Experimental Listening Procedures

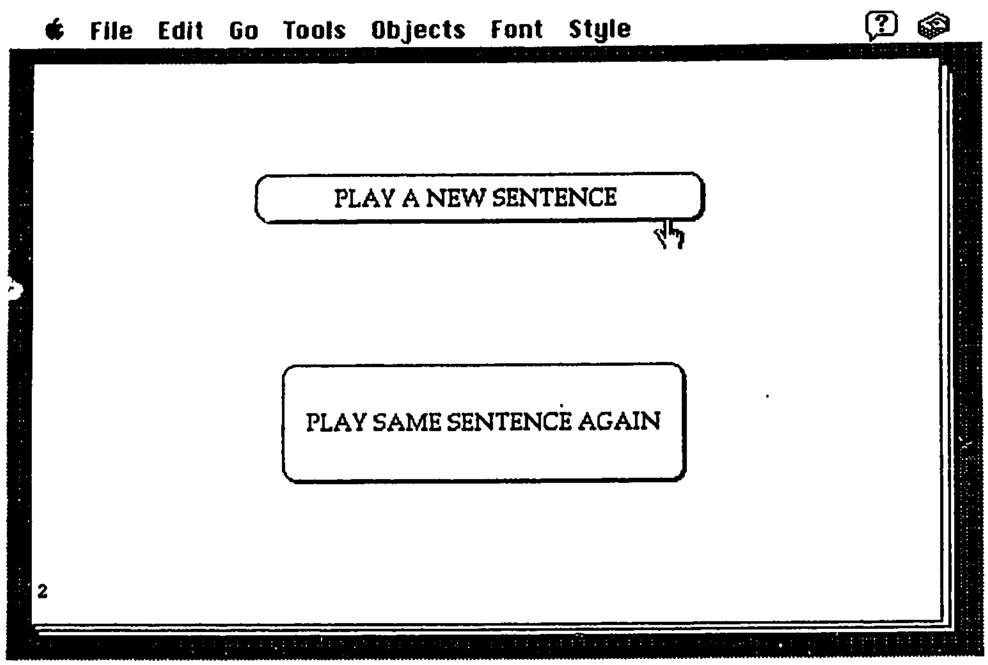
The Macintosh program "HyperCard" was used to randomize the presentation of the unaltered and the pause-altered sentences to the listeners. Listeners heard the recorded samples and transcribed, word for word, the sentences presented (Appendix P). Listeners individually listened to the sentences played back from the computer in a quiet room. The audiosignal from the computer was low-pass filtered at 8.6kHz (Frequency Devices 901), amplified (Realistic SA-150 stereo amplifier) and played through a loudspeaker (Pro III JBL). Prior to the listening task, the loudspeaker level was set at a comfortable listening level for each listener. The listeners received the following instructions via the stacks of the HyperCard program illustrated in Figure 2.

FIGURE 2. Instruction card of HyperCard stack for intelligibility listeners.



Listeners triggered the playback of experimental sentences by using a computer mouse to activate HyperCard 'buttons' labeled "Play a new sentence" and "Play same sentence again" (Figure 3).

FIGURE 3. Trigger card of HyperCard stack for listeners.



The HyperCard system was programmed to ensure that listeners could not play a sentence more than two times: the computer would beep twice and the message "You have already listened to this sentence two times" would appear. In addition, the HyperCard system was programmed to keep track of the order of sentence presentation, the name of the listener, and the date the listening task occurred. This information was stored under a separate file for access later by the principal investigator.

Following the transcription task, listeners were given a short hearing perception test to confirm the adequacy of their hearing at the listening levels they had used for the sentence transcription. Hearing perception was tested by having listeners complete the Ling Five-Sound test (Ling, 1978) just as listeners in the initial stages of the subject selection procedure had done. Each of the 60 listeners repeated all sounds with 100 percent accuracy.

Listener Data Collection

Two sets of sentence intelligibility scores were obtained. One set of scores represented the intelligibility data obtained from the thirty listeners who transcribed the sentences in their unaltered condition. The other set of scores represented the intelligibility data obtained from the thirty listeners who transcribed the same sentences in the pause-altered condition. An overall intelligibility score was derived from each listener's transcription of the fifteen sentences he/she heard. Intelligibility was computed as the number of correctly transcribed words divided by the total (118) number of words (one 6-word, one 7-word, one 9-word, and twelve 8-word sentences) and multiplying this dividend by 100.

Listener Data Analysis

Because listeners were considered "biased" once they had been exposed to a sentence produced by a given talker, traditional approaches to calculation of intrajudge agreement and reliability were adjusted to reduce this bias as much as possible. Ten-percent of listeners from each group were invited to come back and relisten to a re-randomized presentation of all fifteen sentences after a minimum period of three weeks. It was hoped that this hiatus would ensure that listeners had forgotten their original transcription responses for the sentences. Intralistener agreement was assessed on the basis of these repeated measures.

STATISTICAL ANALYSIS

This study employed a between-group, experimental design. The independent variable, within-sentence interword pause status, had two levels: unaltered and altered. The dependent variable consisted of mean intelligibility scores in the form of percent values provided by an independent group of 30 listeners for each level of the independent variable.

A one-tailed t-test for independent means was used to determine if a difference existed between the intelligibility scores obtained for the unaltered and pause-altered sentences. An alpha level of .01 and beta level of .60 were set for this test, with 58 degrees of freedom. The statistical analysis was run using Statview 512 software on a Macintosh SE/30 computer.

It is difficult to make precise statements about how large changes in intelligibility scores must be to be considered clinically or perceptually relevant. Socially important changes in speech performance may not be statistically significant; *vice versa*, statistically significant differences may not signal functionally important changes in speech performance. The final decision about the importance of any changes has been reported to be heavily based on clinical judgment (Yorkston & Beukelman, 1981c). The question of how large improvements must be to exceed the typical ranges of speakers' day-to-day variability and the range of difference that might be the result of sample selection is not known. For the purpose of this study, a clinically significant difference in intelligibility scores between the unaltered and pause-altered condition was set *a priori* at $\geq$ 10 percent.

CHAPTER IV

RESULTS

The purpose of this study was to examine the effects of artificially inserted interword pauses on the intelligibility of selected dysarthric speech. Fifteen sentences, obtained from three dysarthric speakers who exhibited similar prosodic characteristics and sentence intelligibility scores, were digitized and altered by inserting 160 ms pauses between words. Altered and unaltered versions of the sentences were played to two groups of thirty listeners to answer the following hypothesis:

> The mean intelligibility scores for sentences spoken by dysarthric talkers that have been digitally altered by the addition of pauses will be higher than the scores for those same sentences unaltered by pauses.

An independent measures t-test calculated on the intelligibility scores for the control (unaltered) group and for the experimental (pause-altered) group revealed a significant difference ($p \leq .0001$). The insertion of interword pauses improved sentence intelligibility for the dysarthric speech samples used in this study by approximately 5 percent. Listeners transcribed unaltered sentences with an average of 50 percent accuracy (range= 41 percent to 57 percent; S.D.=4.36). Listeners transcribed pause-altered sentences with an average of 55 percent accuracy (range= 44 percent to 67 percent; S.D.= 5.23). The summary statistics are shown in Table 8. The clinical effect size of this statistical difference was small, however, at 0.35 (Ottenbacher & Barrett, 1989).

TABLE 8. Summary statistics for experimental hypothesis.

Degrees of freedom	Unpaired t Value:	Probability (1-tail)
58	3.957	.0001

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
Experimental	30	54.893	5.23	.955
Control	30	49.972	4.363	.797

Intelligibility scores for the altered and unaltered versions were compared for individual speakers and revealed an overall increase in intelligibility for each speaker in the pause-altered sentences. Speaker H appeared to benefit most (7 percent improvement) from the addition of pauses, followed by speaker C (5 percent improvement) and D (3 percent improvement). These individual results are shown in Table 9.

TABLE 9. Change in percent intelligibility for individual speakers averaged over thirty listeners.

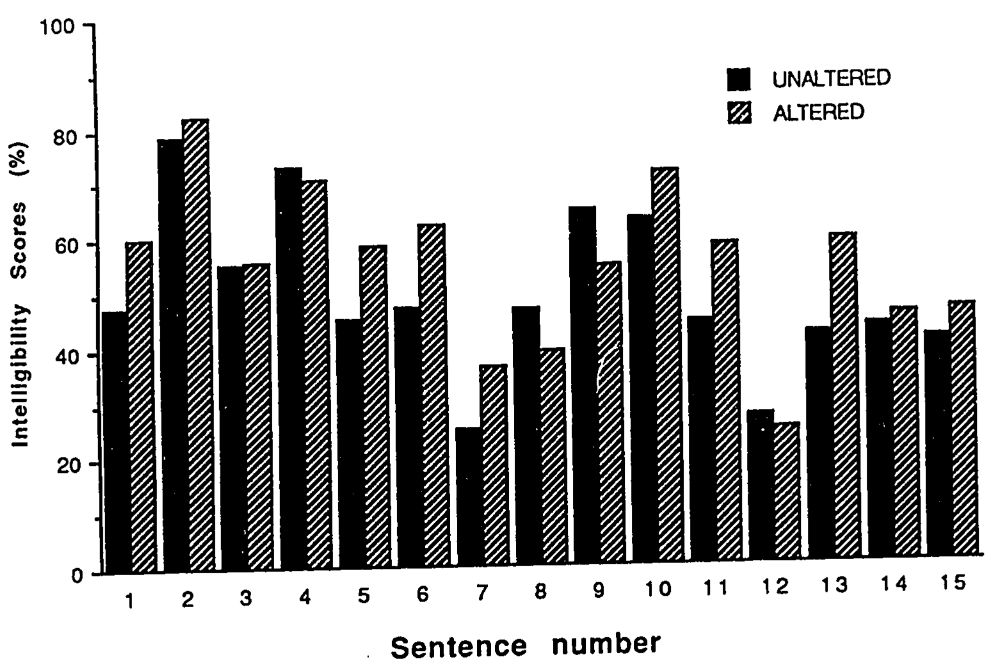
Speaker	Unaltered Version	Pause-altered Version	Percent Difference
C	59.92%	65.37%	+5.45%
D	49.24%	52.68%	+3.44%
H	39.50%	46.42%	+6.92%

Intelligibility scores for individual sentences in the unaltered corpus were examined and compared with scores for the pause-altered versions of those sentences. Table 10 and Figure 4 reveal that four of the sentences (#4, #8, #9, and #12) actually decreased in percent intelligibility (from 2 to 10 percent) following pause-alteration. Six of the sentences improved dramatically (more than 10 percent), two sentences improved moderately (from 5 to 10 percent), and three sentences improved minimally (from 0.4 to 4 percent).

TABLE 10. Intelligibility scores for the unaltered and pause-altered versions of the sentences, and the difference between the two scores for each sentence.

Sentence	Unaltered Version (averaged over 30 listeners)	Altered Version (averaged over 30 listeners)	Percent Difference
1	47.50	60.00	+12.50%
2	78.75	82.08	+3.33%
3	55.42	55.83	+0.41%
4	72.92	70.42	-2.50%
5	45.00	58.52	+13.52%
6	47.04	62.22	+15.18%
7	25.00	36.19	+11.19%
8	46.67	39.17	-7.50%
9	64.58	54.58	-10.00%
10	62.92	71.25	+8.33%
11	44.17	57.92	+13.75%
12	27.08	24.58	-2.50%
13	42.08	58.75	+16.67%
14	43.33	45.00	+1.67%
15	40.83	45.83	+5.00%

FIGURE 4. Intelligibility scores for unaltered and pause-altered sentences.



Intralistener agreement was calculated for six listeners (three in each condition) who agreed to transcribe the same sentences again after a minimum of three weeks had passed following the initial transcription. These intralistener agreement data are reported in Table 11.

TABLE 11. Intra-listener agreement. (C=listeners who heard the controlled or unaltered sentences; E=listeners who heard the experimental or pause-altered sentences).

Listener	1st Listen	2nd Listen	Difference
C-1	47.46%	52.54%	+5.08%
C-4	50.85%	64.41%	+13.56%
C-21	52.54%	56.78%	+4.24%
E-3	49.15%	52.54%	+3.39%
E-13	50.85%	61.86%	+11.01%
E-17	46.61%	51.69%	+5.08%

Although four of the six listeners (C-1, C-21, E-3, and E-17) did not differ in their two transcription scores by more than five percent, two others (C-4 and E-13) exhibited scores on their second transcription that were more than 10 percent higher than those obtained the first time.

CHAPTER V

DISCUSSION

SUMMARY AND INTERPRETATION

This study examined the effects of artificially inserted interword pauses on the intelligibility of selected samples of dysarthric speech. Pauses of 160 ms were inserted via digital technology between the words of fifteen sentences spoken by three dysarthric speakers. The controlled addition of interword pauses was hypothesized to provide information about the potentially beneficial role of pauses to speech intelligibility, and served as a means to model experimentally a word-by-word style of speech.

Clinical versus Statistical Difference

The results of this investigation were associated with a statistically significant difference between intelligibility scores for sentences that were digitally altered by the addition of pauses (55 percent) and scores obtained for unaltered versions of those same sentences (50 percent). On the basis of these results it can be concluded that interword pauses improved the sentence intelligibility of dysarthric speakers in this study by approximately 5 percent. While this improvement in intelligibility was statistically significant, its clinical effect size was small (0.35), and it did not exceed the 10 percent criterion set by the investigator a priori as a clinically significant change. The 5 percent change indicated that interword pauses may be only a part of improving intelligibility to a clinically significant level (10 percent improvement or greater, or an effect size of 0.80 or better).

Yorkston and Beukelman (1981c) acknowledged the difference between clinical and statistical significance:

> Important changes in speech performance may or may not be statistically significant; and vice versa, statistically significant differences may or may not be signaling functionally important changes in speech performance. (p. 21).

Furthermore, Yorkston and Beukelman (1981c) suggested that a clinically significant change is an improvement in sentence intelligibility which is "beyond a speaker's day-to-day variability and beyond the range of difference that might be the result of sample selection (differences in word lists and sentence sets)" (Yorkston & Beukelman, 1981c, p.21).

Day-to-day variability must be considered because dysarthric speakers' recordings of different sentence sets on the same day have resulted in average differences of 8.6 percentage points for some speakers (Yorkston & Beukelman, 1981c). However, Yorkston and Beukelman do clarify that while certain dysarthric speakers may vary considerably from day-to-day, other speakers may be exceptionally stable. Consequently, a 10 percent indicator of clinically significant change for one speaker might be decreased to 5 percent for a stable speaker, or increased to 15 percent for a speaker whose intelligibility varies considerably.

In this study, an average improvement of 5 percent in intelligibility across three dysarthric speakers resulted from the systematic addition of interword pauses to their 8±2-word utterances. Individual speakers' intelligibility scores improved by 6.92 percent (speaker H), 5.45 percent (speaker C) and 3.44 percent (speaker D). None of the improvements in intelligibility surpassed the value of 10 percent which was chosen arbitrarily a priori as a clinically significant change. It therefore can be hypothesized that the improvements in intelligibility produced by pause alteration likely were not large enough to surpass the day-to-day variability of the speakers' performances and could not necessarily be expected to make a functional difference in their everyday attempts at successful, intelligible communication.

However, to reach a fully informed conclusion that the 5 percent improvement in intelligibility reported in this study did not surpass day-to-day fluctuations in intelligibility, an alternate methodology would have to have been implemented. Baseline measures of intelligibility of each of the three speakers would have to have been taken at several points during a single day. A measure of variance could be obtained. The variance value could then be compared with the intelligibility improvements derived from the pause-alteration process, and a less arbitrary and more subject-specific decision about the clinical significance of measurable improvements could be made.

Comparison of Results with Other Studies

Although the results of this study did not reach the investigator's level for a clinically significant difference, a statistically significant improvement was obtained. The statistical results of this study can be compared and contrasted with the results of other pause-alteration studies. The results reported here are similar to those reported by Maassen (1986) who artificially inserted silent pauses between words in sentences spoken by ten deaf children. Maassen's (1986) procedure resulted in a small but statistically significant improvement in his subjects' speech intelligibility of 4 percent (27 percent unaltered, 31 percent pause-altered). In contrast, Hammen (1990) reported a 1 percent change (56 percent unaltered, 57 percent altered) that was non-significant in the intelligibility of dysarthric speech following digital pause alteration. She inserted syntactically appropriate pauses (as opposed to interword pauses) in the sentences of speakers rendered dysarthric by parkinsonism.

Several explanations may be offered for the similarities and differences among the results obtained in each of the three studies. Firstly, the place and length of pauses which were inserted differed in the investigations. Both this investigator and Maassen (1986) altered speech samples by adding 160 ms interword pauses; in contrast, Hammen (1990) added pauses of varying lengths only at syntactically appropriate locations. The decisions made regarding pause placement and distribution of pauses in the Hammen study may have created samples which sounded unusual to her listeners and therefore interfered with improved transcriptions. Perhaps the interword pauses used in this study and in Maassen's were short enough (160 ms) to avoid creating altered sentences which sounded unusual. The rationale for pause-placement in Hammen's study contrasts with the rationale for pause-placement in this study and in Maassen's. Hammen's placement of pauses in places that were syntactically appropriate was chosen to provide listeners with more processing time. Although the addition of brief interword pauses in this study and in Maassen's also increased processing time, the main purpose of the interword pauses was to create more well-defined word boundaries for the listener.

A second explanation for the differences obtained among the results of the studies may lie in the experimental materials used. In this study and in Maassen's (1986), short sentences were used as the experimental material; Hammen (1990) used longer sentences (20-26 words per sentence). The shorter sentences might have been easier for listeners to transcribe because they did not have to listen to and remember a great number of words. In contrast, listeners who participated in Hammen's study might have made transcription errors due to the large number of words they were required to remember and transcribe.

A third explanation for differences among the results of these studies involves the type of speech that was manipulated. Maassen (1986) manipulated deaf speech that was characterized by continuous voicing and a slow rate. Recall that the dysarthric speech manipulated in this study was also slow in rate and was characterized by reduced stress, monoloudness, and monopitch. In contrast, Hammen (1990) manipulated parkinsonian dysarthric utterances which were rapid in rate and often deficient in voicing. The perceptual characteristics of dysarthric speech in the present study are more similar to the characteristics of the speech of the deaf subjects in Maassen's study than to the characteristics of the parkinsonian dysarthric speech manipulated in Hammen's study. Specific speech characteristics might therefore explain the statistically significant results which were obtained by Maassen (1986) and this study, yet not found by Hammen (1990).

A final important difference exists among the studies. Neither the Maassen (1986) study, nor the Hammen (1990) study included a detailed perceptual profile of their speakers. Both studies manipulated the speech of what they thought were "homogeneous" groups (Maassen accessed "deaf speakers", Hammen accessed "parkinsonian speakers") without profiling the specific prosodic characteristics of each speaker. Both studies assumed that speakers with the same disease etiology would exhibit perceptual speech characteristics that would be similar. Examination of the speakers in all three studies reveals that such an assumption may be wrong. The overall intelligibility of individual speakers with the same disease etiology differed in response to pause alterations. The development of perceptual profiles for speakers who might benefit from selective rate control techniques can be considered valuable and perhaps essential from both clinical and research perspectives.

LIMITATIONS OF THE PRESENT STUDY

The results of this investigation show a statistically significant improvement in mean intelligibility scores obtained for sentences spoken by dysarthric talkers that were digitally altered by the addition of pauses compared to scores obtained for those same sentences that were not altered by pauses. This study represents a controlled experimental design: the alteration of dysarthric speech via computer processing techniques and the careful selection of speakers and listeners resulted in a study which was as controlled as possible with respect to a number of instrumental and procedural variables. The results of this study are limited, however, due to the lack of a clinically significant improvement (10 percent or greater). In addition, the artificial nature of the speech task (short sentences read aloud), the treatment applied to the speech signals (pause alteration) and the listening environment in which those speech signals were transcribed are several factors which limit the generalizability of the study. In the text below, these and other limitations of the present study will be presented and discussed in the context of threats to the internal and external validity of this research.

Ventry and Schiavetti (1986) highlight the importance of acknowledging this trade-off between internal and external validity:

> ...threats to external validity are qualitatively different from threats to internal validity. Serious threats to internal validity render results meaningless and uninterpretable and preclude the drawing of valid conclusions about the relations among the variables studied. Threats to external validity, however, only limit the degree to which internally valid results can be generalized. No single research study is expected to have wide-ranging generalizability to many different kinds of subjects, settings, measures. or treatments...the accumulation of several internally valid research studies is necessary to overcome limitations to external validity (p.90).

THREATS TO INTERNAL VALIDITY

Internal validity asks whether experimental treatment makes a difference in a specific experimental instance (Ventry & Schiavetti, 1986). In this study, internal validity refers to whether or not the insertion of interword pauses alone caused a change in the sentence intelligibility. In fact, pause insertion did result in a statistically significant change in sentence intelligibility. However, the difference in intelligibility scores between the unaltered and pause-altered sentences might also be related to two other internal factors: 1) the listeners used in the study and 2) the instrumentation used in the study. These two threats to internal validity are discussed in the text below.

Listener Threats to Internal Validity

When humans are used as raters or judges of other humans' behaviors, internal validity may be threatened. Listeners and judges were used throughout this study. The three listeners who transcribed sentences initially to determine overall intelligibility scores demonstrated adequate interrater agreement (95 percent agreement within a 20 percentage point intelligibility range and 83 percent agreement within a 10 percentage point intelligibility range). However, the lack of perfect agreement among these listeners' transcriptions of the dysarthric speech can be classified as a threat to the internal validity of this study. The lack of perfect agreement might have been related to some of the listeners' becoming more acquainted with/better at deciphering the distorted speech across the listening period, the fact that some listeners experienced fatigue (across the 110 sentence transcription task), or both. However, all sentences were randomized to combat order effects for the transcription task, and listeners were given regular breaks (after every 22 sentences) throughout the task in an effort to reduce potential effects of fatigue. Finally, although sub... hearing acuity or perceptual differences could have affected listeners' transcription abilities, a hearing perception test was administered and all listeners passed.

During the prosodic profile section of the study, three judges rated 20 samples of dysarthric speech on 10 dimensions. Although these judges demonstrated good intrajudge reliability (M=92 percent, range 85 to 95 percent), interjudge reliability was only fair (M=76 percent, range 65 to 85 percent). The lack of complete agreement among judges may have resulted in a less than precise profiling of the prosodic characteristics of the chosen dysarthric speakers and can thus be considered a threat to internal validity. Reasons for the lack of agreement could have included 1) not enough training time on the practice samples of dysarthric speech, 2) too detailed and complex a rating scale (seven-point equal interval) for judges to use reliably and 3) too brief a speech sample for accurate prosodic feature identification (8±2-word sentences rather than continuous speech samples in a paragraph form).

In the final stage of the experiment, thirty listeners were recruited to transcribe the unaltered sentences and thirty listeners the altered sentences. Examination of the transcriptions and intelligibility scores indicated that listeners within each group differed substantially in their listening proficiency. Intelligibility scores for listeners who heard the altered sentences ranged from 44 to 67 percent, indicating a spread of greater than 20 percent. Similarly, the range of intelligibility scores for listeners who heard the unaltered sentences was 41 to 57 percent, a 16 percent difference. Reasons for the differences in listener ability might have included 1) impaired hearing acuity/perception of certain listeners which was not detected on the hearing perception test, 2) natural differences in listeners abilities to decode distorted speech (despite the fact that potential listeners were screened for their exposure to dysarthric speech), and 3) the application of positive or negative strategies employed by the listener to decode speech. With regard to this last explanation, informal analysis of the transcription records revealed that the listeners who were low scorers appeared to leave more blanks and do less 'guessing' about words they could not understand.

Internal validity also may be threatened because differences between subjects in the experimental and control groups may account for the treatment effects rather than the treatment itself (Ventry & Schiavetti, 1986). Potential experimental error associated with subject selection for the large listener groups in this study was controlled by random assignment of eligible listeners to the experimental and control groups. Gender of the listeners in the control and experimental group was not controlled, however, because there was no evidence to suggest that gender would be an issue affecting subjects' ability to do the transcription task. The investigator did attempt to control the potential bias associated with "listening abilities" of the two groups by excluding persons who had previous exposure to dysarthric speakers, were not native speakers of English, or reported a history of hearing loss. At the same time, by virtue of the large groups of listeners (30 in each of the experimental and control groups) recruited for this study, the investigator succeeded in obtaining a sample of listeners that was representative of a population of people who might be expected to have opportunities to interact with dysarthric speakers in their future professional activities.

Instrumental Threats to Internal Validity

Instrumentation used to implement research can compromise the internal validity of the results (Ventry & Schiavetti, 1986). Those threats that are pertinent to this research include 1) the acquisition of the speech sample, 2) the experimental material which was used, and 3) the actual experimental process of inserting interword pauses via the computer. Although the original dysarthric speech sample acquisition was accomplished via a good quality audiocassette recorder and tapes, the recordings were obtained in a room unequipped to minimize noise and reverberation which may have affected the sound quality of the audio record. However, because ideal recording conditions (e.g., via a reel-to-reel tape-recorder in a sound-treated booth) would not have been representative of the conditions under which AIDS recordings typically are done in the clinical setting, it can be argued that the external validity of the recording procedure was strong enough to offset the threat that the procedure might have posed to integrity of the signals recorded. Therefore, the acquisition of the speech samples in less than ideal conditions can be considered a realistic and acceptable threat to the internal validity of this study.

Use of the AIDS sentences as the identifying and experimental element may have resulted in flawed results. Although the data of this study indicated that a speaker's intelligibility could be rated overall as moderately-to-severely impaired, the data also revealed that the same speaker could have scores on individual sentences of 100 percent. Hammen (1990) reported that the third sentence spoken by the dysarthric speakers in her study was "consistently perceived by the judges as less intelligible than the other sentences" (p.47). Hammen attributed this difference to sentence order. In the present study, the order in which sentences were played for listeners was randomized, yet certain sentences of the same length were perceived to be noticeably more or less difficult to transcribe. This difference may have been a result of 1) listener differences, 2) AIDS sentence differences, 3) speaker differences or

4) a combination of listener, sentence, and speaker differences. Natural differences in a listener's ability to decode dysarthric speech may exist. The concept of differing listening abilities among listeners is discussed later in this discussion.

The computer manipulation of the digitized sentences was somewhat imprecise as evidenced by the measurement error of the pause insertion (average measurement error= 23.30ms; range= 174.54ms; see Appendix Q) . Accurate and reliable determination of word boundaries for the insertion of pauses often was imperfect due to the blurred word boundaries or presence of continued voicing between words in the dysarthric speakers' utterances. It was noted during the measurement reliability exercise that while some pauses could be reliably inserted based on good auditory and visual word boundary cues, others such as pauses 8 and 14 (Appendix Q) could not be reliably re-placed because word boundaries were undetectable either visually or auditorally. For every measurement opportunity, the investigator attempted to achieve pause insertions that were as valid and reliable as possible by utilizing both auditory and visual cues as often as necessary until the best possible pause placement was achieved. In spite of all cautions, however, measurement error is likely to exist when working with digitized waveforms of dysarthric speech samples because the waveform of interest, like its acoustical analog, is distorted therefore confounding the investigator's ability to precisely mark the word boundaries. As well, the investigator's experience with the material, coupled with the inherent imprecision of the technique of determining the place of pause insertion, could have created an opportunity for change in pause placement at ambiguous word boundaries across repeated measures.

THREATS TO EXTERNAL VALIDITY

External validity refers to the extent to which the treatment effect obtained in the present study can be generalized (Ventry & Schiavetti, 1986). The results of this study supported the hypothesis that the insertion of pauses in dysarthric speech improved intelligibility. However, the results of this study appear to be somewhat limited in generalizability due to 1) the lack of a clinically significant improvement (10 percent or greater) 2) the select group of dysarthric speakers sampled, 3) the artificial nature of the speech task (short sentences read aloud) 4) the artificial nature of the treatment (pause alteration) and 5) the artificial nature of the listening environment. These threats to the external validity of the study are discussed below.

Lack of Clinical Significance

The addition of interword pauses to the dysarthric speech used in this study improved the intelligibility of the speech an average of five percent This improvement, however, failed to reach what the investigator proposed as a legitimate level of clinical significance. The improvement in intelligibility scores achieved by pause insertion in this study are not sufficiently large to support arguments for the use of pause insertion alone as a means of treating dysarthric speech if clinically significant changes are to be realized.

Speaker Selection as a Threat to External Validity

Subjects selected for an experimental study must be considered for how representative they are of the population to which the researcher wishes to generalize experimental results (Ventry & Schiavetti, 1986). The specifically selected types of speakers used in this study have considerable impact on the generalizations that can be made on the basis of the data obtained from them.

In the present study, based on anecdotal evidence and clinical wisdom alluded to in the literature on dysarthria, a select group of dysarthric speakers was chosen who might benefit from pause alteration. Therefore, the results of the study may be interpreted to indicate that the addition of interword pauses improved the speech of traumatically brain-injured adult males, aged 23 to 47 years (M=33 years), with overall sentence intelligibility scores ranging 55 to 75 percent, and with the following prosodic characteristics: reduced stress, monopitch, monoloudness, and reduced rate of speech. Nothing can be concluded about how pause alteration might work with female speakers with the same prosodic profile, or other dysarthric speakers whose intelligibility is more or less severe than that represented by the subjects of this research.

Nevertheless, although the generalizability of the results of this study are limited to a select group of speakers, the objective methods used in applying an experimental treatment to their speech and the precise intelligibility and prosodic profiling used in selecting the final three speakers for this study, yielded results that have valid implications for the treatment of a very specific type of dysarthric speech pattern. Such data about a specific pattern of dysarthric speech have been lacking in other studies. Future research of this nature could expand the data base on the relationship between types and severities of dysarthria in response to specific treatment methods.

<u>Speech Sample Acquisition as a Threat to External Validity</u>

Speakers in this study were recording as they read sentences aloud. Five 8±2-word sentences were then altered, and used as the experimental material in the study. As a result, the statistically significant changes which have been reported in this study can be safely applied only to spoken material of approximately the same length and delivery style. The number of words per experimental sentence (8±2 words) and the mode of speech sample acquisition (reading aloud) were justified for experimental control reasons. The reader will recall that the number of words in sentences was limited to 8±2 to ensure that listeners were able to transcribe the sentences easily, without having to remember and then transcribe a large number of words per sentence. In addition, a short number of words per sentence was chosen to avoid causing fatigue on the part of the speaker. Finally, the use of experimental material that was read aloud was the only way to obtain speech samples in which the exact content of the spoken utterance was known (to the investigator for intelligibility scoring purposes) despite moderate or severe intelligibility impairments exhibited by a given speaker.

Nature of the Experimental Treatment as a Threat to External Validity

The experimental treatment setting in this study did not involve alteration of the dysarthric subjects' speech patterns by teaching them to insert pauses between their spontaneously spoken words. Rather, the "pause treatment" was artificially achieved via computer alteration of sentences which had been read aloud by the speaker. Although using computer alteration of naturally produced sentences allowed for a high degree of experimental control, the results obtained must be interpreted from an artificial perspective. It is unlikely that live subjects could ever be trained to insert brief pauses consistently between the words of spontaneously spoken sentences. The results gathered from this study therefore provide highly controlled experimental data limited to the effect of the insertion of interword pauses of brief length on sentence intelligibility.

Nature of the Listening Environment as a Threat to External Validity

Listeners were involved in an experimental listening environment which was highly structured and artificial. Listeners were required to listen to sentences from a loudspeaker, and although they were able to adjust the volume to a comfortable listening level, they were able to hear each sentence only twice. Sentences transcribed in this fashion differ from 'real-life' intelligibility tasks where listeners have contextual cues to resolve ambiguities in the speech signal and are face-to-face with the speaker.

CLINICAL AND RESEARCH IMPLICATIONS

Implications for the Treatment of Dysarthric Speakers

The statistically significant results obtained from this study show that improvements in intelligibility can occur simply by the addition of short pauses between words, with no articulatory changes, and no semantic or contextual cues. Thus a measurable improvement in sentence intelligibility can be obtained by manipulating only the time between words - interword pauses. To the extent that the results of this study can be generalized to clinical settings, dysarthric speakers who present with moderate-to-severe intelligibility and prosodic characteristics of monopitch, monoloudness, reduced stress and reduced rate should be encouraged to pause slightly between words. By inserting pauses between words, dysarthric speakers might enjoy the same small improvements (5 percent) in intelligibility which were documented in this study.

Dramatic improvements in the sentence intelligibility of dysarthric speakers reported in the literature (Crow & Enderby, 1989; Yorkston & Beukelman, 1981c; Yorkston, Hammen, Beukelman, & Traynor, 1990) for word-by-word speech styles were not evident in this study. More remarkable improvements in intelligibility must therefore be attributed to something more than the achievement of well-marked word boundaries. Additional adjustments in speech articulation, loudness, and/or prosody may need to occur for more dramatic improvements in sentence intelligibility.

While the addition of interword pauses might not create dramatic improvements in intelligibility, it can be hypothesized that the elimination of certain pauses could be detrimental, and could cause a decrease in intelligibility. The pauses already present in certain dysarthric speech may actually be facilitating speech intelligibility. Deletion of those pauses may result in a decrease in intelligibility as suggested by Maassen (1986) and Hammen (1990). Research which involved the removal of pauses from speech samples of dysarthric talkers would provide information about the benefit of already existing pauses on the intelligibility of dysarthric speech.

Implications for the Training of Listeners

Listeners in the present study who had hearing perception within normal limits, similar language and educational backgrounds, and limited exposure to dysarthric speech differed substantially in their abilities to transcribe the same stimuli; some listeners were more proficient than others at the task.

Perhaps the proficient listeners employed strategies which allowed them to decode distorted speech with greater accuracy than average listeners. Bashford, Riener, and Warren (1992) reported that "...listeners possess rather elegant reconstructive mechanisms. Restoration can be complete, so that missing segments are indistinguishable from those actually present and the listener is unaware that the signal is fragmented" (p.211). In everyday life we encounter speech which may not be dysarthric yet is distorted or obliterated by extraneous transient noises (e.g., coughs, slamming doors, and traffic sounds) (Bashford, Riener, and Warren, 1992). As listeners, we seem to possess "sophisticated mechanisms that can restore the segments of the signals that have been obliterated by noise" (Bashford, Riener, and Warren, 1992, p.211). Perhaps the listeners who participated in the intelligibility transcription portion of this study varied in the sophistication of their "listening mechanisms".

This observation has several important clinical implications. It has been acknowledged that when using intelligibility tests such as the AIDS to monitor the change in an individual dysarthric speaker over time, a "single judge is sufficient, providing that the judge is the same individual each time" (Yorkston and Beukelman, 1981c, p.6). If different judges (ones who differed substantially in natural listening ability) were to listen to and transcribe sentences spoken by a dysarthric speaker across a period of therapy, changes in intelligibility unrelated to treatment could be reported.

Furthermore, if there are varying degrees of listener ability, perhaps listeners themselves can be trained to decode distorted speech with improved accuracy. Greenspan, Nusbaum, and Pisoni (1988) compared transcription accuracy before and after training with synthetic speech. In their study, subjects were trained with synthetic versions of words and sentences, and were provided with correct auditory and visual feedback about the identity of the word or sentence. This type of training resulted subsequently in increased intelligibility scores for the recognition of both words and sentences. The authors hypothesized that mere familiarity with the mechanical sound of the synthetic speech was not sufficient to improve intelligibility, but rather that exposure to specific, detailed acoustic-phonetic information about the structural properties of the synthetic speech was required.

Dysarthric speech can be compared to the synthetic speech reported by Greenspan, Nusbaum, and Pisoni (1988). For example, both synthetic speech and dysarthric speech are degraded in quality. Synthetic speech was described as "end-to-end concatenations of individual words with no pauses or coarticulation phenomena between words" (Greenspan, Nusbaum, and Pisoni, 1988, p.422). The dysarthric speech used in this study was also characterized by 'blurred speech' with few pauses between words. Just as synthetic speech has a limited repertoire of phonemes, dysarthric speakers tend to make general simplification errors which are highly consistent (Yorkston, Beukelman & Bell, 1988). Teaching a listener to attend to and learn the acoustic-phonetic information of a particular dysarthric speech pattern might be one effective way of achieving improved intelligibility and improved communication function. Listener training might be offered to the communication partners of dysarthric speakers who have plateaued in improvement and are unable to make any further changes in their own speech which would facilitate intelligibility for their listeners. Such training might be especially beneficial for caregivers who are in constant contact with dysarthric individuals. Further research is needed to examine listener abilities, listener strategies used to decode distorted speech, and the effects of training programs on listeners' abilities to improve their speech decoding skills.

Implications for Use of Instrumentation

Although the digital speech signal alteration utilized in this research produced an artificial treatment effect, the instrumentation used to achieve it has potentially useful and practical clinical implications. The instrumental hardware (MacRecorder) and computer software programs (SoundEdit;

Hypercard) are relatively inexpensive and allow an investigator to systematically alter one or several aspects of the temporal domain of speech. Similar hardware and software options exist for speech waveform editing in the spectral and amplitude domains, as well. Systematic speech alteration via such hardware and software could be used to demonstrate the potentially beneficial effect of pauses for other patterns of dysarthric speech. The information obtained could then be used for treatment prognostic statements, as an educational tool during the actual treatment of a dysarthric speaker, or for the training of listeners in that speaker's environment.

Implications for Future Research

Continued research in the treatment of dysarthric speakers using various rate control techniques is needed. Future researchers in this area should be encouraged to identify groups of speakers by quantitatively measuring intelligibility as well as perceptually profiling each speaker, as was done in this study. Detailed profiles of which dysarthric speech patterns respond to which types of treatment are needed for further clinical and research endeavors. Research involving intelligibility listening tasks should also use large samples of listeners for increased statistical power and external validity. This study revealed that individual listeners differed substantially in the ability to decode dysarthric speech. In order to offset the differences among listeners, large groups of listeners should be used.

Considering a clinical difference in addition to a statistical difference is an important step in the research process that forces a researcher to evaluate results on a functional level. In this study, the insertion of interword pauses was found to result in a statistically significant difference of approximately five percent ($p \leq .0001$). That same statistically significant difference was then considered on a functional level. A question was asked: would the improvements in intelligibility produced by the insertion of interword pauses exhibited in this study make a functional difference in day-to-day intelligibility performance in the speech of someone with dysarthria? For this particular study, an arbitrary level of clinical significance was set at an average improvement in intelligibility of 10 percent or greater. Consequently, the results were not considered clinically significant. Furthermore, the statistical difference though significant, resulted in only a small clinical effect size. Future studies may wish to consider the important distinction between a statistical and a clinical difference.

CONCLUSIONS

In conclusion, results from the present study suggest that improvement in the sentence intelligibility of selected dysarthric speakers was exhibited after the insertion of interword pauses. A statistically significant improvement of five percent ($p \leq .0001$) was obtained. Interpretation of these results must consider two major limiting variables: 1) the experimental design and methodology resulted in an artificial situation where the speaker's task, the investigator's treatment, and the listener's environment were rigidly controlled and are thus limited in their generalizability, and 2) the insertion of interword pauses did not result in a large effect size nor improve intelligibility to a level considered to be clinically significant by the investigator (10 percent or greater).

Several valid conclusions can be made from this study: 1) the insertion of interword pauses improved intelligibility of selected dysarthric speech by approximately five percent (a statistically significant difference), 2) the insertion of interword pauses into dysarthric speech samples via a computer allowed for strong experimental control over the test stimuli and enhanced the internal validity of the study, 3) the large groups of listeners employed in generating the data that constituted the dependent variable in this study increased the statistical power of the results, and 4) the process of perceptually profiling the prosodic characteristics of reduced stress, monoloudness, monopitch, and reduced rate dysarthric speech in addition to quantitative intelligibility measurements and knowledge of disease etiology enhanced the homogeneity the speaker group from which the experimental speech samples were obtained. Although the results of the present study may be somewhat limited with respect to internal and external validity, the method used and results obtained may be justified because those aspects of the research that are valid will provide essential information for further research in the area.

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APPENDIX A

SPEAKER INFORMATION/CONSENT FORM

<u>Information</u>

The purpose of this study is to examine the speech of people who have problems being understood. The data collected during this experiment will provide valuable information on how to improve the speech of people who have had strokes, brain injuries, or diseases which affect communication.

If you agree, a maximum of <u>one hour</u> of your time will be needed. You will be recorded reading 15 sentences while wearing a microphone.

There are no known risks associated with being audiotape-recorded or participating in the study.

All personal information about you, including your name, address, telephone number and test results will be kept confidential. The recorded data will be stored on computer disks, coded, and grouped together so that you will remain anonymous. Following the completion of the study and publication of the results, the tape recordings and the computer disks will be erased.

Participation is on a voluntary basis and you will be free to withdraw from this study at any time without any consequences.

Joanne Gutek, B.Sc.
Master of Science Candidate
University of Alberta (492-5990)

<u>Consent</u>

I have read the above description of the research project to be conducted by Joanne Gutek.

I understand that I will be required to read 15 sentences while wearing a microphone and being audio-recorded.

I understand that my identity during and after completion of this study will remain confidential.

I understand that participation in this study is voluntary and that I may withdraw from this study at any time without jeopardy.

____________________ ____________________

Participant's Signature — Date

____________________ ____________________

Joanne Gutek
Investigator — Date

____________________ ____________________

Dr. A. Rochet
Thesis Supervisor — Date

APPENDIX B

PARENT/GUARDIAN INFORMATION LETTER

The purpose of this study is to examine the speech of people who have problems being understood. The data collected during this experiment will provide valuable information on how to improve the speech of people who have had strokes, brain injuries, or diseases which affect communication.

If you agree, a maximum of one hour of [subject's name] time will be needed. He/she will be recorded reading 15 sentences while wearing a microphone.

There are no known risks associated with being audiotape-recorded or participating in the study.

All personal information about [subject's name] including his/her name, address, telephone number and test results will be kept confidential. The recorded data will be stored on computer disks, coded, and grouped together so that he/she will remain anonymous. Following the completion of the study and publication of the results, the tape recordings and the computer disks will be erased.

Participation is on a voluntary basis. You and/or [subject's name] will be free to withdraw from this study at any time without any consequences. If you have any questions or concerns you may contact Joanne Gutek B.Sc. at (403) 431-0204.

Thank you for your consideration,

Joanne Gutek, B.Sc.
Master of Science Candidate
University of Alberta

APPENDIX C

SPEAKER HISTORY FORM

Name:____

Date of Recording:________________________________

Birthdate: (D/M/Y):______/______/______

Address:____

Phone Number:______________________

Gender: Male_______ Female_______

Disease Etiology: _________________________

Date of Onset: ____________________

Vision: ______________________

Hearing: _____________________

Native Language: _______________________

Other Languages Spoken: _______________________

APPENDIX D

LISTENER INFORMATION/CONSENT FORM

Information

The purpose of this study is to examine the speech of people who have problems being understood. It is anticipated that the data collected during this experiment ultimately will provide information about ways of improving the speech of people who have had strokes, brain injuries, or diseases which affect how they speak.

This portion of the study will involve your listening to 110 sentences twice each and writing down what you hear. In addition, a short test of your hearing perception will be administered. This study will be conducted in room 2-26 Corbett Hall . The transcription task is tedious and as much as 3 hours of your time may be required. You will be given several short breaks during the task.

All personal information about you, including your name, address, telephone number, and results will be kept confidential. The recorded data will be stored on computer disks, coded, and grouped together so that you will remain anonymous. Following the completion of the study and publication of the results, the computer disks will be erased. You will be free to withdraw from this study at any time without any consequences.

Thank you for your consideration,

Joanne Gutek, B.Sc.
Master of Science Candidate
University of Alberta

Consent

I have read the above description of the research project to be conducted by Joanne Gutek.

I agree to participate.

Participant's Signature	Date
Joanne Gutek Investigator	Date
Dr. A. Rochet Thesis Supervisor	Date

APPENDIX E

LISTENER HISTORY FORM

Name:________________________________

Date: (Day/Month/Year):_______/________/________
Birthdate: (Day/Month/Year):______/_______/________
Address:________________________________
Phone Number:___________________________

Gender: Male_______ Female________

First Language Spoken: ___________________________

Department:
Occupational Therapy ____
Physical Therapy ____

Year of Study: 1st____ 2nd____ 3rd____ 4th_____

Do you have a history of any hearing disorder? yes______ no ______

If yes, please provide details:

____

____

Have you had any extensive exposure (e.g.over one year of daily contact) with persons with speech disorders as a result of disease (e.g. multiple sclerosis, Parkinson's disease), accident (e.g. stroke, traumatic brain injury), or hearing impairment? yes_____ no_____

If yes, please provide details:.

____

____

RESULTS OF SPEECH PERCEPTION TEST				
AMBIENT ROOM NOISE LEVEL:	______			
DISTANCE OF LISTENER FROM LOUDSPEAKER:	______			
DISTANCE OF LISTENER FROM COMPUTER:	______			
PERCEPTION OF ALL FIVE SOUNDS:	______	(YES)	______	(NO)
LOUDNESS LEVEL (dB) OF PLAYBACK:	______	(dB)		

Appendix F

Shortened AIDS Recording Form

ASSESSMENT OF INTELLIGIBILITY OF DYSARTHRIC SPEECH - SHORTENED VERSION

Sentence Intelligibility/Transcription Answer Sheet

Speaker:__________ Listener:__________ Date:__________

# Correct	
____	1.____________________
____	2.____________________
____	3.____________________
____	4.____________________
____	5.____________________
____	6.____________________
____	7.____________________
____	8.____________________
____	9.____________________
____	10.____________________
____	11.____________________

Appendix G

Perceptual Judges' Information/Consent Form

Information

The purpose of this study is to examine certain characteristics of dysarthric speech and the effects of those characteristics on intelligibility. It is anticipated that the data collected during this experiment may provide valuable information on how to improve the speech intelligibility of people with neurogenic communication disorders.

Specifically, your assistance as a fourth year student in speech-language pathology, who has completed the motor speech disorders course, is required for the perceptual rating of prosodic features of ten dysarthric speakers. It is estimated that two to three hours of your time will be needed.

You will first be 'trained' to rate a series of speech samples taken from various sources. Then, you will be asked to rate several dysarthric speech samples on ten levels. All ratings will be conducted in a room in Corbett Hall at the University of Alberta campus via a computer.

All personal information about you, including your name, address, telephone number and perceptual ratings will be kept confidential. The recorded data will be stored on computer disks, coded, and grouped together so that you will remain anonymous. Following the completion of the study and publication of the results, the tape recordings and the computer disks will be erased.

You are free to withdraw from this study at any time without any consequences.

Joanne Gutek, B.Sc.
Master of Science Student
University of Alberta

Consent

I have read the above description of the research project to be conducted by Joanne Gutek.

I agree to participate.

__________________ __________________

Participant's Signature | Date

__________________ __________________

Joanne Gutek
Investigator | Date

__________________ __________________

Dr. A. Rochet
Thesis Supervisor | Date

APPENDIX H

PERCEPTUAL JUDGES' HISTORY FORM

Name:____

Date of Perceptual Rating (D/M/Y):______/______/______

Birthdate: (D/M/Y):______/______/______

Address:__________________________________

Phone Number:________________

Gender: Male____ Female____

Have you completed the motor speech disorders course? _________

Estimated practicum hours spent working with dysarthric individuals to date:

____

Native Language: ___________________

Do you have any history of hearing disorder? ___________________

Appendix I

10 Dimensions of Prosody

1. Monoloudness
   Voice shows monotony of loudness.
   It lacks normal variations in loudness.

2. Excessive loudness variation
   Voice shows sudden, uncontrolled alterations in loudness, sometimes becoming too loud sometimes too weak.

3. Loudness decay
   There is progressive diminution or decay of loudness.

4. Monopitch
   Voice lacks normal pitch and inflectional changes.
   It tends to stay at one pitch level.

5. Reduced stress
   Speech shows a reduction of proper stress or emphasis patterns.

6. Excess and equal stress
   Excess stress on usually unstressed parts of speech.

7. Rate
   Rate of actual speech is abnormally slow or rapid.

8. Variable Rate
   Rate alternately changes from slow to fast.

9. Prolonged intervals
   Prolongation of interword or intersyllable intervals.

10. Inappropriate silences
    There are inappropriate silent intervals.

APPENDIX J
PROSODIC PERCEPTUAL RATING FORM

Date:________________________
Speaker/Sentence:__________________
Judge:________________________

Rating	Characteristic	Description
1 2 3 4 5 6 7	Monoloudness	Voice shows monotony of loudness. It lacks normal variations in loudness.
1 2 3 4 5 6 7	Excessive loudness variation	Voice shows sudden, uncontrolled alterations in loudness, sometimes becoming too loud, sometimes too weak.
1 2 3 4 5 6 7	Loudness decay	There is progressive diminution or decay of loudness.
1 2 3 4 5 6 7	Monopitch	Voice lacks normal pitch and inflectional changes. It tends to stay at one pitch level.
1 2 3 4 5 6 7	Reduced stress	Speech shows reduction of proper stress or emphasis patterns.
1 2 3 4 5 6 7	Excess & equal stress	Excess stress on usually unstressed parts of speech.
1 2 3 4 5 6 7	Rate Slow Rapid	Rate of actual speech is abnormally slow or rapid.
1 2 3 4 5 6 7	Variable Rate	Rate alternately changes from slow to fast.
1 2 3 4 5 6 7	Prolonged intervals	Prolongation of interword or intersyllable intervals.
1 2 3 4 5 6 7	Inappropriate silences	There are inappropriate silent intervals.

Prosodic attributes will be rated between 1 and 7 with:

1 representing no abnormality
2 representing mild and inconsistent (occuring less than 75% of the time)
3 representing mild and consistent (occuring more than 75% of the time)
4 representing moderate and inconsistent
5 representing moderate and consistent
6 representing severe and consistent
7 representing complete dysfunction

APPENDIX K

PROSODIC PROFILE RESULTS - Seven-Point Scale

Key: C=Judge 1, B=Judge 2, N=Judge 3

Speaker G.G.

CHARACTERISTIC	C	B	N	C	B	N
Monoloudness	5	2	2	3	3	3
Monopitch	1	3	3	1	6	2
Reduced Stress	1	1	3	1	1	3
Rate (slow)	2	2	4	1	4	1

CHARACTERISTIC	C	B	N	C	B	N
Excessive loudness	1	1	1	3	1	1
Loudness decay	1	1	1	1	1	1
Excess & equal stress	1	4	1	3	5	1
Variable Rate	1	1	1	1	1	1
Prolonged intervals	2	3	2	1	2	1
Inappropriate silence	1	1	1	1	1	1

Speaker C.S.

CHARACTERISTIC	C	B	N	C	B	N
Monoloudness	5	4	5	5	5	3
Monopitch	6	2	3	1	1	1
Reduced Stress	5	2	3	4	5	3
Rate (slow)	4	4	4	4	4	2

CHARACTERISTIC	C	B	N	C	B	N
Excessive loudness	1	1	1	1	1	1
Loudness decay	1	1	1	1	1	1
Excess & equal stress	2	1	1	1	1	1
Variable Rate	1	1	1	1	1	1
Prolonged intervals	1	1	1	1	1	1
Inappropriate silence	1	1	1	1	1	1

Speaker R.L.

CHARACTERISTIC	C	B	N	C	B	N
Monoloudness	1	3	5	1	5	5
Monopitch	5	5	3	5	5	3
Reduced Stress	3	2	5	1	1	2
Rate (slow)	4	4	4	3	2	5

CHARACTERISTIC	C	B	N	C	B	N
Excessive loudness	1	1	1	1	1	1
Loudness decay	1	1	1	1	1	1
Excess & equal stress	1	1	1	1	2	1
Variable Rate	1	1	1	2	2	1
Prolonged intervals	1	2	1	1	2	4
Inappropriate silence	1	1	1	1	1	1

Speaker D.V.

CHARACTERISTIC	C	B	N	C	B	N
Monoloudness	3	2	5	1	1	1
Monopitch	5	3	1	3	3	2
Reduced Stress	4	1	2	3	1	6
Rate (slow)	5	5	2	2	4	2

CHARACTERISTIC	C	B	N	C	B	N
Excessive loudness	1	1	1	1	1	2
Loudness decay	1	1	1	1	1	1
Excess & equal stress	5	5	1	1	1	1
Variable Rate	1	1	1	1	1	3
Prolonged intervals	1	1	1	1	1	1
Inappropriate silence	1	1	1	1	1	1

Speaker M.F.

CHARACTERISTIC	C	B	N	C	B	N
Monoloudness	5	5	5	5	4	6
Monopitch	5	5	5	6	4	5
Reduced Stress	1	1	1	1	1	5
Rate (slow)	5	5	6	4	3	5

CHARACTERISTIC	C	B	N	C	B	N
Excessive loudness	1	1	1	1	1	1
Loudness decay	1	1	1	1	1	1
Excess & equal stress	3	5	5	6	3	1
Variable Rate	5	5	6	1	1	1
Prolonged intervals	1	1	1	1	1	1
Inappropriate silence	1	1	1	1	1	1

APPENDIX L

PROSODIC PROFILE RESULTS - Five-Point Scale

Key: C=Judge 1, B=Judge 2, N=Judge 3

Speaker G.G.

CHARACTERISTIC	C	B	N	C	B	N
Monoloudness	3	2	2	3	3	3
Monopitch	1	3	3	1	4	2
Reduced Stress	1	1	3	1	1	3
Rate (slow)	2	2	2	1	2	1

CHARACTERISTIC	C	B	N	C	B	N
Excessive loudness	1	1	1	3	1	1
Loudness decay	1	1	1	1	1	1
Excess & equal stress	1	2	1	3	3	1
Variable Rate	1	1	1	1	1	1
Prolonged intervals	2	3	2	1	2	1
Inappropriate silence	1	1	1	1	1	1

Speaker C.S.

CHARACTERISTIC	C	B	N	C	B	N
Monoloudness	3	2	3	3	3	3
Monopitch	3	2	3	1	1	1
Reduced Stress	3	2	3	2	3	3
Rate (slow)	2	2	2	2	2	2

CHARACTERISTIC	C	B	N	C	B	N
Excessive loudness	1	1	1	1	1	1
Loudness decay	1	1	1	1	1	1
Excess & equal stress	2	1	1	1	1	1
Variable Rate	1	1	1	1	1	1
Prolonged intervals	1	1	1	1	1	1
Inappropriate silence	1	1	1	1	1	1

Speaker R.L.

CHARACTERISTIC	C	B	N	C	B	N
Monoloudness	1	3	3	1	3	3
Monopitch	3	3	3	3	3	3
Reduced Stress	3	2	3	1	1	2
Rate (slow)	2	2	2	3	2	3

CHARACTERISTIC	C	B	N	C	B	N
Excessive loudness	1	1	1	1	1	1
Loudness decay	1	1	1	1	1	1
Excess & equal stress	1	1	1	1	2	1
Variable Rate	1	1	1	2	2	1
Prolonged intervals	1	2	1	1	2	2
Inappropriate silence	1	1	1	1	1	1

Speaker D.V.

CHARACTERISTIC	C	B	N	C	B	N
Monoloudness	3	2	3	1	1	1
Monopitch	3	3	1	3	3	2
Reduced Stress	2	1	2	3	1	3
Rate (slow)	3	3	2	2	2	2

CHARACTERISTIC	C	B	N	C	B	N
Excessive loudness	1	1	1	1	1	2
Loudness decay	1	1	1	1	1	1
Excess & equal stress	3	3	1	1	1	1
Variable Rate	1	1	1	1	1	3
Prolonged intervals	1	1	1	1	1	1
Inappropriate silence	1	1	1	1	1	1

Speaker M.F.

CHARACTERISTIC	C	B	N	C	B	N
Monoloudness	3	3	3	3	2	4
Monopitch	3	3	3	4	2	3
Reduced Stress	1	1	1	1	1	3
Rate (slow)	3	3	4	2	3	3

CHARACTERISTIC	C	B	N	C	B	N
Excessive loudness	1	1	1	1	1	1
Loudness decay	1	1	1	1	1	1
Excess & equal stress	3	3	3	4	3	1
Variable Rate	3	3	4	1	1	1
Prolonged intervals	1	1	1	1	1	1
Inappropriate silence	1	1	1	1	1	1

Appendix M

Fifteen Experimental Sentences

1. Speaker C; Sentence 8B
   It was a huge part of my life.

2. Speaker C; Sentence 8C
   This will not be challenged in the court.

3. Speaker C; Sentence 8D
   Fill the pan about half full of gravel.

4. Speaker C; Sentence 8E
   I think we'll be lucky with this one.

5. Speaker C; Sentence 9
   There is often excellent bird watching in the area.

6. Speaker D; Sentence 6
   I said I'd put on weight.

7. Speaker D; Sentence 7
   I hadn't even read for the part.

8. Speaker D; Sentence 8B
   For casual walking, you need no special equipment.

9. Speaker D; Sentence 8C
   Enjoy the fair weather while in the tropics.

10. Speaker D; Sentence 8D
    There is little hope that overfishing will cease.

11. Speaker H; Sentence 8
    The dog sat on the vet's office floor.

12. Speaker H; Sentence 8B
    A fire in straw makes a quick blaze.

13. Speaker H; Sentence 8C
    The wait for work can be very long.

14. Speaker H; Sentence 8D
    That's what I thought it was at first.

15. Speaker H; Sentence 8E
    It can lead to any number of adventures.

APPENDIX N

EXPERIMENTAL LISTENER INFORMATION/CONSENT FORM

Information
The purpose of this study is to examine the speech of people who have problems being understood. It is anticipated that the data collected during this experiment ultimately will provide information about ways of improving the speech of people who have had strokes, brain injuries, or diseases which affect how they speak.

This portion of the study will involve your listening to 15 sentences twice each and writing down what you hear. In addition, a short test which will determine your hearing discrimination will be administered. This study will be conducted in room 2-26 Corbett Hall. A maximum of **30 minutes** of your time will be required.

All personal information about you, including your name, address, telephone number, and results will be kept confidential. The recorded data will be stored on computer disks, coded, and grouped together so that you will remain anonymous. Following the completion of the study and publication of the results, the computer disks will be erased. You will be free to withdraw from this study at any time without any consequences.

Thank you for your consideration,

Joanne Gutek, B.Sc.
Master of Science Candidate
University of Alberta

Consent
I have read the above description of the research project to be conducted by Joanne Gutek.

I agree to participate.

____________________ ____________________
Participant's Signature Date

____________________ ____________________
Joanne Gutek Date
Investigator

____________________ ____________________
Dr. A. Rochet Date
Thesis Supervisor

APPENDIX O

EXPERIMENTAL LISTENER HISTORY FORM

Name:_______________________________
Date: (Day/Month/Year):________/_________/_________
Birthdate: (Day/Month/Year):_______/________/_______
Address:_______________________________
Phone Number:_______________________________

Gender: Male________ Female________

First Language Spoken: ________________________

Department:
Occupational Therapy ______
Physical Therapy ______

Year of Study: 1st_____ 2nd_____ 3rd_____ 4th______

Do you have a history of any hearing disorder? ____________________

If so, please provide details:
____
____
____

Have you had any extensive exposure (e.g.over one year of daily contact) with persons with speech disorders as a result of disease (multiple sclerosis, Parkinson's disease), accident (traumatic brain injury), or hearing impairment? ____________

If so, please provide details:.
____
____
____

RESULTS OF SPEECH PERCEPTION TEST

PERCEPTION OF ALL FIVE SOUNDS? ______ (PASS) ______ (FAIL)

LOUDNESS LEVEL (DB) OF PLAYBACK: ______ (DB)

APPENDIX P

EXPERIMENTAL TRANSCRIPTION FORM

SENTENCE INTELLIGIBILITY/TRANSCRIPTION ANSWER SHEET

Listener: ______________

Date: ______________

# Correct	Key	
____	____	1.______________
____	____	2.______________
____	____	3.______________
____	____	4.______________
____	____	5.______________
____	____	6.______________
____	____	7.______________
____	____	8.______________
____	____	9.______________
____	____	10.______________
____	____	11.______________
____	____	12.______________
____	____	13.______________
____	____	14.______________
____	____	15.______________

APPENDIX Q

MEASUREMENT ERROR FOR THE DIGITAL PAUSE INSERTION.

Pause Number	First Pause Placement	Second Pause Placement	Change in ms
1	506.19	494.55	11.64
2	837.82	843.64	5.82
3	960.00	1000.73	40.73
4	1728.00	1721.46	6.54
5	1914.19	1960.73	46.54
6	2222.55	2210.91	11.64
7	1559.28	1576.73	17.45
8	2100.37	2274.91	174.54
9	2903.28	2891.64	11.64
10	3426.91	3426.81	0.1
11	6725.82	6731.64	5.82
12	849.46	874.44	24.98
13	1559.28	1536.00	23.28
14	610.91	727.28	116.37
15	837.82	837.82	0
16	978.91	925.10	53.81
17	4651.64	4667.09	15.45
18	1536.00	1541.82	5.82
19	2405.82	2432.00	26.78
20	3176.73	3162.91	0.14
21	4068.91	4062.35	6.56
22	477.10	494.55	17.45
23	709.82	711.28	1.46
24	590.55	610.91	20.36
25	454.55	448.00	6.55
26	610.91	648.73	37.82
27	558.55	546.91	11.64
28	506.19	517.82	11.63
29	704.00	715.64	11.64
30	535.28	514.91	20.73